6-2-2020 3:00 PM

The Relationship Between Schizotypal Traits and the Perceptual Processes of Multisensory Integration, Temporal Processing, and Speech Perception

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A thesis submitted in partial fulfillment of the requirements for the Master of Science degree in Psychology

Abstract

Multisensory integration, the binding of sensory information from different sensory modalities, may contribute to perceptual symptomatology in schizophrenia, including hallucinations and aberrant speech perception. Differences in multisensory integration and temporal processing, an important component of multisensory integration, are consistently found in schizophrenia. Evidence is emerging that these differences extend across the schizophrenia spectrum, including individuals in the general population with higher schizotypal traits. In two studies, the relationship between schizotypal traits and perceptual functioning is investigated. We hypothesized associations between higher schizotypal traits and decreased multisensory integration, increased auditory speech distractibility, and less precise temporal processing. In Study 1, higher schizotypal traits were associated with higher rates of multisensory integration. In Study 2, higher schizotypal traits were not associated with multisensory integration, audiovisual speech-in-noise perception, auditory speech distractibility, or temporal processing. These mixed findings suggest that perceptual differences do not always exist in the lower end of the schizophrenia spectrum.

Keywords

multisensory integration, schizophrenia spectrum disorders, schizotypy, audiovisual, speech perception, distractibility, McGurk effect, ternary synchrony judgment task, speech-in-noise task

Lay Summary

People with schizophrenia have problems combining what they see and hear, which might be why they experience hallucinations and problems with understanding speech. People with a lot of schizotypal traits may have similar issues to people with schizophrenia, just at a lower level. We found that people with more schizotypal traits are sometimes more likely to combine sound syllables and mouth movement syllables that are different. We also found that these people do not have problems telling when a voice and a speaker's mouth movements happen at different times. Also, they are not more distracted by a voice that does not match a speaker's mouth movements. This means that people with higher schizotypal traits do not face all the same problems as people with schizophrenia. However, they sometimes incorrectly combine what they see and hear. This may lead to unusual perceptual experiences such as hallucination-like experiences and problems understanding speech.

Acknowledgements

I would like to thank my supervisor, Dr. Ryan Stevenson, for all of his help during my master's and during the process of writing my thesis. He was extremely helpful and patient during every stage of my research projects, from conceptualization to MATLAB coding, data analysis, and writing, and I couldn't have done it without him. I would also like to thank the members of the Sensory and Perception lab for their help with data collection, software programs, and for their feedback. Thank you also to my committee members for their valuable feedback.

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List of Abbreviations

Abbreviation	Meaning
ms	Millisecond(s)
t	Student distribution value
p	Probability
r	Correlation coefficient
N	Number of participants
SD	Standard deviation
M	Mean
R^2	Correlation effect size
RDoC	Research Domain Criteria
ab	Indirect effect
c’	C Prime; Direct Effect
c	Total Effect
SE	Standard Error
95% CI	95% Confidence Interval
BF	Bayesian Factor
F	F distribution value
β	Standardized coefficient
±	Plus or Minus
sr^2	Semi Partial Correlation
PSS	Point of Subjective Simultaneity
TBW	Temporal Binding Window
SPD	Schizotypal Personality Disorder
SJ3	Ternary synchrony judgment
SOA	Stimulus Onset Asynchrony
SPQ	Schizotypal Personality Questionnaire
MSI	Multisensory Integration

Chapter 1

1. Introduction

1.1 Multisensory Integration and Temporal Processing

The ability of our brains to integrate information received from different senses into coherent, unitary percepts is foundational to how we experience the world. This process, called multisensory integration, is vital to typical perception, as most of our daily perceptual experiences are multisensory. There are many benefits to having multisensory integration abilities as opposed to perceiving sensory inputs from different sensory modalities as isolated. These benefits include better abilities to detect (Lovelace, Stein, & Wallace, 2003; Stein & Wallace, 1996), localize (Nelson et al., 1998; Wilkinson, Meredith, & Stein, 1996), and more quickly respond to stimuli in the environment (Diederich & Colonius, 2004; Hershenson, 1962). Multisensory integration also allows for better identification of ambiguous stimuli (Green & Angelaki, 2010) and more accurate speech perception (Ross, Saint-Amour, Leavitt, Javitt, & Foxe, 2007).

While multisensory integration occurs without conscious effort, it is nonetheless a challenging cognitive task, as one must determine which inputs, from an overwhelming amount of sensory information, should be integrated, and which should not (Stevenson, Ghose, et al., 2014). This is determined based on whether the sensory inputs have come from the same environmental event, or whether the events were separate. As this is not always clear, multisensory integration is guided by the temporal and spatial proximity of information across different sensory modalities, as information that is temporally and spatially coincident is more likely to have originated from the same environmental event (Stein & Meredith, 1993). This means that the closer together in time and space two inputs are, the more likely they are to be bound together and perceived as having occurred as part of the same environmental event.

As temporal proximity is such an important cue for determining whether multisensory integration should occur, an accurate temporal processing system is required for accurate multisensory integration (Ferri et al., 2017; Martin, Giersch, Huron, & Wassenhove, 2013; Stevenson, Zemtsov, & Wallace, 2013). Temporal processing abilities vary drastically between individuals (Ferri et al., 2017). These abilities can be quantified by measuring the temporal binding window (TBW) – the window of time within which multisensory information is linked and perceived as occurring simultaneously. Individuals with wider temporal binding windows more frequently perceive multisensory stimuli simultaneously when they should be perceived as discrete. For example, individuals with wider temporal binding windows might perceive audiovisual speech as synchronized at longer temporal offsets than individuals with narrower temporal binding windows. Additionally, individuals with wider temporal binding windows may mistakenly integrate stimuli from separate environmental events (Ferri et al., 2017). The size of a person's temporal binding window has been shown to be associated with the degree of multisensory integration that occurs for that person, with, in general, a larger temporal binding window being associated with less accurate multisensory integration (Martin et al., 2013). Importantly, temporal binding windows that are too narrow are also maladaptive, as this can result in not binding together congruent information. As such, it is best to have a happy medium, where the temporal binding window is neither too wide nor too narrow.

1.2 Multisensory Integration and Temporal Processing in Schizophrenia

Schizophrenia is a severe psychiatric condition affecting approximately 1% of the population worldwide (Insel, 2010). Individuals with schizophrenia experience a variety of complex symptoms, from perceptual abnormalities to social cognition difficulties, which greatly impact daily well-being and functioning (American Psychiatric Association, 2013). Several theories have brought forth the idea that differences in the sensory processing of stimuli may be contributing to the perceptual symptoms of schizophrenia. The "panmodal processing imprecision hypothesis of schizophrenia" posits that individuals with schizophrenia are less precise in their use of sensory and cognitive information (Javitt, Liederman, Cienfuegos, & Shelley, 1999). For example, individuals with schizophrenia are impaired in their ability to discriminate between different tones and weights, and require larger differences to detect changes in sensory information (Javitt et al., 1999). These sensory discrimination deficits arise from imprecise encoding of sensory representations within transient memory storage (Javitt et al., 1999). As these basic sensory representations feed into higher-level processes, disrupted integrity in early, low-level sensory representations may contribute to perceptual and cognitive symptoms. If sensory representations are less precise, they may be less accurate in the temporal information they contain, meaning larger time differences are required to detect differences in onset of stimulus presentations. Since stimuli are more likely to be integrated when they occur close together in time, if individuals do not perceive them as occurring with temporal proximity, then multisensory integration is less likely to occur for these stimuli. As a result, it is possible that lower precision in using sensory information could include issues with temporal processing, which could contribute to issues with multisensory integration. Meanwhile, the "disconnection hypothesis" suggests a molecular and neural basis for schizophrenia symptoms, in which synaptic efficacy, neuronal circuitry, and overall connectivity in the brain is altered in schizophrenia (Friston, Brown, Siemerkus, & Stephan, 2016). Through the "disconnection hypothesis," it can be predicted that there is less connectivity between auditory and visual neural systems, ultimately leading to issues with multisensory integration.

In support of such theories, empirical evidence suggests that the perceptual symptoms of schizophrenia, such as hallucinations, may be related to alterations in temporal processing and multisensory integration systems (Stevenson, Park, et al., 2017). In fact, individuals with schizophrenia have been found to have less precise temporal processing abilities, both in the visual modality alone (Capa, Duval, Blaison, & Giersch, 2014; de Boer-Schellekens, Stekelenburg, Maes, Van Gool, & Vroomen, 2014; Giersch et al., 2009; Lalanne, Van Assche, Wang, & Giersch, 2012; Schmidt, McFarland, Ahmed, McDonald, & Elliott, 2011; Tenckhoff, Tost, & Braus, 2002), auditory modality alone (Foucher, Lacambre, Pham, Giersch, & Elliott, 2007) and in audiovisual modalities together (Foucher et al., 2007; Martin et al., 2013; Noel, Stevenson, & Wallace, 2018; Stevenson et al., 2017). Stevenson et al. (2017) found that individuals with schizophrenia had less precise temporal processing than controls, but within individuals with schizophrenia, those who had more severe hallucinations tended to have narrower temporal binding windows. Evidently, the role of temporal processing in contributing to schizophrenia symptoms may be more complex than expected. Nevertheless, the temporal processing system in schizophrenia does appear to be altered relative to individuals without schizophrenia.

Likely as a result of these alterations in temporal processing, individuals with schizophrenia also show deficits in multisensory integration compared to controls (de Jong, Hodiamont, Van den Stock, & de Gelder, 2009; Ross, Saint-Amour, Leavitt, Molholm, et al., 2007; Tseng et al., 2015; Williams, Light, Braff, & Ramachandran, 2010). Deficits in multisensory integration in schizophrenia are found especially in the realm of audiovisual speech integration (Tseng et al., 2015). While there have been some findings of intact multisensory integration in schizophrenia, (e.g. de Boer-Schellekens et al., 2014), in general this is not the case (for a review see Zhou et al., 2018).

1.3 The Schizophrenia Spectrum

The schizophrenia spectrum ranges from schizotypy in the general population to schizotypal personality disorder (SPD), early or prodromal psychosis, and finally, schizophrenia. Schizotypy refers to schizotypal personality traits within the general population that are attenuated versions of the signs and symptoms of schizophrenia (Ettinger, Meyhöfer, Steffens, Wagner, & Koutsouleris, 2014). There are slightly different conceptualizations of schizotypy in the literature. The concept of schizotypy originates from Meehl, who hypothesized a quasi-dimensional approach of schizophrenia where "the schizotaxic condition" leads to schizotypy under normal conditions, and under a combination of genetic and environmental adversities, leads to diagnosable schizophrenia (Meehl, 1962). Not long after, Eysenck and Claridge hypothesized a fully dimensional approach in which schizotypy is a trait with a normal distribution across the population (Eysenck & Eysenck, 1968; Gordon, 1972; Rawlings, Williams, Haslam, & Claridge, 2008). The current study will use the fully dimensional definition of schizotypy. According to this definition, schizotypy itself is not a clinically diagnosable condition, but these individuals are at a slightly higher risk of developing schizophrenia and other psychotic illnesses (Kwapil, Gross, Silvia, & Barrantes-Vidal, 2013).

Like schizophrenia, the features of schizotypy can be organized into three groups: positive (experiences of illusions, unusual perceptual experiences, bizarre or magical thinking, depersonalisation, and derealisation), negative (anhedonia, avolition, reduced emotional expression, and social isolation) and disorganized (odd behaviour, thought, and speech) (Raine, 2006; American Psychiatric Association, 2013). Schizotypy can be expressed in a variety of ways, such that some individuals may have more positive symptoms, while others have more negative or disorganized symptoms (Ettinger et al., 2014). These schizotypal traits, as measured by various reliable questionnaires, appear to exist on a continuum, with the highest degree of schizotypal traits being diagnosable with schizophrenia (Raine, 1991).

A key characteristic of schizophrenia spectrum disorders can be categorized as perceptual disturbances. These symptoms are likely related to differences in sensory processing in the brains of these individuals. Several sensory deficits in both schizotypy and schizophrenia have been found, in the form of deficits in auditory pitch discrimination (Bates, 2005), sensory gating (Park, Lim, Kirk, & Waldie, 2015), sensory prediction (Teufel, Kingdon, Ingram, Wolpert, & Fletcher, 2010), pre-pulse inhibition (Wan, Thomas, Pisipati, Jarvis, & Boutros, 2017), and olfactory scent identification (Park & Schoppe, 1997). Evidence from work on cognition, perception, and motor control, as a whole, reveals that individuals who have more schizotypal traits tend to have slight deficiencies in performance that are similar but attenuated to the deficits seen in individuals with schizophrenia (Ettinger et al., 2014). Considering the significant overlap between schizophrenia and schizotypy found through retrospective, longitudinal, family, genetic, environmental, cognitive, and neurobiological investigations (Ettinger et al., 2014), it makes sense that these similarities in altered sensory processing have been found.

1.4 Multisensory Integration and Temporal Processing Across the Schizophrenia Spectrum

Of particular interest to the present study, multisensory integration and temporal processing differences appear to be present across the schizophrenia spectrum. Early investigations in individuals with higher levels of schizotypal traits in the general population have revealed poorer tactile-proprioceptive (Ferri, Ambrosini, & Costantini, 2016) and audio-tactile temporal processing (Ferri et al., 2017), similarly to individuals with schizophrenia. Additionally, individuals with higher schizotypy tend to have stronger responses to visual-tactile (rubber-hand and Barbie doll) illusions (Asai, Mao, Sugimori, & Tanno, 2011; Germine, Leigh, Cohen, & Lee, 2013; Van Doorn, De Foe, Wood, Wagstaff, & Hohwy, 2018), which also aligns with findings in schizophrenia (Peled, Ritsner, Hirschmann, Geva, & Modai, 2000; Thakkar, Nichols, Mcintosh, & Park, 2011). Similarly, like individuals with schizophrenia (Haß et al., 2017), those with higher schizotypy have also been found to have stronger responses to the audiovisual double-flash (fission) illusion (Ferri, Venskus, Fotia, & Cooke, 2018). Stronger responses to these illusions indicates poorer temporal processing, in that individuals who are less attuned to temporal offsets are more prone to perceiving the illusions. This early evidence suggests that the multisensory integration and temporal processing differences seen in schizophrenia are also found in individuals in the lower end of the schizophrenia spectrum.

1.5 Speech Perception Across the Schizophrenia Spectrum

Considering the importance of intact multisensory integration and temporal processing in everyday perceptions, processes like audiovisual speech perception may be impacted across the schizophrenia spectrum. Combined audiovisual speech perception in individuals with schizophrenia has been investigated in only two studies. Firstly, Ross and colleagues (2007) found that individuals with schizophrenia experience less benefit from observing the visual component of speech while hearing the auditory component (Ross, Saint-Amour, Leavitt, Molholm, et al., 2007a). In other words, controls improved in their word perception accuracy when they had both visual and auditory information compared to only auditory information. In contrast, individuals with schizophrenia showed less improvement than controls in word perception accuracy in audiovisual trials compared to unisensory auditory trials. Improvements in accuracy from unisensory to multisensory perception, referred to as multisensory gain, are reflective of multisensory integration. These results therefore reveal that individuals with schizophrenia experience less multisensory integration during audiovisual speech perception. Secondly, de Gelder and colleagues (2002) found that when incongruent auditory and visual speech stimuli were presented, in the form of different phonemic syllables, individuals with schizophrenia were less influenced by visual information than controls (de Gelder, Vroomen, Annen, Masthof, & Hodiamont, 2002). Individuals with schizophrenia reported both visual syllables, and syllables combining the visual and auditory syllables, less often than controls. Individuals with schizophrenia also had poorer lip-reading abilities compared to controls. It may be that less accurate lip-reading led to less reliance on visual information, which, in addition to impaired multisensory integration, resulted in less influence of visual information on audiovisual speech perception.

Such findings of impaired lip-reading, or unisensory visual speech perception, among individuals with schizophrenia have been found for sentences (Myslobodsky, Goldberg, Johnson, Hicks, & Weinberger, 1992), words (Schonauer, Achtergarde, & Reker, 1998), and vowel-consonant-vowel utterances (de Gelder et al., 2002). It has also been found that during unisensory visual speech perception, individuals with schizophrenia show less activation in the posterior inferior temporal cortex, occipital cortical areas, temporal areas, and the inferior frontal gyrus (Surguladze et al., 2001). However, intact visual speech perception has also been found, with no differences in perception of visual words (Myslobodsky et al., 1992).

Additionally, in the unisensory auditory domain, individuals with schizophrenia are impaired in accurately perceiving auditory words, even without background noise or babble

(Bull & Venables, 1974; DeLisi et al., 1997; Shedlack et al., 1997; Titone & Levy, 2004). Individuals with schizophrenia also have impaired auditory speech perception in the context of noisy background babble (Hoffman, Rapaport, Mazure, & Quinlan, 1999) and recorded cafeteria noise (Shedlack et al., 1997). Interestingly, Hoffman et al. (1999) found that among individuals with schizophrenia who experience auditory hallucinations of voices, speech perception is even less accurate than individuals with schizophrenia who do not experience these hallucinations. Speech perception in the context of background phonetic noise is also more impaired among individuals with schizophrenia who experience auditory hallucinations compared to those who do not (Lee, Chung, Yang, Kim, & Suh, 2004). However, intact auditory speech perception has also been found, with no deficits in the recognition of auditory words presented with pink noise (Ross, Saint-Amour, Leavitt, Molholm, et al., 2007b).

Altogether, while there appear to be unisensory deficits in auditory and visual speech perception, these unisensory deficits are not always found. While audiovisual speech perception in schizophrenia has not been widely investigated, it appears that individuals with schizophrenia do not experience as much multisensory gain in perception accuracy as individuals without schizophrenia. This suggests that impairments in multisensory integration are impacting audiovisual speech perception in schizophrenia. Meanwhile, the possible unisensory speech perception deficits suggest that isolated sensory processing of speech is also impaired.

1.6 Speech Distractibility Across the Schizophrenia Spectrum

In addition to deficits in speech perception accuracy, individuals with schizophrenia are also impaired at ignoring distracting auditory speech (Moser, Cienfuegos, Barros, & Javitt, 2001; Oltmanns & Neale, 1975). This means that they tend to have poorer perception accuracy of target speech and increased perception of irrelevant, distracting speech. Higher severity of disorganized speech is related to greater impairments in ignoring distracting speech (Moser et al., 2001). This distractibility impacts not only speech perception, but also communication. When presented with distracting speech while trying to speak, individuals with schizophrenia have substantially higher levels of communication failures compared to when they are not presented with distracting auditory speech (Moskowitz, Davidson, & Harvey, 1991). In contrast, individuals without schizophrenia have drastically fewer communication failures, and there is no change in communication failures between conditions with and without distracting speech. Individuals with higher levels of schizotypal traits are also more easily distracted by auditory speech (Marsh, Vachon, & Sörqvist, 2017) and visual non-speech stimuli (Braunstein-Bercovitz & Lubow, 1998). Individuals with prodromal psychosis symptoms who perceived higher levels of speech when presented with multiple overlapping background voices, subsequently had elevated risk for schizophrenia diagnosis (Hoffman et al., 2007). This greater susceptibility to attend to distracting auditory speech appears to be due to deficits either in the allocation of attention or in the available attentional resources (Bestelmeyer, 2012). These deficits may also be due to deficits in sensory gating in schizophrenia (Mcdowd, Filion, Harris, & Braff, 1993).

1.7 Hallucinations in Schizophrenia

Given that most individuals with schizophrenia experience verbal hallucinations (Thomas et al., 2007), and that the speech perception system in schizophrenia seems to be impaired, it is likely that there is a connection between the two. It is possible that impaired multisensory integration and temporal processing, as well as increased speech distractibility are accounting for both verbal hallucinations and impaired audiovisual speech perception.

One of the top theories of auditory verbal hallucinations postulates that they may result from the interpretation of one's internal thoughts as external voices (Jones, 2010). This theory can be extended to cross-modal audiovisual hallucinations, which are more common in schizophrenia than unisensory hallucinations (Lim et al., 2016; McCarthy-Jones et al., 2017). Specifically, mistaken binding of external visual speech with internal thoughts provides a potential explanation for audiovisual verbal hallucinations (Jones & Fernyhough, 2007). Issues with temporal processing could be partially responsible for this mis-binding, because of errors with determining when two stimuli are perfectly simultaneous. In support of a relationship between temporal processing and hallucinations in schizophrenia, it has been found that individuals with more severe hallucinations have narrower temporal binding windows than individuals with less severe hallucinations (Stevenson, Park, et al., 2017). These findings are counterintuitive, because narrower windows indicate better precision in knowing when two things are happening synchronously versus asynchronously. However, maybe for individuals with schizophrenia, wider temporal binding windows are actually preferable. This could be because the sensory gating deficits in schizophrenia result in more sensory noise entering their perceptual systems, such as distracting auditory speech (Mcdowd et al., 1993). Since individuals with schizophrenia pay increased attention to irrelevant speech, this makes it possible that they are erroneously integrating this unrelated speech with what they see visually. Considering that individuals with schizophrenia may be slightly poorer lip-readers (Schonauer et al., 1998), they may be more likely to take irrelevant auditory information and bind it mistakenly with visual facial speech information. Also, with additional sensory noise, there are more options of sensory information to be bound together. If one’s temporal binding window is narrower, this means there is less “wiggle room” for two things to be bound together. When it comes to speech, it seems that having more margin for error, in the form of a wider temporal binding window, is desirable. The temporal binding window is, in fact, wider for speech than it is for simple flashes and beeps, or a hammer hitting a nail (Wallace & Stevenson, 2014). This additional flexibility in the temporal binding window for speech stimuli is likely because speech has a longer duration than short flashes and beeps, or the banging of a hammer. Also, auditory and visual speech components are usually not perfectly synchronous, especially in situations where the speaker is far away from the listener. In cases like this, the auditory speech component would reach the ear after the visual component would reach the eye (Wallace & Stevenson, 2014). So for speech, a wider temporal binding window may be beneficial because it accounts for these temporal differences in the auditory and visual components of speech. Altogether, if the temporal binding window is too narrow, and there are many more options of stimuli to be bound together, it is more likely that two mismatching components are erroneously bound together. In support of this theory of binding mismatching auditory and visual words, individuals with schizophrenia have lower levels of neural activity compared to controls in response to incongruent auditory and visual words (Szycik, Münte, Dillo, Mohammadi, & Samii, 2009). In individuals without schizophrenia, increased levels of neural activity during incongruent presentations is thought to represent increased awareness of this incongruent presentation. The finding that individuals with schizophrenia have less neural activity suggests that they are more forgiving of these incongruent representations.

1.8 The Current Study

Previous work suggests that individuals with schizophrenia show differences in multisensory integration, temporal processing, speech perception, and distractibility to auditory speech. There is little research investigating whether these differences extend across the schizophrenia spectrum, but early findings do suggest that this is the case. The current study aims to investigate whether higher levels of schizotypal traits are associated with differences in audiovisual multisensory integration, temporal processing, speech perception, and distractibility to auditory speech.

Two separate studies were conducted. Study 1 investigates multisensory integration using the McGurk task, correlating McGurk effect perceptions with schizotypal traits. Study 2 uses three tasks (McGurk, speech-in-noise, and ternary synchrony judgement tasks) to investigate multisensory integration, temporal processing, audiovisual speech perception and auditory speech distractibility, and correlates these with levels of schizotypal traits. We measure schizotypal traits using the Schizotypal Personality Questionnaire (SPQ), hypothesizing that higher levels of schizotypal traits, specifically *Unusual Perceptual Experiences* and *Odd Speech* subscales, will be associated with (1) decreased multisensory integration, (2) increased susceptibility to distracting auditory speech, and (3) less precise temporal processing.

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Chapter 2

2. Experiment I – Schizotypal Personality Traits and Multisensory Integration: An Investigation Using the McGurk Effect

2.1 Introduction

Multisensory integration is the process by which the brain combines sensory information from multiple modalities, for example auditory and visual information, into coherent, unitary percepts. This ability is crucial to everyday perception, as the majority of sensory experiences are multisensory. As a result of multisensory integration, individuals are better at detecting (Lovelace, Stein, & Wallace, 2003; Stein & Wallace, 1996), localizing (Nelson et al., 1998; Wilkinson et al., 1996), and have faster response times to stimuli in the environment (Diederich & Colonius, 2004; Hershenson, 1962). Multisensory integration also aids with speech perception (Ross, Saint-Amour, Leavitt, Javitt, et al., 2007) and identification of ambiguous stimuli (Green & Angelaki, 2010). While multisensory integration does not require conscious effort, one must determine which sensory inputs originate from the same external event and thus should be integrated, and which should be processed independently (Stevenson, Ghose, et al., 2014). This is a computationally difficult cognitive feat to achieve given the overwhelming amount of sensory information entering each sensory system at any given moment. There are a number of different types of information embedded within the sensory inputs themselves that can be used as cues to bind, the most salient of which are the temporal and spatial coincidence of information across different sensory modalities (Stein & Meredith, 1993). In short, the more temporally and spatially coincident two sensory inputs are, the more likely they originated from the same external event, and thus the more likely that they should be integrated. Temporal processing abilities vary quite drastically between individuals in both clinical and nonclinical

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groups (Wallace & Stevenson, 2014), and within these individual differences, multisensory temporal precision has been directly associated with the frequency and accuracy of multisensory integration (Ferri et al., 2017; Martin et al., 2013; Stevenson et al., 2013).

With multisensory integration being so important for normal perception of the world, it follows that alterations in one's multisensory integration abilities might contribute to atypical perceptual experiences, such as those observed across the schizophrenia spectrum (Stevenson, Park, et al., 2017; Wallace & Stevenson, 2014; Wallace, Woynaroski, & Stevenson, 2020). Indeed, individuals with schizophrenia have been shown to have decreased multisensory integration as well as impairments in perceptual processes that underlie multisensory integration, such as temporal processing. Altered temporal processing in schizophrenia has been found in both unisensory (Capa et al., 2014; de Boer-Schellekens et al., 2014; Giersch et al., 2009; Lalanne et al., 2012; Tenckhoff et al., 2002) and multisensory processing (Foucher et al., 2007; Martin et al., 2013; Stevenson, Park, et al., 2017; Zhou et al., 2018). Since multisensory temporal precision has been directly associated with the frequency and accuracy of multisensory integration (Ferri et al., 2017; Martin et al., 2013; Stevenson et al., 2013), it is not surprising that individuals with schizophrenia who have temporal deficits also have altered multisensory integration (de Jong, Hodiamont, Van den Stock, & de Gelder, 2009; White et al., 2014; Williams, Light, Braff, & Ramachandran, 2010, but see Martin et al., 2013; Romero et al., 2016). These multisensory integration deficits in schizophrenia have been found specifically in the realm of audiovisual speech integration (de Gelder et al., 2002; Pearl et al., 2009; Ross, Saint-Amour, Leavitt, Molholm, et al., 2007; Stekelenburg, Maes, Van Gool, Sitskoorn, & Vroomen, 2013, but see Surguladze et al., 2001).

Individuals on the less severe end of the schizophrenia spectrum appear to share these multisensory integration and temporal processing deficits. The schizophrenia spectrum ranges from minor levels of schizotypal traits in the general population (schizotypy) to schizotypal personality disorder, early or prodromal psychosis, and at the extreme, schizophrenia. Schizotypal traits are personality characteristics that occur along a continuum from healthy, imaginative states to psychosis, a continuum referred to as the schizophrenia spectrum. While individuals across this spectrum experience similar symptoms, they differ greatly in severity of these symptoms. For example, evidence from work on cognition, perception, and motor control, as a whole, reveals that individuals who have more schizotypal traits tend to have deficiencies in performance that are similar but attenuated to those seen in individuals with schizophrenia (Ettinger et al., 2014). While schizotypy is not a clinically diagnosable condition, individuals exhibiting higher levels of schizotypal traits in the general population are at an elevated risk of developing schizophrenia and other psychotic illnesses (Kwapil et al., 2013). Like schizophrenia, the features of schizotypy can be organized into three groups: positive (experiences of illusions, unusual perceptual experiences, bizarre or magical thinking, depersonalisation, and derealisation), negative (anhedonia, avolition, reduced emotional expression, and social isolation) and disorganized (odd behaviour, thought, and speech) (Raine, 2006); American Psychiatric Association, 2013).

Within the positive symptom dimension, “unusual perceptual experiences” is a common symptom across the schizophrenia spectrum. This symptom is likely related to differences in sensory processing. Several sensory deficits in both schizotypy and schizophrenia have been reported. Like schizophrenia, deficits in auditory pitch discrimination (Bates, 2005), sensory gating (Park, Lim, Kirk, & Waldie, 2015), sensory prediction (Teufel et al., 2010), prepulse

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inhibition (Wan et al., 2017), and olfactory scent identification (S. Park & Schoppe, 1997) have been noted in schizotypy. Considering the significant overlap between schizophrenia and schizotypy found through retrospective, longitudinal, family, genetic, environmental, cognitive, and neurobiological investigations (Ettinger et al., 2014), it is not surprising that these similarities in altered sensory processing have been found.

There is a scarcity of investigation into multisensory integration in schizotypy, but early findings have indicated alterations in temporal processing and multisensory integration in individuals with schizotypal traits in the general population. Specifically, individuals with higher schizotypy tend to have stronger responses to visual-tactile (Asai et al., 2011; Germine et al., 2013) and audiovisual illusions (Ferri, Venskus, Fotia, & Cooke, 2018). Individuals with higher schizotypy also tend to have poorer tactile-proprioceptive (Ferri et al., 2016) and audio-tactile temporal processing (Ferri et al., 2017). These findings together indicate that temporal processing and multisensory integration appear to be altered in individuals with higher schizotypal traits.

Here, we assessed the relationship between multisensory integration and schizotypal traits. To assess multisensory integration, we used the McGurk effect (McGurk & MacDonald, 1976). Participants were presented with a speaker uttering the auditory syllable “ba” coincidentally with the speaker visually articulating the syllable “ga”. The McGurk effect occurs when participants report perceiving the speaker saying “da” or “tha”, a syllable that is not present in either of the unisensory stimuli, and a percept that is thus strong evidence of integration. We measured schizotypal traits through the Schizotypal Personality Questionnaire (SPQ; Raine, 1991), with the hypothesis that higher levels of schizotypal traits would be associated with reduced perception of the McGurk effect. In particular, we predicted that the

McGurk effect would be related to the *Unusual Perceptual Experiences* and *Odd Speech* subscales of the SPQ.

2.2 Materials and Methods

2.2.1 Participants

105 adult participants (60 female, mean age = 18.60, SD = 1.99, range = 17 to 35) completed the current experiment. Seven additional participants were excluded, six participants who did not complete the multisensory McGurk task, and one participant who did not complete the unisensory task. Experimental protocols were approved by Western University's Non-Medical Research Ethics Board. All individuals self-reported normal hearing and normal or corrected-to-normal vision. All participants reported that English was the first language they learned. Participants were recruited via the undergraduate research participation pool. All participants included in data analysis (N = 105) completed both multisensory and unisensory versions of the McGurk task, and the SPQ (Raine, 1991). Sample size was based on a power analysis using results from Ferri et al. (2018), in which schizotypal traits measured by the SPQ were related to a multisensory illusion, revealing an effect size of $\rho = 0.26$. With this effect size, 101 participants were needed to achieve a power of 0.85 (G*Power 3.1.9.4).

2.2.2 Stimuli

2.2.2.1 McGurk Task

All stimuli throughout the study were presented using MATLAB 2018a (MATHWORKS Inc., Natick, MA) software with the Psychophysics Toolbox extensions (Brainard, 1997; Pelli, 1997). Audio stimuli were presented binaurally through BOSE QuietComfort 35 noise-cancelling headphones.

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The videos used for the McGurk task have been used previously in studies of the McGurk effect (Quinto, Thompson, Russo, & Trehub, 2010; Stevenson, Siemann, et al., 2014). Stimuli consisted of one audiovisual clip of a female speaker saying either the syllable “ba” or “ga”, at a normal rate and volume with a neutral facial expression. Auditory stimuli were delivered at a comfortable level (calibrated to approximately 72 dB SPL) presented through noise-cancelling headphones. Visual stimuli were cropped to square, down-sampled to a resolution of (400 × 400 pixels) spanning 11.8 cm per side or 11.23 degrees of visual angle and converted from color to grayscale. Presentations were shortened to 2 s, and each presentation included the entire articulation of the syllable, including pre-articulatory gestures.

Stimuli included visual-only, auditory-only, and congruent audiovisual presentations of the phoneme “ba” or “ga,” and the McGurk stimuli, a visual “ga” presented with an auditory “ba”. All presentations were temporally synchronous.

2.2.2.2 Schizotypal Personality Questionnaire

The Schizotypal Personality Questionnaire (SPQ; Raine, 1991) is a 74-item questionnaire frequently used in the general population. Each item requires either a “Yes” or “No” answer, with the total score summing up “Yes” responses. The items of the SPQ can be reliably broken down into nine subscales: *Ideas of Reference, Excessive Social Anxiety, Odd Beliefs or Magical Thinking, Unusual Perceptual Experiences, Odd or Eccentric Behavior, No Close Friends, Odd Speech, Constricted Affect,* and *Suspiciousness.* A widely-replicated three-factor model of the SPQ groups the nine subscales into three factors that match the three areas impacted in both schizophrenia and schizotypal personality disorder: Cognitive-Perceptual, Disorganized, and Interpersonal (Badcock & Dragović, 2006; Chen, Hsiao, & Lin, 1997; Fossati, Raine, Carretta, Leonardi, & Maffei, 2003; Raine, Lencz, Scerbo, & Kim, 1994;

Reynolds, Raine, Mellingen, Venables, & Mednick, 2000; Wuthrich & Bates, 2006). High sampling validity has been reported for the SPQ, as well as high internal reliability (0.91), test-retest reliability (0.82), convergent validity (0.59 to 0.81), discriminant validity, and criterion validity (0.63, 0.68) (Raine, 1991).

2.2.3 Procedures

2.2.3.1 McGurk Task

Participants sat approximately 60 cm from the monitor, in a sound- and light-controlled room. A researcher sitting next to the participant monitored the participant to make sure his/her eyes remained on the screen. The task was divided into two separate runs, a multisensory and a unisensory run, always presented in that order. All stimulus presentations included a female actor speaking a single syllable. The audiovisual run included congruent “ba”, congruent “ga”, and the McGurk stimulus, an auditory “ba” paired with a visual “ga”. The unisensory run included random visual and auditory presentations of “ba” and “ga”.

Both runs began with a screen instructing them to identify what syllable the speaker said in modality-neutral wording (“What did she say?”). Each trial began with a fixation screen that randomly jittered from 0.5 to 1.5 seconds, and multi-speaker babble which ramped up linearly for 500 ms and continued during the stimulus presentation. After the stimulus presentation, the visual frame was removed (except for the auditory condition). The multi-speaker babble continued on its own for another 500 ms with a linear ramp down, and each trial was concluded by an additional 250 ms fixation screen. After each presentation, participants were shown a response screen that asked them to report what the speaker said by pressing one of four keys, “b,” “g,” “d,” or “t,” representing “ba,” “ga,” “da,” and “tha,” respectively. Immediately after the response, the fixation screen for the subsequent trial was presented.

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In the multisensory run, participants were presented with a total of 60 trials, with each audiovisual condition presented 20 times in random order. The unisensory run began in the same manner as the multisensory run, and trial structures were identical with the exception of stimulus presentations. Each unisensory condition was presented 10 times, for a total of 40 trials. Unisensory conditions included auditory and visual “ba” and “ga” presentations.

2.2.3.2 Schizotypal Personality Questionnaire

The SPQ was completed online through Qualtrics prior to each study visit.

2.2.4 Analysis

2.2.4.1 McGurk Task

For each of the seven conditions, an accuracy score was calculated for each participant. This was calculated as the proportion of trials the participant accurately identified as the syllable that was presented. For the McGurk trials, accuracy was defined as the proportion of trials the participant reported having perceived “da” or “tha”. Average visual accuracy was calculated as the average proportion of visual-alone trials perceived correctly as “ba” or “ga”. Average auditory accuracy was calculated as the average proportion of auditory-alone trials perceived correctly as “ba” or “ga”.

2.2.4.2 Schizotypal Personality Questionnaire

Overall SPQ total scores, and SPQ subscale scores were calculated for each participant. Four participants missed a small number of items. Three participants missed one item, and one participant missed four items. Missing data points were replaced based on the participants’ average responses to the other items within that subscale.

2.2.4.3 *A Priori* Analyses

Pearson correlations were first conducted between the McGurk effect and two subscales of the SPQ that were expected *a priori* to correlate negatively with the McGurk effect: *Unusual Perceptual Experiences* and *Odd Speech*. *Unusual Perceptual Experiences* was hypothesized to be correlated since altered multisensory integration, as measured by the McGurk effect, is thought to contribute to altered perceptual experiences (Stevenson, Park, et al., 2017). *Odd Speech* was predicted to be correlated because the McGurk effect is a speech-related task.

If significant relationships were found between the McGurk effect and a subscale, Pearson correlations were then run between both average auditory and average visual accuracy and that subscale to account for the possibility that individual differences in the perception of the unisensory speech components may influence the perception of the McGurk effect. In the case of subscales correlating with both the McGurk effect and unisensory accuracy, a two-stage hierarchical multiple regression was conducted to assess whether the relationship between that subscale and the McGurk effect may be accounted for by differences in unisensory perception as opposed to multisensory integration. Perceived McGurk effect was entered in Model 1, and unisensory accuracy in Model 2 in order to assess whether the relationship between the McGurk effect and the subscale could be accounted for by unisensory accuracy.

For significant correlations between the McGurk effect, unisensory accuracy, and a subscale or factor, mediational analyses were conducted. The subscale or factor was entered as the dependent variable, and McGurk effect and unisensory accuracy entered as both mediators and predictors to test directionality of the mediation.

2.2.4.4 Exploratory Analyses

Exploratory analyses were performed in which the remaining subscales were related to speech perceptions using Pearson correlations. Analyses were identical to that with planned comparisons above, however, initial correlations were subjected to a Benjamini-Hochberg correction for multiple comparisons (q = 0.05), and follow-up testing was only conducted where correlations survived correction for multiple comparisons.

2.3 Results

2.3.1 McGurk Task

The proportion of phonemes perceived for congruent audiovisual "ba" (*M* = 0.99, *SD* = 0.02) and "ga" (*M* = 0.99, *SD* = 0.02), incongruent audiovisual "da" (*M* = 0.49, *SD* = 0.34), unisensory auditory "ba" (*M* = 0.93, *SD* = 0.11) and "ga" (*M* = 0.99, *SD* = 0.03), and unisensory visual "ba" (*M* = 0.99, *SD* = 0.04) and "ga" (*M* = 0.63, *SD* = 0.29) presentations are shown for each individual in Figure 1.

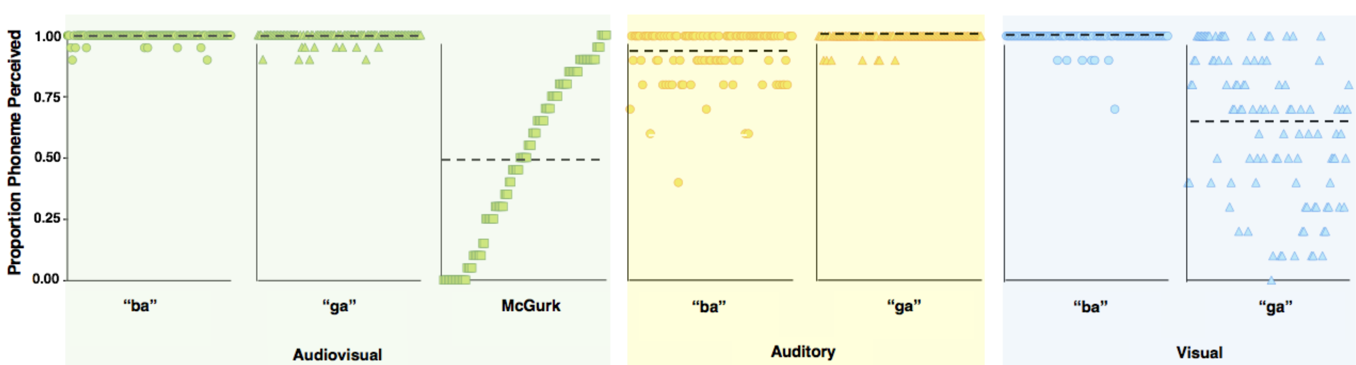

Figure 1: Proportion of phonemes perceived for congruent audiovisual "ba" and "ga", incongruent audiovisual "da", unisensory auditory "ba" and "ga", and unisensory visual "ba" and "ga" presentations. Note. Dashed lines indicate group means.

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2.3.2 Schizotypal Personality Questionnaire

The total SPQ scores (*M* = 22.81, *SD* = 13.36) ranged from 2 to 54. The possible scores for the SPQ can range between 0 and 74. Using the 10% high and low cut-offs reported for the original validation of the SPQ of 41 and 12, respectively (Raine, 1991), 15 individuals, or 14.29%, met the high cut-off, and 22 individuals, or 21.90%, met the low cut-off. As such, the current sample filled a wide range of the scale.

Factor scores are as follows: Interpersonal (*M* = 10.96, *SD* = 6.94, range = 0 to 27), Cognitive-Perceptual (*M* = 7.29, *SD* = 5.44, range = 0 to 23), Disorganized (*M* = 4.57, *SD* = 3.47, range = 0 to 13). Factor scores met the entire range of possible scores for each factor.

Subscale scores are as follows: *Ideas of Reference* (*M* = 3.68, *SD* = 2.56, range = 0 to 9), *Excessive Social Anxiety* (*M* = 3.68, *SD* = 2.52, range = 0 to 8), *Odd Beliefs or Magical Thinking* (*M* = 1.14, *SD* = 1.47, range = 0 to 7), *Unusual Perceptual Experiences* (*M* = 2.47, *SD* = 1.86, range = 0 to 9), *Odd or Eccentric Behavior* (*M* = 1.48, *SD* = 1.86, range = 0 to 7), *No Close Friends* (*M* = 2.62, *SD* = 2.31, range = 0 to 8), *Odd Speech* (*M* = 3.09, *SD* = 2.08, range = 0 to 8), *Constricted Affect* (*M* = 2.10, *SD* = 1.83, range = 0 to 8), and *Suspiciousness* (*M* = 2.56, *SD* = 2.17, range = 0 to 8). Subscale scores met the entire range of possible scores for each subscale.

2.3.3 *A Priori* Results

The proportion of trials on which the McGurk effect was perceived was expected *a priori* to negatively correlate with two subscales of the SPQ: *Unusual Perceptual Experiences* and *Odd Speech*. Surprisingly, perceived McGurk effect was not significantly correlated with scores on the *Unusual Perceptual Experiences* subscale, *r*(103) = .086, 95% CI = [-0.107, 0.273], *p* = .382 (Figure 2). Perceived McGurk effect was significantly positively correlated with scores on the *Odd Speech* subscale, *r*(103) = .229, 95% CI = [0.039, 0.403], *p* = .019 (Figure 3A).

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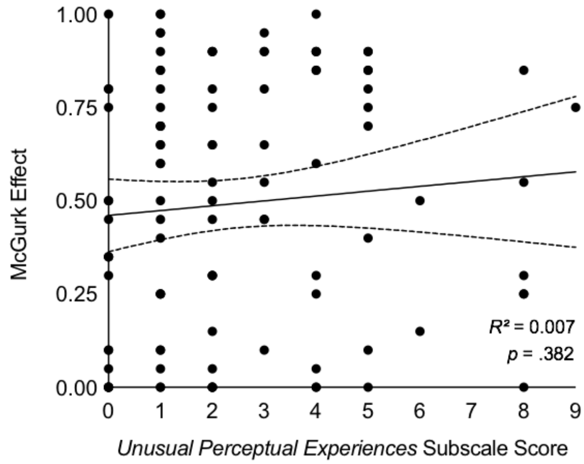

Figure 2: Scatterplot showing correlations between the McGurk effect and *Unusual Perceptual Experiences* subscale score.

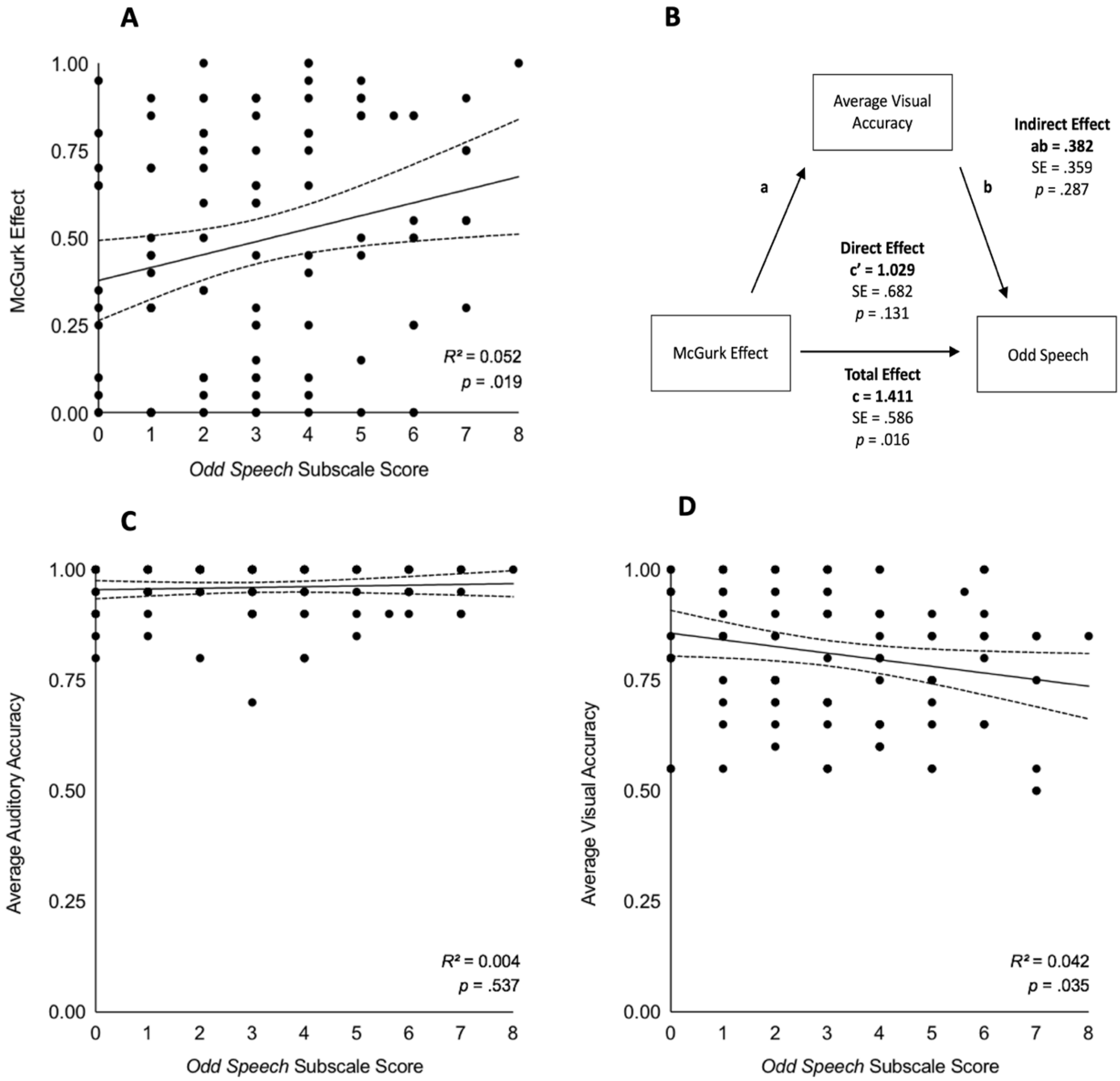

Figure 3: (A) Scatterplot showing correlation between the Odd Speech subscale and McGurk effect. (B) Summary of mediational analysis for perceived McGurk effect predicting Odd Speech subscale scores with average visual accuracy as a mediator. (C) and (D) Scatterplot showing correlations between Odd Speech subscale and average auditory and visual accuracy, respectively.

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Given the significant correlation between McGurk perceptions and *Odd Speech,* further analysis was conducted to investigate whether this effect was specifically multisensory. As auditory and visual perception may influence performance on the audiovisual McGurk effect, Pearson correlations were conducted between both auditory and visual accuracy and the *Odd Speech* subscale. There was not a significant correlation between auditory accuracy and *Odd Speech*, $r(103) = .061$, 95% CI = [-0.132, 0.250], $p = .537$ (Figure 3C). There was, however, a significant negative correlation between visual accuracy and *Odd Speech*, $r(103) = -.206$, 95% CI = [-0.383, -0.015], $p = .035$ (Figure 3D).

To assess whether the relationship between the McGurk effect and the *Odd Speech* subscale could be influenced by visual speech perception, a two-stage hierarchical multiple regression was conducted with *Odd Speech* subscale scores as the dependent variable. Perceived McGurk effect was entered in Model 1, and visual accuracy in Model 2. Perceived McGurk effect and average visual accuracy were significantly intercorrelated, $r(103) = -.519$, 95% CI = [-0.646, -0.364], $p < .001$ (Figure S1), however, collinearity statistics (VIF = 1.369, Tolerance = 0.730, Minimum Tolerance = 0.730) suggest that this intercorrelation did not impact the regression. Detailed regression statistics are reported in Table 1.

Table 1: Summary of hierarchical regression analysis for perceived McGurk effect and average visual accuracy predicting Odd Speech subscale scores

Predictor	B (unstandardized coefficient)	Partial correlation (*pr*)	*p*-value
Step 1: R^2 = .052, $F(1,103) = 5.692$, p = .019			
McGurk effect	1.411	.229	**.019**
Step 2: R^2 = .063, $F(2,102) = 3.416$, p = .037			
McGurk effect	1.029	.146	.140
Average visual accuracy	-1.643	-.105	.290

The hierarchical multiple regression revealed that in Model 1, the McGurk effect contributed significantly to the regression model and accounted for 5.2% of the variance in *Odd Speech*. Introducing average visual accuracy explained an additional 1.0% of the variance in *Odd Speech*, a change in R^2 that was not significant. While the McGurk effect was a significant predictor of *Odd Speech* and the addition of visual accuracy did not significantly add to the model predicting *Odd Speech*, the McGurk effect itself was no longer significant as an individual predictor in Model 2, suggesting that the relationship between visual perception and

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Odd Speech may account, at least partially, for the relationship between multisensory integration, as indexed by the McGurk effect, and *Odd Speech*.

Mediational analyses for the *Odd Speech* subscale (Tables S1 & S2) and the Disorganized factor (Tables S3 & S4) revealed that neither average visual accuracy (Figure 3B) nor the McGurk effect were mediators.

2.3.4 Exploratory Results

While specific *a priori* predictions were made and tested for the *Unusual Perceptual Experiences* and the *Odd Speech* subscales, exploratory analyses were performed in which Pearson's correlations were conducted between the McGurk effect and total SPQ scores, the three factors of the SPQ (Interpersonal, Cognitive-Perceptual, and Disorganized), and the subscales within each of these factors. Total SPQ scores were not significantly correlated with the McGurk effect (Figure S2). The Interpersonal factor was also not significantly correlated with the McGurk effect (Figure S3). Within the Interpersonal factor, the *Excessive Social Anxiety* subscale was not significantly correlated with the McGurk effect (Figure S4), nor was the *Constricted Affect* subscale (Figure S5), or the *Suspiciousness* subscale (Figure S6). The relationship between the McGurk effect and *No Close Friends* approached significance, but did not survive corrections for multiple comparisons (Figure S7). The Cognitive-Perceptual factor was not significantly correlated with the McGurk effect (Figure S8). Within the Cognitive-Perceptual factor, *Ideas of Reference* subscale (Figure S9) and *Odd Beliefs or Magical Thinking* (Figure S10) were not significantly correlated with the McGurk effect. The Disorganized factor was significantly correlated with the McGurk effect (Figure 4). Within the Disorganized factor, the *Odd or Eccentric Behaviour* subscale was significantly correlated with the McGurk effect following corrections for multiple comparisons (Figure 5A). See Table 2 for detailed statistics of Pearson's correlations.

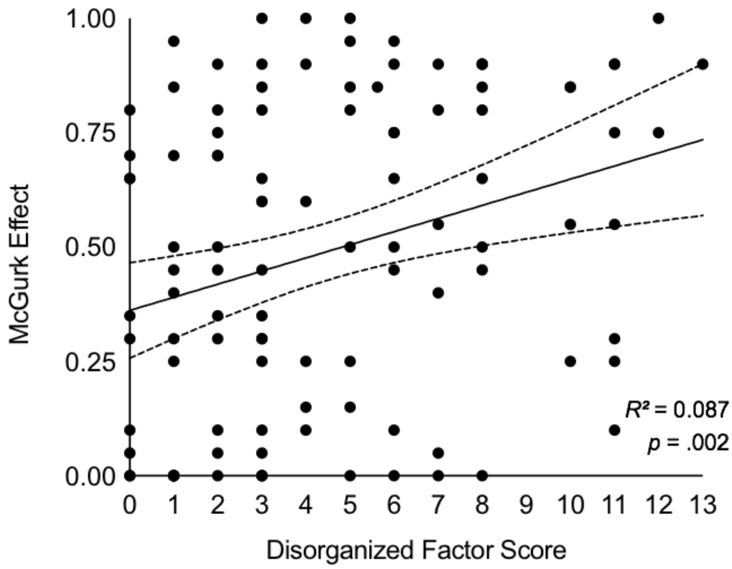

Figure 4: Scatterplot showing correlations between perception rate of the McGurk effect and the Disorganized factor.

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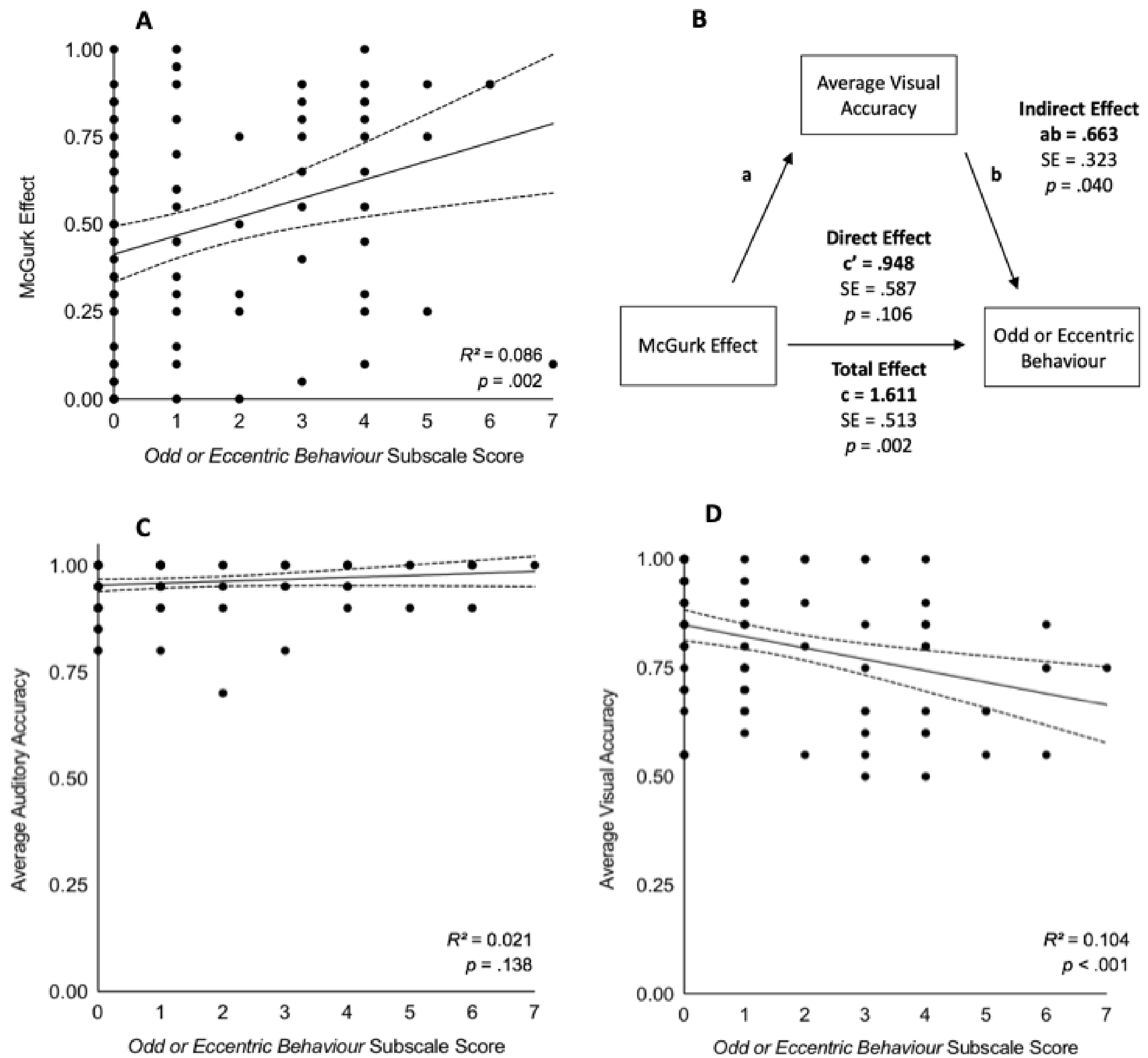

Figure 5: (A) Scatterplot showing correlation between the Odd or Eccentric Behaviour subscale and McGurk effect. (B) Summary of mediational analysis for perceived McGurk effect predicting Odd or Eccentric Behaviour subscale scores with average visual accuracy as a mediator. (C) and (D) Scatterplot showing correlations between Odd or Eccentric Behaviour subscale and average auditory and visual accuracy, respectively.

Table 2: Pearson's correlations between the McGurk effect and total SPQ scores, the three factors of the SPQ (Interpersonal, Cognitive-Perceptual, and Disorganized), and the subscales within each of these factors.

	r(103)	95% CI	*p*-value	Adjusted *p*-value
Total SPQ	.122	[-0.071, 0.307]	.216	.475
Interpersonal	.121	[-0.072, 0.306]	.218	.400
Excessive Social Anxiety	.064	[-0.129, 0.253]	.513	.705
Constricted Affect	.102	[-0.091, 0.288]	.298	.468
Suspiciousness	.026	[-0.166, 0.217]	.789	.868
No Close Friends	.188	[-0.004, 0.366]	.055	.202
Cognitive-Perceptual	-.042	[-0.232, 0.151]	.671	.820
Ideas of Reference	-.152	[-0.334, 0.041]	.121	.333
Odd Beliefs or Magical Thinking	-.022	[-0.213, 0.170]	.823	.823
Unusual Perceptual Experiences	.086	[-0.107, 0.273]	.382	.382
Disorganized	.295	[0.110, 0.461]	.002	**.022**
Odd or Eccentric Behaviour	.293	[0.107, 0.459]	.002	**.011**
Odd Speech	.229	[0.039, 0.403]	.019	**.038**

The positive, significant relationship between the *Odd or Eccentric Behaviour* subscale and the McGurk effect was investigated further. As with the *Odd Speech* subscale, auditory and visual accuracy were examined to determine whether they played a role in how the McGurk effect was related with the *Odd or Eccentric Behaviour* subscale. Pearson correlations were conducted between both auditory and visual accuracy and the *Odd or Eccentric Behaviour* subscale. There was not a significant correlation between auditory accuracy and *Odd or Eccentric Behaviour*, $r(103) = .146$, 95% CI = [-0.047, 0.328], $p = .137$ (Figure 5C). There was, however, a significant negative correlation between visual accuracy and *Odd or Eccentric Behaviour*, $r(103) = -.322$, 95% CI = [-0.484, -0.139], $p = .001$ (Figure 5D). The influence of visual accuracy on the McGurk effect's relationship with *Odd or Eccentric Behaviour* was investigated further with a hierarchical multiple regression.

To assess whether the relationship between the McGurk effect and the *Odd or Eccentric Behaviour* subscale could be accounted for by the relationship between visual speech perception, a two-stage hierarchical multiple regression was conducted with *Odd or Eccentric Behaviour* subscale scores as the dependent variable. Perceived McGurk effect was entered in Model 1, and visual accuracy in Model 2. Perceived McGurk effect and average visual accuracy were significantly intercorrelated, $r(103) = -.519$, 95% CI = [-0.646, -0.364], $p < .001$ (Figure S1), however, collinearity statistics (VIF = 1.369, Tolerance = 0.730, Minimum Tolerance = 0.730) suggest that this intercorrelation did not impact the regression. Detailed regression statistics are reported in Table 3.

Table 3: Summary of hierarchical regression analysis for perceived McGurk effect and average visual accuracy predicting Odd or Eccentric Behaviour subscale scores.

Predictor	B (unstandardized coefficient)	Partial correlation (*pr*)	*p* value
Step 1: R^2 = .086, F(1,103) = 9.682, p = .002			
McGurk effect	1.611	.293	**.002**
Step 2: R^2 = .125, F(2,102) = 7.306, p = .001			
McGurk effect	0.948	.156	.114
Average visual accuracy	-2.848	-.208	**.034**

The hierarchical multiple regression revealed that in Model 1, the McGurk effect contributed significantly to the regression model and accounted for 8.6% of the variance in *Odd or Eccentric Behaviour*. Introducing average visual accuracy explained an additional 3.9% of the variance in *Odd or Eccentric Behaviour*, a significant change in R^2. Together, perceived McGurk effect and average visual accuracy predicted 12.5% of the variance in *Odd or Eccentric Behaviour*. However, while the overall model including the McGurk effect and visual accuracy significantly predicted *Odd or Eccentric Behaviour,* only average visual accuracy remained significant at the individual variable level.

Mediational analyses revealed that average visual accuracy fully mediated the relationship between the McGurk effect and *Odd or Eccentric Behaviour* (Table 4; Figure 5B).

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When McGurk effect was entered as the mediator and average visual accuracy as the predictor, no mediation effect was found (Table S5).

Table 4: Summary of mediational analysis for perceived McGurk effect predicting Odd or Eccentric Behaviour subscale scores with average visual accuracy as a mediator.

Mediation Estimates

Effect	Label	Estimate	SE	Z	p	% Mediation
Indirect	a × b	0.663	0.323	2.053	**0.040**	41.133
Direct	c	0.948	0.587	1.616	0.106	58.867
Total	c + a × b	1.611	0.513	3.142	**0.002**	100.000

Path Estimates

	Label	Estimate	SE	Z	p
McGurk Effect → Average Visual Accuracy	a	-0.233	0.037	-6.225	**< .001**
Average Visual Accuracy → Odd/Eccentric Beh	b	-2.848	1.310	-2.174	**0.030**
McGurk Effect → Odd/Eccentric Beh	c	0.948	0.587	1.616	0.106

2.4 Discussion

This study is the first to investigate the relationship between schizotypal traits and perception of the McGurk effect, a measure of multisensory integration. We hypothesized that individuals with higher levels of schizotypal traits would perceive the McGurk effect at lower

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rates. Surprisingly, the opposite was found, in that higher schizotypy was associated with increased perception of the McGurk effect. Specifically, we found a novel relationship between the McGurk effect and the Disorganized factor of the SPQ, including the two subscales: *Odd Speech* and *Odd or Eccentric Behaviour*. Interestingly, the relationship between the McGurk effect and *Odd or Eccentric Behaviour* was fully mediated by visual accuracy, suggesting that these results may be a result of broader sensory issues including visual and multisensory processing.

The finding of higher schizotypy being associated with increased McGurk perception is in contrast to investigations of the McGurk effect in individuals with schizophrenia. This literature has found that there is either no difference in McGurk perception compared to controls (Martin et al., 2013; Romero et al., 2016), or decreased perception of the McGurk effect compared to controls (de Gelder et al., 2002; Pearl et al., 2009; White et al., 2014). The reason for the current opposing findings is not entirely clear, but they do align with findings in schizophrenia of increased proneness to other perceptual illusions that rely on multisensory integration. Specifically, individuals with schizophrenia are more prone than controls to perceiving the double-flash or fission illusion, in which one visual flash presented with two auditory beeps results in the perception of two visual flashes (Haß et al., 2017). Individuals with schizophrenia also experience the rubber hand illusion stronger and faster than controls (Peled et al., 2000). In the rubber hand illusion, brushstrokes are applied to one's hidden hand synchronously to a visible rubber hand, resulting in a feeling that the rubber hand belongs to one's body. Asynchronous stroking of the rubber hand usually leads to lower perceptions of the illusion (Botvinick & Cohen, 1998), but individuals with higher schizotypy do not have lower perceptions of the rubber hand illusion when asynchronous stroking is applied (Asai et al., 2011). This suggests that high schizotypy individuals have altered multisensory temporal processing, such that they do not recognize that the stroking has become asynchronous. This is seen across the schizophrenia spectrum, with individuals with higher levels of schizotypal traits showing less precise multisensory temporal processing (Dalal, Muller, & Stevenson, 2020). It also suggests that high schizotypy individuals are more permissive of the binding together of incongruent stimuli, which in an asynchronous rubber hand illusion would be a temporal mismatch of visual and tactile information. The McGurk effect is inherently incongruent, in that it requires individuals to bind mismatching auditory and visual information. Notably, the syllabic incongruence in the McGurk effect is different from the temporal incongruence in the asynchronous rubber hand illusion. Nevertheless, if individuals within the schizophrenia spectrum are less restrictive with binding incongruent stimuli broadly speaking, this could explain the higher perception of the McGurk effect and other perceptual illusions. It has also been found that individuals across the schizophrenia spectrum have increased openness to experience (Chmielewski, Bagby, Markon, Ring, & Ryder, 2014), a personality trait describing increased imagination, broad-mindedness, and curiosity (Woo, Saef, & Parrigon, 2015). It is possible that greater openness to experience makes these individuals less skeptical of and more easily susceptible to perceptual illusions. It is also possible that there is a non-linear relationship between schizotypal traits and multisensory integration, and that multisensory integration is not linearly impacted across the schizophrenia spectrum.

As with overall schizotypal traits, *Odd Speech* was positively correlated with the McGurk effect as opposed to the predicted negative correlation. While not in the predicted direction, this association between a speech-based task and a subscale of *Odd Speech* makes intuitive sense. This relationship was not confined to *Odd Speech*, but was found throughout the

Disorganized factor. From a conceptual standpoint, one can imagine how increased McGurk effect perception may be related to disorganized symptomatology, which spans across speech (characterized by difficulty maintaining a train of thought, rambling, jumping from topic to topic, using words in unusual ways, etc.) and behaviour (characterized by lack of impulse control, difficulty completing tasks, and unusual mannerisms, habits, and appearance) (Raine et al., 1994). If visual perceptions are less reliable, and audiovisual stimuli are being integrated erroneously, this impacts how speech is perceived, therefore impacting reciprocal communication. Similarly, it is entirely possible that a less reliable perceptual system may impacting behaviours, as perceiving one's environment unreliably could alter one's interactions with the environment, perhaps leading to unusual behaviours. Future work should further investigate the relationship between sensory processing generally, and multisensory integration specifically, and disorganized schizotypal traits.

Individuals who had higher Disorganized factor scores not only had higher rates of McGurk effect perception, but they also tended to be worse lip-readers. Poorer lip-reading was significantly associated with increased perception of the McGurk effect. Poorer lip-reading mediated the relationship between the McGurk effect and *Odd or Eccentric Behaviour,* but not between the McGurk effect and *Odd Speech* or the Disorganized factor more broadly. The current finding of poorer lip-reading abilities among high schizotypy individuals aligns with previous research into speech perception in schizophrenia, in which these individuals show less speech perception improvement from visual speech input compared to controls, suggesting either poorer lip-reading abilities or poorer multisensory integration, or a combination of both (Ross, Saint-Amour, Leavitt, Molholm, et al., 2007b), though without a visual-only condition in this previous study it is unknown whether lip-reading abilities were actually poorer in individuals with schizophrenia. Individuals with schizophrenia may also be poorer at lip-reading sentences (Myslobodsky et al., 1992) and single words (Schonauer et al., 1998). Individuals with schizophrenia also show less neural activation compared to controls in response to silent visual speech, specifically with less activation in the posterior inferior temporal cortex, occipital cortical areas, temporal areas, and the inferior frontal gyrus being found (Surguladze et al., 2001). Taken together, the current results and previous literature on visual speech perception in schizophrenia suggest that individuals with schizophrenia may have impaired lip-reading abilities, and that this may extend to individuals with higher disorganized schizotypal traits.

In contrast to our hypotheses, *Unusual Perceptual Experiences* were not associated with the McGurk effect. It was predicted that they would be associated because the McGurk effect is a measure of multisensory integration, and multisensory integration abnormalities are thought to contribute to *Unusual Perceptual Experiences*, such as hallucinations or less severe perceptual anomalies (hallucination-like experiences). This is because multisensory integration and temporal processing, which are altered in individuals with schizophrenia and vary based on the level of schizotypal traits (Dalal et al., 2020), are crucial for accurate everyday perceptions, such as audiovisual speech (Stein & Meredith, 1993). Considering that the majority of hallucinations experienced by individuals with schizophrenia are audiovisual in nature (Lim et al., 2016; McCarthy-Jones et al., 2017), and often speech-based (Hugdahl & Sommer, 2018), it is possible that these anomalies are partially arising from the mis-binding of visual and auditory stimuli (Stevenson, Park, et al., 2017), such as the mis-binding of inner auditory speech with external visual sources (Jones & Fernyhough, 2007).

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2.5 Conclusion

In sum, the present study suggests increased multisensory integration in individuals with high levels of schizotypal traits. Specifically, individuals with high levels of Disorganized factor traits had an increased proneness to the McGurk effect. Individuals with higher levels of schizotypal traits also showed poorer lip-reading abilities, which mediated susceptibility to the McGurk effect for only one of the schizotypal traits (*Odd or Eccentric Behaviour*). This work provides further support for the conceptualization of schizotypal traits as a broad spectrum, and suggests that individuals with higher levels of these traits have different sensory experiences and perhaps receptive communicative abilities compared to individuals with lower levels of these traits.

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Chapter 3

3. Experiment II – Schizotypal traits are not related to multisensory integration or audiovisual speech perception

The integration of auditory and visual speech signals is essential for accurate perception of everyday audiovisual speech. These integration processes are especially important in noisy environments, in which one cannot rely solely on auditory signals, and the speaker's facial movements can be especially helpful (Ross, Saint-Amour, Leavitt, Javitt, et al., 2007). The process by which auditory and visual speech signals are integrated, multisensory integration, is highly complex, as the brain must decide from an overwhelming amount of sensory information which information occurred together and should be integrated, and which should not (Stevenson, Ghose, et al., 2014). Temporal processing plays a crucial role in multisensory integration, as temporal proximity of auditory and visual signals is a cue to bind, such that the closer together in time two signals are, the more likely they are to be integrated (Stein & Meredith, 1993; Vroomen & Keetels, 2010).

Investigators have begun to explore the possibility that impairments in both multisensory integration and temporal processing may be contributing to perceptual deficits found among individuals with schizophrenia. A number of theoretical frameworks of schizophrenia predict difficulties in multisensory integration. Some theories, such as the *disconnection hypothesis*, postulate that schizophrenia symptomatology is associated with decreased inter-region connectivity (Friston et al., 2016). Such inter-region connectivity between auditory and visual systems is necessary for multisensory integration, and thus this hypothesis may also predict atypical integration. Alternatively, theories such as the *panmodal processing imprecision*

A version of this paper was submitted to *Consciousness and Cognition* (Muller, Dalal, & Stevenson, *submitted*)

hypothesis directly postulate that schizophrenia symptomatology is derived in part from imprecise sensory processing across modalities (Javitt et al., 1999).

In support of these theories, there have been numerous empirical findings of impaired temporal processing of sensory inputs in individuals with schizophrenia, both in the visual modality alone (Capa et al., 2014; de Boer-Schellekens et al., 2014; Giersch et al., 2009; Lalanne et al., 2012; Schmidt et al., 2011; Tenckhoff et al., 2002) and in audiovisual modalities together (Foucher et al., 2007; Martin et al., 2013; Noel et al., 2018; Stevenson, Park, et al., 2017). Individuals with schizophrenia also have decreased audiovisual multisensory integration compared to controls (de Jong, Hodiamont, Van den Stock, & de Gelder, 2009; Ross et al., 2007; Tseng et al., 2015; Williams, Light, Braff, & Ramachandran, 2010) (Zhou et al., 2018). These deficits in multisensory integration are pronounced during speech perception, providing evidence for a logical link between multisensory integration and temporal processing impairments and symptoms of social communication problems in schizophrenia (Tseng et al., 2015).

As a result of impaired multisensory integration and temporal processing, individuals with schizophrenia gain less benefit from seeing visual speech stimuli in audiovisual speech in the context of noise (Ross, Saint-Amour, Leavitt, Molholm, et al., 2007a). Individuals with schizophrenia also have impairments in unisensory auditory speech perception in the context of background speech noise (Hoffman et al., 1999; Shedlack et al., 1997; Wu et al., 2012), particularly individuals with schizophrenia who experience auditory hallucinations (Hoffman et al., 1999; Lee et al., 2004). However, individuals with schizophrenia are also impaired in the perception of auditory words without background noise (Bull & Venables, 1974; DeLisi et al., 1997; Shedlack et al., 1997; Titone & Levy, 2004). These deficits appear to be present at early stages of auditory phoneme processing, as revealed by altered event-related potentials in response to phoneme changes (Kasai et al., 2002, 2003).

Individuals with schizophrenia are also impaired at ignoring distracting speech, resulting in poorer perception accuracy of target speech and increased perception of irrelevant, distracting speech (Moser et al., 2001; Oltmanns & Neale, 1975). Indeed, speech perception is more impaired when embedded in background speech than when embedded in white noise (Wu et al., 2012), and greater impairments in ignoring such distracting speech is related to severity of disorganized speech production (Moser et al., 2001). Additionally, a greater tendency to extract meaningful speech from incomprehensible overlapping background babble among individuals with prodromal psychosis symptoms is predictive of subsequent schizophrenia diagnosis (Hoffman et al., 2007). This greater susceptibility of individuals across the schizophrenia spectrum to attend to distracting auditory speech appears to be due to deficits either in the allocation of attention, in the available attentional resources (Bestelmeyer, 2012), or in sensory gating abilities (Mcdowd et al., 1993). Taken together, this evidence suggests that impaired multisensory integration and temporal processing, in combination with increased distractibility, may lead to impaired speech perception.

These three perceptual issues, impaired multisensory integration and temporal processing and increased distractibility, may also potentially contribute to clinical symptoms such as auditory speech hallucinations (Stevenson, Park, et al., 2017). One of the leading theories explaining auditory verbal hallucinations suggests that they occur when individuals mistakenly interpret their own inner voice as external (Jones, 2010). Taken further, considering that most hallucinations experienced by individuals with schizophrenia are audiovisual (Lim et al., 2016; McCarthy-Jones et al., 2017), such hallucinations could arise from the erroneous binding of visual external cues with inner auditory speech (Jones & Fernyhough, 2007). Such erroneous binding may arise from issues with temporal processing. With that said, while individuals with schizophrenia have less precise temporal processing than controls overall, within individuals with schizophrenia, those who had more severe hallucinations tended to have narrower temporal binding windows (Stevenson, Park, et al., 2017). Evidently, the role of temporal processing in contributing to schizophrenia symptoms may be more complex than expected. While narrower temporal binding windows are usually thought to be more beneficial as they reflect more precise multisensory temporal precision, wider windows may be adaptive for individuals with schizophrenia due to unreliable unisensory processing. Finally, increased distractibility to auditory speech may also contribute to this erroneous binding. Increased attention to irrelevant speech may result in integrating this irrelevant speech with what is seen visually. Considering that individuals with schizophrenia are slightly poorer lip-readers (Schonauer et al., 1998), they may be more likely to take irrelevant auditory information and bind it mistakenly with visual facial speech information.

The current study aims to investigate the hypothesis that impaired multisensory integration and temporal processing, as well as increased distractibility, contribute to symptoms within the schizophrenia spectrum. We will investigate this hypothesis by measuring these perceptual processes in individuals in the general population with higher levels of schizotypal traits. These schizotypal traits, measured by various self-report questionnaires, are attenuated versions of symptoms found in schizophrenia, covering domains of unusual perceptual experiences, communication, social behaviour, delusion-like thoughts, and suspiciousness (Raine, 1991). Multiple lines of evidence have converged to support the idea of the schizophrenia spectrum, with similarities being found between individuals with schizotypal

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traits and schizophrenia in genetic, cognitive, perceptual, and neurobiological areas (Ettinger et al., 2014). Not only do individuals with higher levels of schizotypal traits show many similarities to individuals with schizophrenia, but they are also at higher risk of developing schizophrenia in the future (Kwapil et al., 2013). Investigating perceptual deficits within individuals with these lower-level traits can therefore be seen as a way of identifying cognitive biomarkers present across the spectrum that may be found in individuals who are prodromal for schizophrenia, in order to understand how to better predict the development of schizophrenia and begin treatment earlier for these individuals. As mentioned earlier, some of these potential cognitive biomarkers, which we will investigate in the current study, are in the areas of multisensory integration and temporal processing, as well as speech perception and auditory distractibility, all of which appear to be perceptual commonalities across the schizophrenia spectrum. Early evidence suggests that individuals with higher levels of schizotypal traits have poorer temporal processing in tactile-proprioceptive (Ferri et al., 2016) and audio-tactile (Ferri et al., 2017) domains, suggesting wider temporal binding windows. Additionally, those with higher schizotypy have also been found to have increased perception of the audiovisual double-flash (fission) illusion (Ferri, Venskus, Fotia, & Cooke, 2018), which also suggests wider temporal binding windows in these individuals. Additionally, individuals with higher schizotypy have stronger responses to visual-tactile (rubber-hand and Barbie doll) illusions, demonstrating altered multisensory integration (Asai et al., 2011; Germine et al., 2013; Van Doorn et al., 2018). These individuals are also more easily distracted by auditory speech (Marsh et al., 2017) and visual non-speech stimuli (Braunstein-Bercovitz & Lubow, 1998).

We aimed to replicate these findings of altered audiovisual temporal processing, multisensory integration, and auditory speech distractibility, as well as to investigate for the first

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time whether schizotypy is associated with poorer audiovisual speech perception. Here, in three experiments, we assessed the relationship between schizotypal traits and measures of audiovisual speech perception, auditory speech distractibility, multisensory integration, and temporal processing. All participants completed all three experiments, as well as the Schizotypal Personality Questionnaire (SPQ; Raine, 1991), a measure of schizotypal traits. Experiment 1 used a speech-in-noise task to assess auditory, visual, and audiovisual speech perception, as well as multisensory gain and susceptibility to distracting auditory speech relative to schizotypal traits. In Experiment 2, multisensory integration was directly tested using the McGurk Effect, and was related to schizotypal traits. Finally, in Experiment 3, the precision of multisensory temporal processing of speech stimuli was measured and related to schizotypal traits. The hypotheses, methods, and analyses of the present study were pre-registered within the Open Science Framework (link to the locked pre-registration: https://osf.io/f2vsz/?view_only=ccd886cd0d26462b96593f8c0e4b498e). Within this pre-registration, it was hypothesized that reduced audiovisual speech perception, multisensory integration and temporal processing across tasks would be associated with higher levels of schizotypal traits, specifically *Unusual Perceptual Experiences* and *Odd Speech*.

3.1 General Materials and Methods

3.1.1 Participants

Ninety-nine (70 female, mean age = 18.10 years old, SD = 0.92, range = 17-22) from Western University completed the current experiment. 19 additional participants were excluded (eight did not complete the questionnaires, seven did not complete all of the behavioural measures, and four did not follow task directions). Experimental protocols were approved by Western University's Non-medical Research Ethics Board. All individuals self-reported normal

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hearing and normal or corrected-to-normal vision. All participants reported that English was the first language they learned. Participants were recruited via the undergraduate research participation pool. All participants completed all three experiments, including the speech ternary synchrony judgment (SJ3) task, both multisensory and unisensory versions of the McGurk task, the speech-in-noise (SiN) task, and the Schizotypal Personality Questionnaire (SPQ; Raine, 1991).

3.1.2 Schizotypal Traits

The Schizotypal Personality Questionnaire (SPQ; Raine, 1991) is a 74-item questionnaire frequently used in the general population. Each item requires either a “Yes” or “No” answer, with the total score summing up “Yes” responses. The items of the SPQ can be reliably broken down into nine subscales: *Ideas of Reference, Excessive Social Anxiety, Odd Beliefs or Magical Thinking, Unusual Perceptual Experiences, Odd or Eccentric Behavior, No Close Friends, Odd Speech, Constricted Affect,* and *Suspiciousness.* A widely-replicated three-factor model of the SPQ groups the nine subscales into three factors that match the three areas impacted in both schizophrenia and schizotypal personality disorder: Cognitive-Perceptual, Disorganized, and Interpersonal (Badcock & Dragović, 2006; Chen et al., 1997; Fossati et al., 2003; Raine et al., 1994; Reynolds et al., 2000; Wuthrich & Bates, 2006). High sampling validity has been reported for the SPQ, as well as high internal reliability (0.91), test-retest reliability (0.82), convergent validity (0.59 to 0.81), discriminant validity, and criterion validity (0.63, 0.68) (Raine, 1991).

Overall SPQ total, factor, and subscale scores were calculated for each participant (Figure 6). Using the 10% high and low cut-offs reported for the original validation of the SPQ of 41 and 12, respectively (Raine, 1991), seven individuals, or 7.07%, met the high cut-off, and

20 individuals, or 20.20%, met the low cut-off. As such, the current sample filled a wide range of the scale.

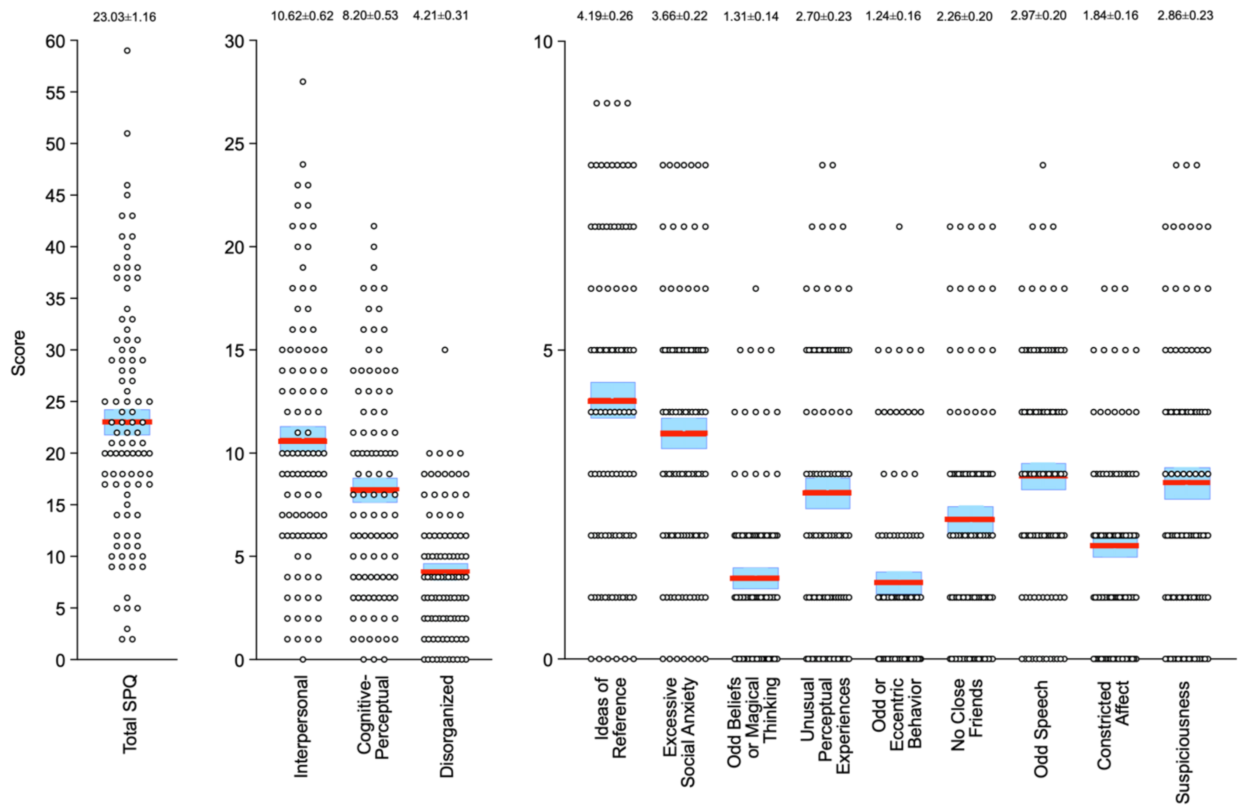

Figure 6: Overall SPQ total, factor, and subscale scores for each participant. *Note.* Red lines indicate mean and blue error bars indicate standard error. Red lines indicate group means, and blue indicates standard error. Values above each cluster indicate mean ± standard error. Maximum possible scores for SPQ total, factor, and subscales are, in order: 74, 33, 25, 16, 9, 8, 7, 9, 7, 9, 9, 8, 8.

3.1.3 General Procedures

The SPQ was completed online through Qualtrics prior to each study visit. For Experiments 1, 2, and 3, participants sat approximately 60 cm from the monitor, in a sound- and light-controlled room. A researcher sitting next to the participant monitored the participant to make sure his/her eyes remained on the screen. All stimuli throughout Experiments 1, 2, and 3 were presented

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using MATLAB 2018a (MATHWORKS Inc., Natick, MA) software with the Psychophysics Toolbox extensions (Brainard, 1997; Pelli, 1997). Audio stimuli were presented binaurally through BOSE QuietComfort 35 noise-cancelling headphones.

3.2 Experiment 1

3.2.1 Rationale and Hypotheses

Experiment 1 used a speech-in-noise task (Stevenson et al., 2015; Stevenson et al., 2011; Stevenson et al., 2010; Stevenson and James, 2009; Stevenson et al., 2009), in which individuals must identify words in the presence of noisy background speech, to measure audiovisual speech perception. Using a modification of the speech-in-noise task, in which additional auditory distractor words were added, susceptibility to these distractor words were assessed. The purpose of this manipulation was to test the hypothesis that poorer abilities to tune out distracting auditory information, resulting in unrelated auditory information being mistakenly bound with visual information, could contribute to auditory hallucinations among individuals across the schizophrenia spectrum. The speech-in-noise task also allowed for the measurement of multisensory integration by comparing speech perception in unisensory and multisensory conditions. Gains in speech perception between unisensory and multisensory conditions indicated multisensory integration.

It was hypothesized that two subscales within the SPQ would be associated with the speech-in-noise task: *Unusual Perceptual Experiences* and *Odd Speech*. We hypothesized that individuals with higher levels of these perceptual- and speech-based schizotypal traits would have reduced multisensory integration, showing less benefit from multisensory input relative to unisensory input in the speech-in-noise task. We also expected that individuals with higher schizotypy would demonstrate reduced audiovisual speech perception, and increased

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susceptibility to distracting auditory speech. We expected this increased susceptibility to be the case especially for the “Different Time” condition, in which the distracter word preceded the target word by 250 ms.

3.2.2 Materials and Methods

3.2.2.1 Stimuli

Stimuli for the speech-in-noise task included audiovisual (AV) recordings of a female speaker saying 144 triphonemic nouns. Stimuli were selected from a previously published stimulus set, The Hoosier Audiovisual Multi-talker Database (Sheffert et al., 1996). All stimuli were spoken by speaker F1. The stimuli selected were monosyllabic English words that were matched across sets for accuracy on both visual-only and audio-only recognition (Lachs and Hernandez, 1998), and were also matched across sets in lexical neighborhood density (Luce and Pisoni, 1998; Sheffert et al., 1996). Audio signal levels were measured as root mean square (RMS) contrast and equated across all words. All words lasted 2 s and included all pre-articulatory gestures. Visual stimuli were grayscale and square, spanning 9.9 cm per side or 9.43° of visual angle. This set of single words has been used successfully in previous studies of multisensory integration (e.g. Stevenson et al., 2015).

All presentations included 8-channel multitalker babble at 66 dB SPL. The presentation of auditory babble presentation began 500 ms prior to the beginning of the word and ended 500 ms following the end of the word. The RMS of the auditory babble was linearly ramped up and down, respectively, during the pre- and post-stimulus 500 ms periods, and was presented with the first and last frames of the visual word, respectively. Auditory stimuli were presented at two signal-to-noise ratios (SNR), 54 dB (-12 dB SPL SNR) or 66 dB (0 dB SPL SNR).

3.2.2.2 Procedures

Each participant was presented with six separate runs of 24 single-word presentations consisting of a single condition, for a total of 144 words. Two of the conditions were unisensory, while the other four were audiovisual. All six conditions, including the visual-only condition, included auditory multitalker babble at 66 dB SPL. Three of the audiovisual conditions included a second, auditory-only distractor word in addition to the target word. One of these auditory words corresponded to the visual speaker (target), and one word did not (distractor). The visual word presentations were never manipulated.

The six conditions were:

1) *Visual-only:* visual speaker only, no auditory word presentation.
2) *Auditory-only*: auditory target words only, at 54 dB SPL; blank screen, no visual word presentation.
3) *Audiovisual:* visual and auditory presentations of the same word at the same time, at 54 dB SPL.
4) *Same time audiovisual:* auditory target and distractor words presented at same time as visual target word. Both target and distractor words at 54 dB SPL.
5) *Different volume audiovisual:* auditory target and distractor words presented at same time as visual target word, with false word 12 dB SPL louder. Distractor words at 66 dB SPL; target words at 54 dB SPL.
6) *Different time audiovisual:* auditory target and distractor words presented at different times, with distractor word beginning 250 ms before presentation of visual and auditory target word. Both target and distractor words at 54 dB SPL.

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Experimental procedures were identical for all runs. Participants were instructed to attend to the speaker at all times, and to report the word they perceived by typing “What the speaker said”. The experimenter verbally confirmed the participant’s report to correct for spelling errors and ambiguous pronunciation, and then the next word was presented. No time limit was given for participant responses. Each run lasted approximately 5 minutes, and run orders and condition-to-word-list pairings (including distractor word lists) were randomized across participants. No words were repeated.

3.2.2.3 Analysis

As done previously (Stevenson et al., 2015; Stevenson, Segers, et al., 2017), responses were scored at both the whole-word level and at the phoneme level. Whole words were scored as correct only if the entire word reported was correct. Each tri-phonemeic word was also scored on the proportion of phonemes that were perceived correctly. When distractor words were present, scores were tabulated for both. Word and phoneme accuracies were calculated as the average score across all trials for each condition, as was distractor susceptibility.

Multisensory gain was calculated by comparing accuracy scores in audiovisual trials relative to the predicted audiovisual accuracy based on the unisensory component accuracies assuming independence, using the following equation (Stevenson et al., 2015):

$$pAV = p(A) + p(V) - [p(A) * p(V)],$$

where pAV represents a null hypothesis of the response to audiovisual presentations if the auditory and visual information are processed independently, and where p(A) and p(V) represent response accuracy to auditory- and visual-only presentations, respectively. Absolute increase was calculated as:

$$observed\ AV\ accuracy - pAV\ accuracy,$$

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while proportion increase was calculated as:

$$\frac{observed\ AV\ accuracy - pAV\ accuracy}{1 - pAV\ accuracy}$$

Pearson correlations were then conducted between distractor word and phoneme susceptibility and SPQ scores, as well as between multisensory gain and SPQ scores.

3.2.3 Results

The proportion of word and phoneme accuracy for all six conditions of the speech-in-noise task are shown for each individual in Figures 7 and 8. Multisensory gain was significantly greater than zero in all instances, including word accuracy measured by absolute ($t(98) = 14.55$, $p < 0.001$, $d = 1.46$) and proportional ($t(98) = 14.65$, $p < 0.001$, $d = 1.47$) gain, and phoneme accuracy measured by absolute ($t(98) = 7.05$, $p < 0.001$, $d = 0.71$) and proportional ($t(98) = 6.12$, $p < 0.001$, $d = 0.62$) gain.

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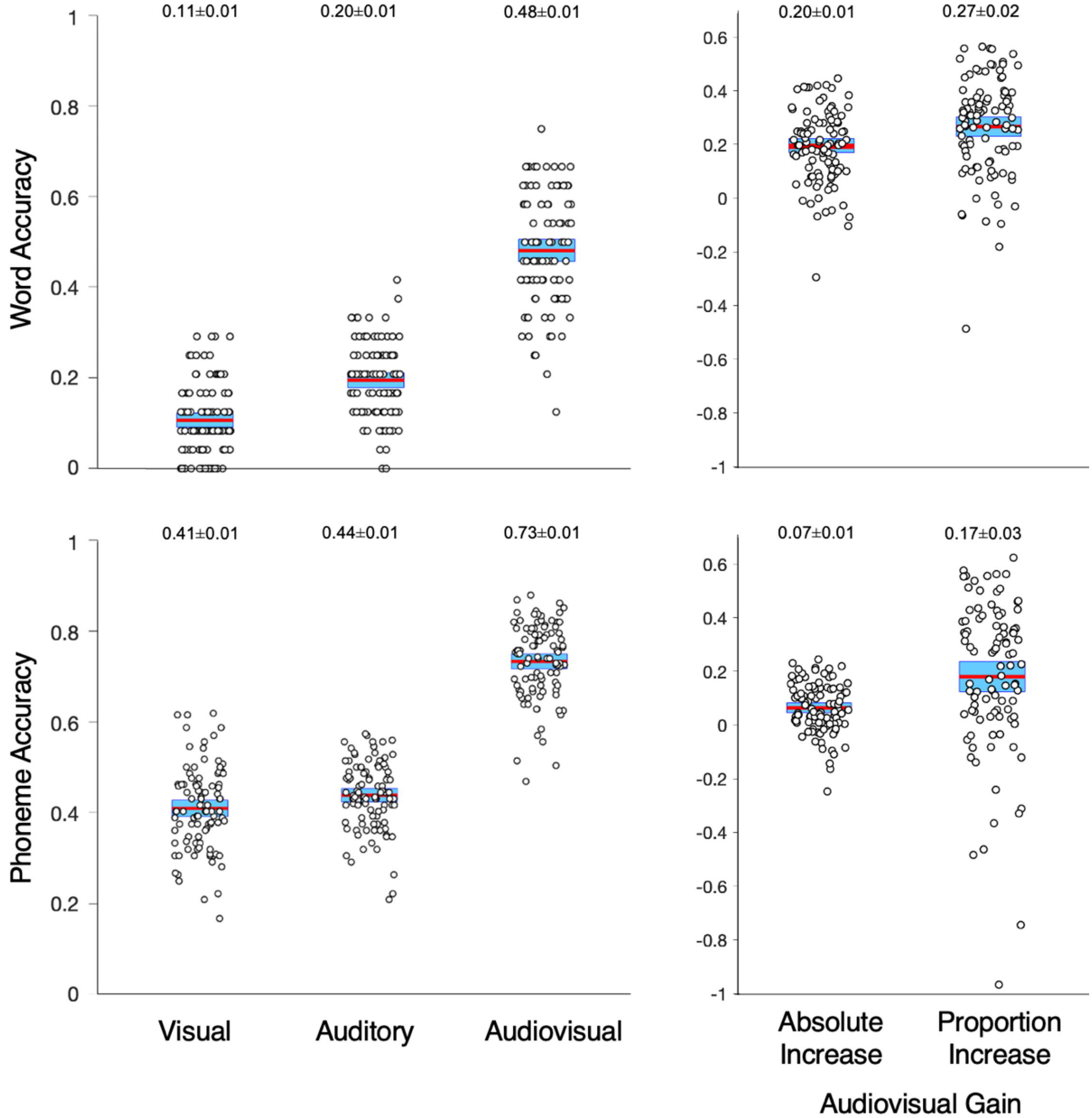

Figure 7: Proportion of word and phoneme accuracy for visual, auditory, and audiovisual conditions of the speech-in-noise task, as well as audiovisual gain. *Note.* Red lines indicate group means, and blue indicates standard error. Values above each cluster indicate mean ± standard error.

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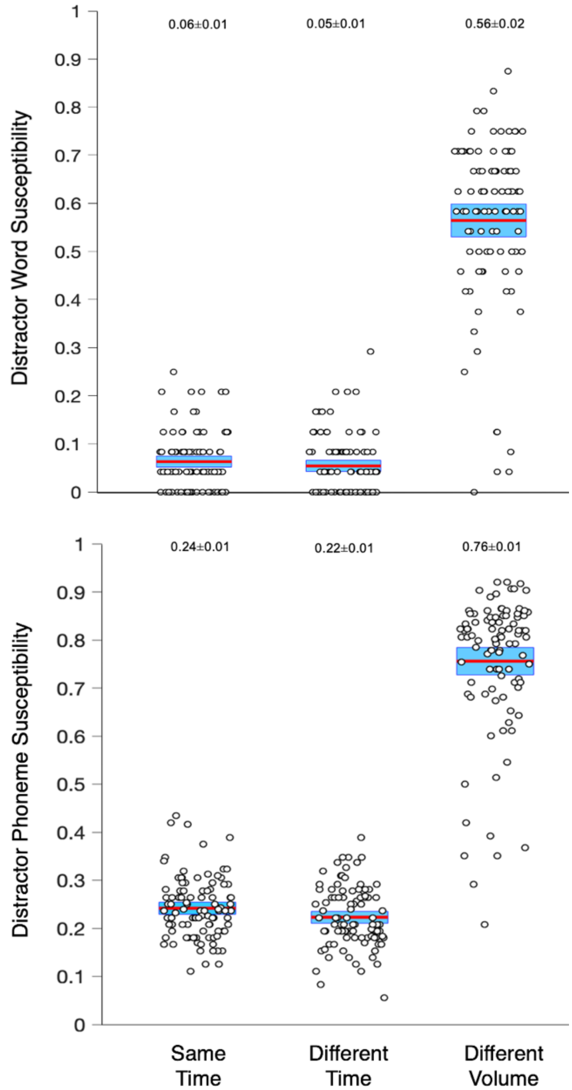

Figure 8: Proportion of word and phoneme accuracy for Same Time, Different Time, and Different Volume conditions of the speech-in-noise task. *Note.* Red lines indicate group means, and blue indicates standard error. Values above each cluster indicate mean ± standard error.

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3.2.3.1 Relating Speech-in-Noise Task and Schizotypal Traits

Pearson correlations were conducted between word and phoneme accuracy and SPQ scores, as well as between multisensory gain and SPQ scores. Target word and phoneme accuracy were expected *a priori* to negatively correlate with *Unusual Perceptual Experiences* and *Odd Speech.* Multisensory gain was expected *a priori* to negatively correlate with two subscales of the SPQ: *Unusual Perceptual Experiences* and *Odd Speech*. Distractor word and phoneme susceptibility were expected *a priori* to positively correlate with *Unusual Perceptual Experiences* and *Odd Speech.*

In the audiovisual condition, target phoneme accuracy was not significantly correlated with scores on the *Unusual Perceptual Experiences* subscale, nor was target word accuracy. Similarly, in the audiovisual condition, target phoneme accuracy was not significantly correlated with scores on the *Odd Speech* subscale, nor was target word accuracy (Table 5). As all Bayes factors were below 0.160, this provides substantial evidence (according to Jeffreys in Jarosz & Wiley (2014)) in support of the null hypothesis that *Unusual Perceptual Experiences* and *Odd Speech* are not associated with phoneme or word accuracy in audiovisual speech.

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Table 5: Correlations between target phoneme and word accuracy and *Unusual Perceptual Experiences* and *Odd Speech* subscales for audiovisual speech.

	r(97)	95% CI	*p*-value	Bayes Factor
Unusual Perceptual Experiences				
Phoneme Accuracy	.071	[-0.128, 0.265]	.483	0.160
Word Accuracy	.023	[-0.175, 0.219]	.822	0.129
Odd Speech				
Phoneme Accuracy	-.009	[-0.206, 0.189]	.933	0.126
Word Accuracy	-.021	[-0.217, 0.177]	.833	0.128

Multisensory gain, as measured by absolute increase from predicted audiovisual accuracy to actual audiovisual accuracy, was not significantly correlated with scores on the *Unusual Perceptual Experiences* subscale for phoneme accuracy or for word accuracy. Multisensory gain measured by the proportion increase from predicted audiovisual accuracy to actual audiovisual accuracy was also not significantly correlated with scores on the *Unusual Perceptual Experiences* subscale for phoneme accuracy or for word accuracy. Likewise, multisensory gain measured by absolute increase was not significantly correlated with scores on the *Odd Speech* subscale for phoneme accuracy or for word accuracy. Multisensory gain measured by proportion increase was not significantly correlated with scores on the *Odd Speech* subscale for phoneme accuracy or for word accuracy (Table 6). As all Bayes factors were below 0.144, this provides substantial evidence (according to Jeffreys in Jarosz & Wiley (2014)) in support of the null hypothesis that *Unusual Perceptual Experiences* and *Odd Speech* are not associated with multisensory gain for audiovisual speech.

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Table 6: Correlations between multisensory gain and *Unusual Perceptual Experiences* and *Odd Speech* subscales for audiovisual speech.

	$r(97)$	95% CI	p-value	Bayes Factor
Unusual Perceptual Experiences				
Phoneme Accuracy				
Absolute Increase	-.053	[-0.248, 0.146]	.600	0.144
Proportion Increase	-.025	[-0.221, 0.173]	.804	0.130
Word Accuracy				
Absolute Increase	-.039	[-0.235, 0.160]	.699	0.135
Proportion Increase	-.019	[-0.216, 0.179]	.850	0.128
Odd Speech				
Phoneme Accuracy				
Absolute Increase	.000	[-0.197, 0.197]	.997	0.126
Proportion Increase	-.007	[-0.204, 0.191]	.946	0.126
Word Accuracy				
Absolute Increase	-.051	[-0.246, 0.148]	.616	0.142
Proportion Increase	-.030	[-0.226, 0.168]	.768	0.131

In the audiovisual Same Time condition, distractor phoneme susceptibility was not significantly correlated with scores on the *Unusual Perceptual Experiences* subscale, nor was distractor word susceptibility. Similarly, in the audiovisual Same Time condition, distractor phoneme susceptibility was not significantly correlated with scores on the *Odd Speech* subscale, nor was distractor word susceptibility.

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In the audiovisual Different Time condition, distractor phoneme susceptibility was not significantly correlated with scores on the *Unusual Perceptual Experiences* subscale, but distractor word susceptibility was significantly negatively correlated (Figure 9). In the audiovisual Different Time condition, distractor phoneme susceptibility was not significantly correlated with scores on the *Odd Speech* subscale, nor was distractor word susceptibility.

In the audiovisual Different Volume condition, distractor phoneme susceptibility was not significantly correlated with scores on the *Unusual Perceptual Experiences* subscale, nor was distractor word susceptibility. Similarly, in the audiovisual Different Volume condition, distractor phoneme susceptibility was not significantly correlated with scores on the *Odd Speech* subscale, nor was distractor word susceptibility (Table 7).

Almost all Bayes factors in this analysis were below 0.247, providing substantial evidence (according to Jeffreys in Jarosz & Wiley (2014)) in support of the null hypothesis that *Unusual Perceptual Experiences* and *Odd Speech* are not associated with phoneme or word susceptibility for all conditions of the speech-in-noise task. The Bayes factor for the relationship between *Unusual Perceptual Experiences* and distractor word susceptibility in the Different Time condition provided weak or anecdotal evidence in support of the null hypothesis.

Table 7: Correlations between distractor phoneme and word susceptibility and Unusual Perceptual Experiences and Odd Speech subscales for audiovisual speech conditions.

	r(97)	95% CI	*p*-value	Bayes factor
Same Time				
Unusual Perceptual Experiences				
Phoneme Susceptibility	-.068	[-0.262, 0.131]	.502	0.157
Word Susceptibility	-.031	[-0.227, 0.167]	.762	0.131
Odd Speech				
Phoneme Susceptibility	.033	[-0.166, 0.229]	.745	0.132
Word Susceptibility	.054	[-0.145, 0.249]	.597	0.144
Different Time				
Unusual Perceptual Experiences				
Phoneme Susceptibility	-.115	[-0.305, 0.084]	.258	0.236
Word Susceptibility	-.203	[-0.385, -0.006]	**.044**	0.923
Odd Speech				
Phoneme Susceptibility	-.004	[-0.201, 0.194]	.972	0.126
Word Susceptibility	.000	[-0.197, 0.197]	.998	0.126
Different Volume				
Unusual Perceptual Experiences				
Phoneme Susceptibility	-.036	[-0.232, 0.163]	.724	0.134
Word Susceptibility	-.119	[-0.309, 0.080]	.242	0.247
Odd Speech				
Phoneme Susceptibility	.056	[-0.143, 0.251]	.585	0.146
Word Susceptibility	.082	[-0.117, 0.275]	.417	0.174

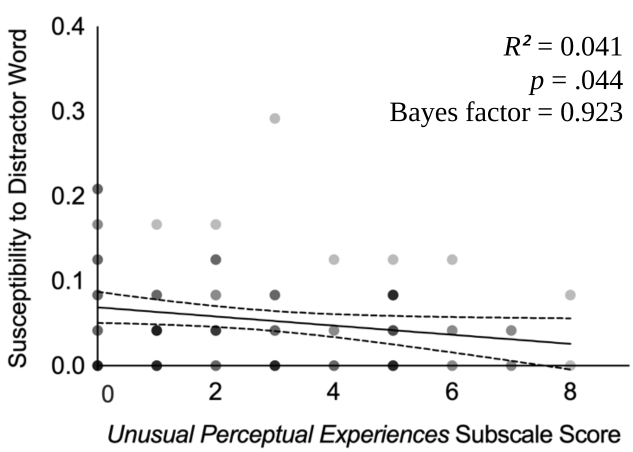

Figure 9: Scatterplot showing the correlation between *Unusual Perceptual Experiences* subscale score and susceptibility to the distractor word in the audiovisual Different Time

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condition of the speech-in-noise task. *Note.* Darker points indicate more individual points in that location. Dashed lines indicate 95% confidence intervals.

3.2.4 Discussion

In Experiment 1, the relationship between performance in the speech-in-noise task and schizotypal traits, particularly *Unusual Perceptual Experiences* and *Odd Speech,* was investigated. No evidence was found for any relationship, and Bayesian analysis provided substantial evidence for the null in most cases. This included null findings in three a priori analyses comparing the *Unusual Perceptual Experiences* and *Odd Speech* subscales with audiovisual speech perception accuracy, multisensory gain, and susceptibility to distracting auditory speech in any condition (Same Time, Different Time, and Different Volume).

3.3 Experiment 2

3.3.1 Rationale and Hypotheses

In Experiment 2, the McGurk effect (McGurk & MacDonald, 1976) was used as a measure of multisensory integration. In this task, participants were presented with a speaker uttering the auditory syllable “ba” coincidentally with the speaker visually articulating the syllable “ga”. Participants commonly report perceiving the speaker saying “da” or “tha”, a syllable that is not present in either of the unisensory stimuli, and a percept that is thus strong evidence of integration.

It was hypothesized that higher levels of schizotypal traits, specifically *Unusual Perceptual Experiences* and *Odd Speech,* would be associated with increased perception of the McGurk effect. While poorer multisensory integration would normally result in decreased perception of the McGurk effect, previous unpublished work from our lab revealed the opposite direction of results.

3.3.2 Materials and Methods

3.3.2.1 Stimuli

The videos used for the McGurk task have been used previously in studies of the McGurk effect (Quinto et al., 2010; Stevenson, Siemann, et al., 2014). Stimuli consisted of one audiovisual clip of a female speaker saying either the syllable “ba” or “ga”, at a normal rate and volume with a neutral facial expression. Auditory stimuli were delivered at a comfortable level (calibrated to approximately 72 dB SPL) presented through noise-cancelling headphones. Visual stimuli were cropped to square, down-sampled to a resolution of (400 × 400 pixels) spanning 11.8 cm per side or 11.23 degrees of visual angle and converted from color to grayscale. Presentations were shortened to 2 s, and each presentation included the entire articulation of the syllable, including pre-articulatory gestures.

Stimuli included visual-only, auditory-only, and congruent audiovisual presentations of the phoneme “ba” or “ga,” and the McGurk stimuli, a visual “ga” presented with an auditory “ba”. All presentations were temporally synchronous.

3.3.2.2 Procedures

The task was divided into two separate runs, a multisensory and a unisensory run, always presented in that order. Both runs began with a screen instructing them to identify what syllable the speaker said in modality-neutral wording (“What did she say?”). Each trial began with a fixation screen that randomly jittered from 0.5 to 1.5 seconds, and multi-speaker babble which ramped up linearly for 500 ms, continued during the stimulus presentation, and linearly ramped down over 500 ms following stimulus presentation. A 250 ms fixation screen was then

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presented, folled by a response screen asking “What did she say?”. Participants responded via button press of, “b,” “g,” “d,” or “t,” representing “ba,” “ga,” “da,” and “tha,” respectively. Immediately after the response, the fixation screen for the subsequent trial was presented.

Audiovisual conditions included congruent “ba”, congruent “ga”, and the McGurk stimulus, an auditory “ba” paired with a “ga”. Each audiovisual condition presented 20 times in random order, for a total of 60 trials. Unisensory conditions included auditory- and visual only presentations of “ba” and “ga”. Each unisensory condition was presented 10 times in random order, for a total of 40 trials.

3.3.2.3 Analysis

For each of the six non-McGurk conditions, an accuracy score was calculated for each participant. This was calculated as the proportion of trials the participant accurately identified as the syllable that was presented. Average visual and auditory accuracy was calculated as the average proportion of visual- and auditory-alone trials perceived correctly across syllables.

For the McGurk trials, the proportion of McGurk percept was initially calculated as the proportion of trials the participant reported having perceived “da” or “tha”. To account for some individuals’ increased reporting of “da” or “tha” in the absence of the illusion, the absolute change from unisensory to multisensory reports of “da” or “tha” was calculated:

$$p(AV\ McGurk) - p(A + V - (A * V))$$

where p(AV McGurk) represents the individual’s proportion of McGurk percepts with audiovisual McGurk stimuli, and p(A + V – (A*V)) represents the proportion of “da” percepts with unisensory “ba” and “ga” stimuli.

Pearson correlations were conducted between both McGurk perception rate and SPQ scores, and the absolute change and SPQ scores.

3.3.3 Results

The proportion of phonemes perceived are shown for each individual in Figure 10.

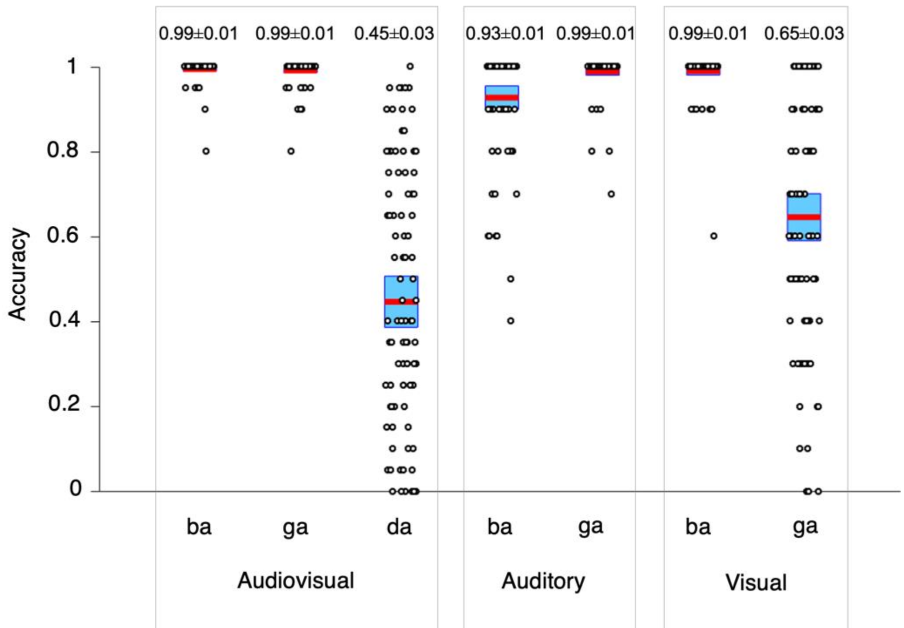

Figure 10: Proportion of phonemes perceived for congruent audiovisual "ba" and "ga", incongruent audiovisual "da" or McGurk effect, unisensory auditory "ba" and "ga", and unisensory visual "ba" and "ga" presentations. *Note.* Red lines indicate group means, and blue indicates standard error. Accuracy represents the proportion of accurate responses. Values above each cluster indicate mean ± standard error.

3.3.3.1 Relating McGurk Task and Schizotypal Traits

The proportion of trials on which the McGurk effect was perceived was expected *a priori* to negatively correlate with two subscales of the SPQ: *Unusual Perceptual Experiences* and *Odd Speech*. Surprisingly, perceived McGurk effect was not significantly correlated with scores on the *Unusual Perceptual Experiences* subscale, $r(97) = -.014$, 95% CI = [-0.211, 0.184], $p = .887$, Bayes Factor = 0.127, or the *Odd Speech* subscale, $r(97) = .028$, 95% CI = [-0.170, 0.224], $p =$

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.784, Bayes Factor = 0.130. As all Bayes factors were below 0.130, this provides substantial evidence (according to Jeffreys in Jarosz & Wiley (2014)) in support of the null hypothesis that *Unusual Perceptual Experiences* and *Odd Speech* are not associated with the McGurk effect.

3.3.4 Discussion

Neither of the *a priori* subscales (*Unusual Perceptual Experiences* and *Odd Speech*) were related to perception of the McGurk effect. As the McGurk effect is a measure of multisensory integration, this suggests that the schizotypal traits measured in this sample are not related to this measure of multisensory integration.

3.4 Experiment 3

3.4.1 Rationale and Hypotheses

In Experiment 3, a speech-based ternary synchrony judgment task (SJ3; Alcalá-Quintana & García-Pérez, 2013) was used to measure temporal processing. From this SJ3 task, we measured temporal binding window and point of subjective simultaneity for each participant. The point of subjective simultaneity is the timepoint at which an individual determines two stimuli to be synchronized. It was hypothesized that higher levels of schizotypal traits, specifically *Unusual Perceptual Experiences* and *Odd Speech,* would be associated with both larger temporal binding window and point of subjective simultaneity.

3.4.2 Materials and Methods

3.4.2.1 Stimuli

Stimuli for the ternary synchrony judgment (SJ3) task were identical to the McGurk task, except that only the “ba” audiovisual stimuli were included. As in the McGurk task, stimuli included multi-speaker babble. Stimulus onset asynchronies (SOAs) were 0, ±50, ±100, ±150,

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±200, ±300, and ±400 ms, with positive values denoting a presentation with a visual lead and negative values an auditory lead. An SOA of zero denotes a synchronous presentation.

3.4.2.2 Procedures

Each SOA was presented randomly 10 times, with a total of 130 audiovisual presentations of the syllable. After each presentation, the response screen gave three options: 1 = visual first, 2 = same time, or 3 = audio first. Following participant response, a fixation cross was presented for 500 ms plus a randomly generated jitter drawn from a standard uniform distribution from 0-1000 ms, followed by the initiation of the next stimulus presentation.

3.4.2.3 Analysis

Responses from the SJ3 task were used to calculate a temporal binding window and point of subjective simultaneity for each participant. The MATLAB analysis protocol from (Alcalá-Quintana & García-Pérez, 2013) was used. First, the count of responses for each SOA was calculated. This is the number of trials for a given SOA in which the individual responded with "audio first", "visual first", or "synchronous". The three response-types for each SOA were then fitted to three psychometric functions. Two sigmoid curves were fitted to the audio-first and visual-first responses, and one parabolic curve was fitted to the synchronous responses at each SOA. The audio-first simultaneity boundary was calculated as the crossing point of the psychometric functions for audio-first and synchronous judgments. The visual-first simultaneity boundary was calculated as the crossing point of the psychometric functions for visual-first and synchronous judgments. The temporal binding window was calculated as the distance between the audio-first and visual-first simultaneity boundaries. The point of subjective simultaneity was calculated as the midway point between the two simultaneity boundaries, or the peak of the parabolic curve for synchronous responses (Alcalá-Quintana & García-Pérez, 2013).

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Pearson correlations were then conducted between the temporal binding window and scores on the *Unusual Perceptual Experiences* and *Odd Speech* subscales of the SPQ, as well as between the point of subjective simultaneity and scores on these subscales.

3.4.3 Results

Temporal binding windows and point of subjective simultaneity are shown for each individual in Figure 11.

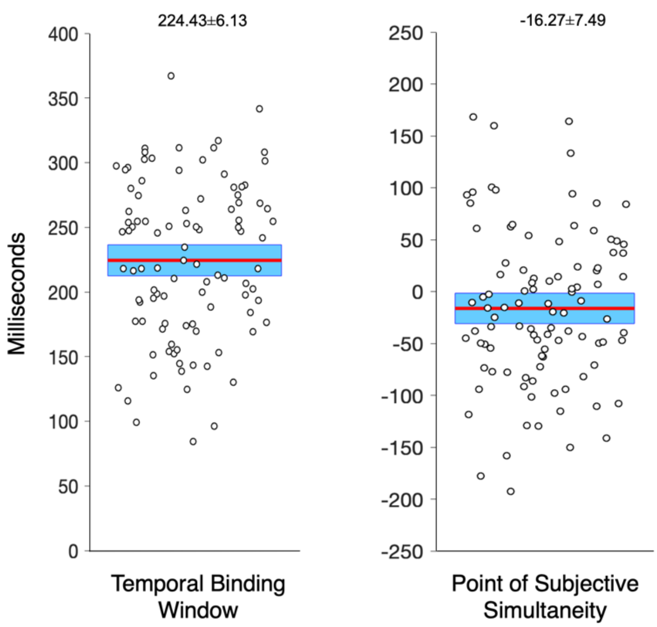

Figure 11: Temporal binding window and point of subjective simultaneity in milliseconds. *Note.* Red lines indicate group means, and blue indicates standard error. Values above each cluster indicate mean ± standard error.

3.4.3.1 Relating Speech Ternary Synchrony Judgment Task and Schizotypal Traits

Pearson correlations were conducted between temporal binding window and SPQ, and point of subjective simultaneity and SPQ scores. Temporal binding window and point of subjective simultaneity were expected *a priori* to positively correlate with *Unusual Perceptual*

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Experiences and *Odd Speech.* Neither temporal binding window nor point of subjective simultaneity were significantly correlated with either subscale (Table 8). As all Bayes factors were below 0.324, this provides substantial evidence (according to Jeffreys in Jarosz & Wiley (2014)) in support of the null hypothesis that *Unusual Perceptual Experiences* and *Odd Speech* are not associated with the temporal binding window or point of subjective simultaneity.

Table 8: Correlations between temporal binding window and point of subjective simultaneity and *Unusual Perceptual Experiences* and *Odd Speech* subscales.

	r(97)	95% CI	*p*-value	Bayes Factor
Unusual Perceptual Experiences				
Temporal Binding Window	.031	[-0.167, 0.227]	.763	.131
Point of Subjective Simultaneity	-.066	[-0.260, 0.133]	.519	.154
Odd Speech				
Temporal Binding Window	-.067	[-0.261, 0.132]	.508	.156
Point of Subjective Simultaneity	-.140	[-0.328, 0.059]	.165	.324

3.4.4 Discussion

We found no evidence that multisensory temporal processing was related to schizotypal traits in the general population. While *Unusual Perceptual Experiences* and *Odd Speech* were *a priori* expected to correlate with temporal binding window and point of subjective simultaneity, neither were found to be related with these subscales.

3.5 General Discussion

This study investigated the relationship between perceptual- and speech-related schizotypal traits and measures of audiovisual speech perception, multisensory integration, and

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temporal processing. We hypothesized that individuals in the general population with higher levels of *Unusual Perceptual Experiences* and *Odd Speech* schizotypal traits would demonstrate reduced audiovisual speech perception, increased susceptibility to distracting auditory speech, lower multisensory integration, and altered multisensory temporal processing. We found evidence to the contrary, however. Individuals' levels of *Unusual Perceptual Experiences* and *Odd Speech* did not relate to audiovisual speech perception, as measured by a speech-in-noise task. Overall, these individuals also did not differ in the amount of susceptibility to distracting auditory speech in the speech-in-noise task, although an inconclusive relationship between *Unusual Perceptual Experiences* and distractor word susceptibility in the Different Time condition emerged. Individuals with higher levels of *Unusual Perceptual Experiences* and *Odd Speech* also did not differ in the amount of gain experienced from multisensory rather than unisensory speech, indicating no differences in multisensory integration. As another indicator of intact multisensory integration, these individuals did not show differences in the McGurk effect. Finally, levels of these traits were not related to differences in temporal processing, as measured by a speech-based ternary synchrony judgment task.

Our finding that audiovisual speech perception is not related to schizotypal traits is not in alignment with previous literature, in which individuals with schizophrenia have impaired auditory speech perception in the context of background speech noise (Hoffman et al., 1999; Shedlack et al., 1997; Wu et al., 2012), particularly individuals with schizophrenia who experience auditory hallucinations (Hoffman et al., 1999; Lee et al., 2004). Specifically, background speech results in greater impairments in speech perception than background white noise (Wu et al., 2012). However, individuals with schizophrenia are also impaired in the perception of auditory words without background noise (Bull & Venables, 1974; DeLisi et al., 1997; Shedlack et al., 1997; Titone & Levy, 2004). These deficits appear to be present at early stages of auditory phoneme processing, as revealed by altered event-related potentials in response to phoneme changes in individuals with schizophrenia (Kasai et al., 2002, 2003).

Similarly, our finding that schizotypal traits are not related to susceptibility to distracting auditory speech is surprising, considering previous findings in individuals within the schizophrenia spectrum. Individuals with schizophrenia are impaired at ignoring distracting speech, resulting in poorer perception accuracy of target speech and increased perception of irrelevant, distracting speech (Moser et al., 2001; Oltmanns & Neale, 1975). Higher severity of disorganized speech is related to greater impairments in ignoring distracting speech (Moser et al., 2001). Additionally, a greater tendency to extract meaningful speech from incomprehensible overlapping background babble among individuals with prodromal psychosis symptoms is predictive of subsequent schizophrenia diagnosis (Hoffman et al., 2007). Individuals with higher levels of schizotypal traits are also more easily distracted by auditory speech (Marsh et al., 2017) and visual non-speech stimuli (Braunstein-Bercovitz & Lubow, 1998). This greater susceptibility of individuals across the schizophrenia spectrum to attend to distracting auditory speech appears to be due to deficits either in the allocation of attention, in the available attentional resources (Bestelmeyer, 2012), or in sensory gating abilities (Mcdowd et al., 1993).

Additionally, our findings that multisensory integration was not related to schizotypal traits in these individuals does not align with much of the related literature. Audiovisual multisensory integration has been previously investigated in relation to schizotypal traits in the general population, with increased integration being found in the form of stronger responses to the McGurk illusion (Muller, Dalal, & Stevenson, 2020) and the double-flash illusion (Ferri, Venskus, Fotia, Cooke, & Romei, 2018). Investigations using visual-tactile illusions, which require multisensory integration, have also been conducted. Individuals with higher schizotypy tend to have stronger responses to visual-tactile (rubber-hand and Barbie doll) illusions (Asai et al., 2011; Germine et al., 2013; Van Doorn et al., 2018), which also aligns with findings in schizophrenia (Peled et al., 2000; Thakkar et al., 2011). These illusions, while requiring intact multisensory integration, also assess traits like susceptibility to out-of-body experiences and altered perception of body ownership, which are higher among individuals in the schizophrenia spectrum (Benson, Brugger, & Park, 2019; Hur, Kwon, Lee, & Park, 2014). This may explain why the intact multisensory integration found in these visual-tactile illusions does not align with the majority of investigations into audiovisual multisensory integration in individuals with schizophrenia, which have found decreased multisensory integration compared to controls (de Jong, Hodiamont, Van den Stock, & de Gelder, 2009; Ross et al., 2007; Tseng et al., 2015; Williams, Light, Braff, & Ramachandran, 2010). Deficits in multisensory integration in schizophrenia are found especially in the realm of audiovisual speech integration (Tseng et al., 2015). While there have been some findings of intact multisensory integration in schizophrenia (e.g. de Boer-Schellekens et al., 2014), in general this is not the case (for a review see Zhou et al., 2018).

Our finding that individuals with higher levels of perceptual- and speech-related schizotypal traits demonstrated intact temporal processing is also inconsistent with previous literature in this area. Albeit scarce, this literature includes findings that individuals in the general population with higher levels of schizotypal traits have poorer temporal processing in tactile-proprioceptive (Ferri et al., 2016) and audio-tactile (Ferri et al., 2017) domains, suggesting wider temporal binding windows. Additionally, those with higher schizotypy have also been found to have increased perception of the audiovisual double-flash (fission) illusion

(Ferri, Venskus, Fotia, & Cooke, 2018), which also suggests wider temporal binding windows in these individuals. Similarly, numerous findings have indicated impaired temporal processing and wider temporal binding windows in individuals with schizophrenia, both in the visual modality alone (Capa et al., 2014; de Boer-Schellekens et al., 2014; Giersch et al., 2009; Lalanne et al., 2012; Schmidt et al., 2011; Tenckhoff et al., 2002) and in audiovisual modalities together (Foucher et al., 2007; Martin et al., 2013; Noel et al., 2018; Stevenson, Park, et al., 2017). While Stevenson et al. (2017) found that individuals with schizophrenia had less precise temporal processing than controls, they found that within individuals with schizophrenia, those who had more severe hallucinations tended to have narrower temporal binding windows. Together, these findings suggest that there is a complex relationship between temporal processing and schizophrenia symptoms.

These null findings provide a number of interesting insights towards understanding multisensory speech perception in the schizophrenia spectrum. One possibility is that the perceptual differences observed in schizophrenia are specific to individuals diagnosed with schizophrenia diagnoses, and that individuals in the general population with subclinical schizotypal traits may not show these perceptual differences. That is, there may be a non-linear relationship between level of severity on the schizophrenia spectrum and degree of perceptual differences such that the relationship is weak or non-existent at lower levels of schizotypy, but become more substantive as clinical severity increases. It is also possible that the schizophrenia spectrum may be better described by a quasi-dimensional view rather than a fully dimensional view.

Additionally, there may be more experiment-based explanations for finding these null effects in the context of disagreeing literature. Males tend to score higher in schizotypy than females (Bora & Baysan Arabaci, 2009), and male risk for psychosis peaks between ages 21 and 25 (Kessler et al., 2007; Li, Ma, Yang, & Wang, 2016). The peak age of psychosis onset in females is three to five years later than males, ranging from ages 25 to 30 (Li et al., 2016). Our sample, however, had a mean age of 18 and a high proportion of female participants (>70%). As a result, it is possible that the levels of schizotypal traits in the current sample were simply too low to be able to detect perceptual alterations, though scores on the SPQ did span a significant portion of the range. Likewise, given the sex differences present in schizotypal traits and onset of psychosis, it is also possible that there are sex differences in perceptual symptoms. It may thus be fruitful for future work to investigate schizotypal traits in a slightly older, less female-dominated, community sample. Likewise, it may be beneficial to use multiple measures of schizotypy to increase our ability to reliably detect schizotypal traits in this sample.

To conclude, the current study did not find evidence of a relationship between schizotypal traits and altered multisensory integration, audiovisual temporal processing, audiovisual speech perception, or auditory distractibility. Considering that the literature in this area includes several findings of perceptual differences among individuals in the schizophrenia spectrum, this area certainly requires further investigation to elucidate the nature of these findings.

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A version of this paper was submitted to *Consciousness and Cognition* (Muller, Dalal, & Stevenson, *submitted*)

Chapter 4

4. Discussion

The current studies aimed to examine whether higher levels of schizotypal traits are associated with decreased multisensory integration, temporal processing, speech perception, and increased distractibility to auditory speech.

Results from Study 1 revealed an association between individuals with higher levels of schizotypal traits and increased multisensory integration, as measured by higher levels of McGurk effect perception. Specifically, the Disorganized factor of the SPQ, which measures disorganized speech and behaviour, was associated with higher levels of McGurk effect perception, which was associated with poorer lip-reading. Poorer lip-reading mediated the relationship between the McGurk effect and the *Odd or Eccentric Behaviour* subscale within the Disorganized factor. The findings of poorer lip-reading align with similar findings in schizophrenia (Myslobodsky et al., 1992; Schonauer et al., 1998). However, the McGurk findings are inconsistent with previous investigations of the McGurk effect in individuals with schizophrenia, which have found either no differences relative to controls (Martin et al., 2013; Romero et al., 2016), or decreased perception compared to controls (de Gelder et al., 2002; Pearl et al., 2009; White et al., 2014). As this is the first investigation of the McGurk effect in individuals in the general population with schizotypal traits, it is possible that a different pattern of responsiveness to the McGurk effect is found among individuals who are on the lower end of the spectrum.

In contrast to Study 1, results from Study 2 indicated that higher levels of schizotypal traits were not associated with multisensory integration, temporal processing, speech perception, or distractibility to auditory speech. Through Bayesian analyses, we found strong support for the lack of a relationship between these perceptual differences and schizotypal traits. The finding of intact multisensory integration is surprising, especially considering that we replicated the design of Study 1 as part of Study 2, using the same measures of the McGurk effect and the SPQ, with the same type of sample. It is possible that this difference may be due to differences in SPQ scores. While mean SPQ scores did not differ between samples, only 7% of the sample in Study 2 met the 10% high cut-off from the original validation of the SPQ (Raine, 1991), while 14% of the sample in Study 1 met the high cut-off. Perhaps fewer individuals passing these higher cut-offs means that there were fewer individuals driving the association between SPQ scores and behavioural measures in Study 2. It could also be that not enough individuals had “severe” enough symptomatology to affect our behavioural measures.

Our finding of no association between schizotypal traits and multisensory integration is also in contrast to much previous work, which has found that individuals with schizophrenia display less multisensory integration (de Jong et al., 2009; Noel et al., 2018; Ross, Saint-Amour, Leavitt, Molholm, et al., 2007a; Tseng et al., 2015; Williams et al., 2010; Zhou et al., 2018). There are findings of intact multisensory integration in schizophrenia (De Boer-Schellekens, Stekelenburg, Maes, Van Gool, & Vroomen, 2014), but such findings are infrequent.

Similarly, our finding that schizotypal traits were not associated with temporal processing does not align with previous findings of associations between impaired audiovisual (Dalal et al., 2020) tactile-proprioceptive (Ferri et al., 2016) and audio-tactile (Ferri et al., 2017) temporal processing and higher levels of schizotypal traits. Our finding is also inconsistent with findings in schizophrenia of impaired visual (Capa et al., 2014; de Boer-Schellekens et al., 2014; Giersch et al., 2009; Lalanne et al., 2012; Schmidt et al., 2011; Tenckhoff et al., 2002) and audiovisual (Foucher et al., 2007; Martin et al., 2013; Noel et al., 2018; Stevenson, Park, et al., 2017) temporal processing.

Additionally, our finding of no relationship between speech perception or distractibility to auditory speech and schizotypal traits is not in line with previous literature, which has found that individuals across the schizophrenia spectrum are more easily distracted by auditory speech and background noise (Hoffman et al., 1999; Marsh et al., 2017; Moser et al., 2001; Oltmanns & Neale, 1975; Shedlack et al., 1997; Wu et al., 2012).

In conclusion, we obtained mixed findings, with support for an association between enhanced multisensory integration and schizotypal traits, as well as support for no such association. We also found support for the lack of any association between perceptual processes like temporal processing, speech perception, and auditory speech distractibility and schizotypal traits.

4.1 Implications

There are a number of possible reasons for these null findings. It could be that the quasi-dimensional conceptualization of the schizophrenia spectrum better explains the current data than the fully dimensional conceptualization. Using the fully dimensional approach, we expected to find similar but attenuated perceptual deficits across the fully dimensional schizophrenia spectrum. However, perhaps Meehl's (1962) quasi-dimensional, diathesis-stress model approach towards schizotypy is more accurate. Using this approach, we can imagine that an individual with certain diatheses might be more prone to having higher levels of schizotypal traits. However, perhaps the "stress" component is missing in these cases, where environmental adversities or certain epigenetic changes have not yet "triggered" the development of schizophrenia, along with its pronounced perceptual symptomatology. The healthy individuals we are testing may possess some traits that make them more susceptible to schizophrenia, but they may be quite different from schizophrenia in that this schizophrenia switch has not been flicked on, so to speak. Another possibility is that this area of schizophrenia symptomatology is not dimensional at all, and that these perceptual symptoms are only found among individuals with schizophrenia diagnoses.

Additionally, we assumed that a linear relationship exists between schizophrenia spectrum severity and magnitude of perceptual differences, but perhaps this is actually a non-linear relationship. In other words, perhaps perceptual differences do not exist, or are very mild, at the lower end of the schizophrenia spectrum, and at the higher end of the spectrum they do exist.

Nevertheless, investigating perceptual functioning in healthy individuals with schizotypal traits has the potential to reveal important information about the development of schizophrenia. Individuals with higher levels of schizotypal traits are more likely to develop schizophrenia, but this does not occur for the majority of these individuals (Kwapil et al., 2013). Investigating those with higher levels of these traits may be useful, as we can try to determine if there are differences between people who develop schizophrenia versus those who do not.

Importantly, alterations in multisensory integration, temporal processing, speech perception, and distractibility to auditory speech, have the potential to function as cognitive biomarkers. These biomarkers, when detected in people, can help predict future risk for schizophrenia. They also have the potential to be used to assess treatment progress and outcomes. Studies such as this one are important in determining whether these are potentially effective and useful biomarkers. This study suggests that the McGurk effect may be a useful biomarker in detecting individuals with higher levels of schizotypal traits, as we found in Study

1 that increased McGurk effect perception was associated with higher levels of schizotypal traits. Likewise, as we found in Study 1 that poorer lip-reading was associated with higher levels of schizotypal traits, this also has the potential to function as a biomarker. A longitudinal approach would be necessary to determine whether these measures are truly indicative of schizophrenia risk. Meanwhile, the other measures, namely the speech-in-noise task and the ternary synchrony judgment task, may only be appropriate in detecting individuals who are at higher risk, or more severe on the schizophrenia spectrum.

4.2 Future Directions

It may be that a certain level of severity in symptoms is required before consistent, measurable perceptual differences can be found. If this is the case, it may be more beneficial in the future for such investigations to be conducted in individuals on the schizophrenia spectrum with more severe symptomatology. Future work may also benefit from conceptualizing schizotypy from a quasi-dimensional approach rather than a fully dimensional one.

Investigating potential treatment options for schizophrenia is an exciting avenue in this area. Antipsychotic medications are often not effective in treating all symptoms of schizophrenia, especially negative symptoms, and prolonged use results in many adverse side effects (Young, Taylor & Lawrie, 2015). For this reason, it is valuable to explore alternative approaches of treatment, such as perceptual training programs to narrow or widen the temporal binding window (Powers, Hillock, & Wallace, 2009). In these perceptual training programs, individuals are shown two slightly asynchronous stimuli and must decide if they are simultaneous or not. Immediately after responding, they are given feedback on whether their response was correct or not. This process, when repeated several dozen times, results in a more accurate ability to determine when two stimuli are occurring simultaneously. These perceptual training programs have been conducted on healthy participants, revealing neural changes (Powers et al., 2012), as well as changes in multisensory integration lasting for at least one week after learning (De Niear et al., 2017). This training appears to be somewhat effective in altering the size of temporal binding windows among children with autism spectrum disorder (Feldman et al., 2020), suggesting potential efficacy among individuals in the schizophrenia spectrum. Future work in this area will determine whether such programs improve temporal processing and multisensory integration, as well as downstream perception and communication, potentially improving the well-being and functioning of individuals across the schizophrenia spectrum.

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Appendix A

Ethics Approval

Date: 17 July 2019

To: Prof. Ryan Stevenson

Project ID: 108105

Study Title: Linking sensory perception and communication, social competency, and personality traits

Application Type: Continuing Ethics Review (CER) Form

Review Type: Delegated

Meeting Date: 02/Aug/2019

Date Approval Issued: 17/Jul/2019

REB Approval Expiry Date: 27/Jun/2020

Lapse in Approval: June 28, 2019 to July 17, 2019

Dear Prof. Ryan Stevenson,

The Western University Non-Medical Research Ethics Board has reviewed this application. This study, including all currently approved documents, has been re- approved until the expiry date noted above.

REB members involved in the research project do not participate in the review, discussion or decision.

The Western University NMREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the Ontario Personal Health Information Protection Act (PHIPA, 2004), and the applicable laws and regulations of Ontario. Members of the NMREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB. The NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000941.

Please do not hesitate to contact us if

you have any questions. Sincerely,

Daniel Wyzynski, Research Ethics Coordinator, on behalf of Prof. Randal Graham, NMREB Chair

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).

Appendix B

Letter of Information

Linking sensory perception and communication, social competency, and personality traits

Information letter - Adult

Prof. Ryan Stevenson
Department of Psychology
Western University
[redacted]

1. Invitation to participate

You're invited to participate in a study investigating how sensory perception influences how we interact with the world.

2. Purpose of the Study

The purpose of the study is to understand how people use the things they hear and see, how they put what they hear and see together, and how this processes develops to impact how people interact with the world. Almost everything people do in the world depends on how we perceive the world, yet little is known about how our perceptual abilities shape the development of our communicative abilities, social abilities, and personalities. This study seeks to explore these relationships.

3. How long will you be in the study?

The study will take from 1-4 hours, depending on which portion of the experiment you are participating in. Behavioural, eye tracking, and EEG portions of the study will last no longer that 2 hours, and questionnaires will take no longer than 2 hours to complete.

4. What are the study procedures?

In order to participate, individuals must: a) normal or corrected-to-normal hearing and vision; and b) no known neurological issues (epilepsy, brain injury, etc.). You will be asked to look at pictures, listen to sounds, and watch some short videos that have been created specifically to understand how people attend to and understand what they see and what they hear. During the session, your eye movements may be recorded and tracked using eye-tracking equipment. If you are volunteering to participated in an EEG session, you will be asked to wear a soft, damp net over your head while you attend to the presentations that will allow us to non-invasively record your brain's activity. We will ask you to not wear makeup to an EEG session, and hair products (i.e. a hair dryer, shampoo, towels) will be provided following the EEG. This portion of participation may last up to two hours.

You may be asked to complete several questionnaires about a range of personal skills and characteristics, and may be asked to complete a problem solving task and vocabulary test. This portion of participation may last up to two hours. Participation will take place at Western Universities London campus or online.

5. What are the risks and harms of participating?

There are no known or anticipated risks or discomforts associated with participating in this study.

6. What are the benefits of participating in this study?

You may not directly benefit from participating in this study but information gathered may provide benefits to society as a whole which include understanding the role that sensory perception plays in typical development, which may lead to theories and practices to help individuals who exhibit impaired sensory perception.

7. Can participants choose to leave the study?

Participation is completely voluntary, *you can withdraw from the study at any time*. If you decide to stop participating, you will still be eligible to receive the promised compensation for agreeing to be in this project. In the event you withdraw from the study, all associated data collected will be immediately destroyed wherever possible.

8. How will participants' information be kept confidential?

All information obtained during the study will be held in strict confidence to the fullest extent possible by law. While we do our best to protect your information there is no guarantee that we will be able to do so. The inclusion of your date of birth may allow someone to link the data and identify you. The mitigate this risk to the greatest extent possible, all data will be de-identified immediately following collection and labelled with a Participant ID, and the file linking your identifying information and Participant ID will be kept under lock and key. Representatives of The University of Western Ontario Non-Medical Research Ethics Board may require access to your study-related records to monitor the conduct of the research. The experimental data acquired in this study may, in an anonymized form that cannot be connected to you, be used for teaching purposes, be presented at meetings, published, shared with other scientific researchers or used in future studies. Your name or other identifying information will not be used in any publication or teaching materials without your specific permission.

9. **Are participants compensated to be in this study?**

Yes. Participants from the SONA system will be compensated with 1 research credit per hour toward PSYC1000 for participating in this study. If you are enrolled in a course other than Psych 1000, your compensation will be based on your course outline. If you have any questions about the time or compensation, please feel free to contact the investigators before you consider signing the consent. Otherwise, compensation will be $5.00 for every 30 minutes of participation.

10. **What are the Rights of Participants?**

Your participation in this study is voluntary. You may decide not to be in this study. Even if you consent to participate you have the right to not answer individual questions or to withdraw from the study at any time. If you choose not to participate or to leave the study at any time it will have no effect on your academic standing if you are a student.

We will give you new information that is learned during the study that might affect your decision to stay in the study.

You do not waive any legal right by signing this consent form.

11. **Whom do participants contact for questions?**

If you have questions about this research study please contact: Prof. Ryan Stevenson at the Department of Psychology, Western University, [redacted]

If you have any questions about your rights as a research participant or the conduct of this study, you may contact The Office of Research Ethics [redacted]

Thank you for your interest and participation in this study, it is greatly appreciated!

This letter is yours to keep for future reference.

Appendix C

Consent Form

<u>Linking sensory perception and communication, social competency, and personality traits</u>

INFORMED CONSENT FORM

Prof. Ryan Stevenson
Department of Psychology
Western University
[redacted]

I have read the Letter of Information, have had the nature of the study explained to me and I agree to participate. All questions have been answered to my satisfaction.

Questionnaires:	□ Yes	□ No
Behavioural:	□ Yes	□ No
EEG:	□ Yes	□ No
fMRI:	□ Yes	□ No

Name (please print): ________________________________

Signature: ________________________________

Date: ________________________________

Name of Person Obtaining Consent________________________________

Signature of Person Obtaining Consent________________________________

Date for Person Obtaining Consent________________________________

Appendix D

Questionnaire

Schizotypal Personality Questionnaire

Ideas of Reference

1. Do you sometimes feel that things you see on the TV or read in the newspaper have a special meaning for you?

10. I am aware that people notice me when I go out for a meal or to see a film.

19. Do some people drop hints about you or say things with a double meaning?

28. Have you ever noticed a common event or object that seemed to be a special sign for you?

37. Do you sometimes see special meanings in advertisements, shop windows, or in the way things are arranged around you?

45. When shopping do you get the feeling that other people are taking notice of you?

53. When you see people talking to each other, do you often wonder if they are talking about you?

60. Do you sometimes feel that other people are watching you?

63. Do you sometimes feel that people are talking about you?

Excessive Social Anxiety

2. I sometimes avoid going to places where there will be many people because I will get anxious.

11. I get very nervous when I have to make polite conversation.

20. Do you ever get nervous when someone is walking behind you?

29. I get anxious when meeting people for the first time.

38. Do you often feel nervous when you are in a group of unfamiliar people?

46. I feel very uncomfortable in social situations involving unfamiliar people.

54. I would feel very anxious if I had to give a speech in front of a large group of people.

71. I feel very uneasy talking to people I do not know well.

Odd Beliefs or Magical Thinking

3. Have you had experiences with the supernatural?

12. Do you believe in telepathy (mind-reading)?

21. Are you sometimes sure that other people can tell what you are thinking?

30. Do you believe in clairvoyancy (psychic forces, fortune telling)?

39. Can other people feel your feelings when they are not there?

47. Have you had experiences with astrology, seeing the future, UFOs, ESP, or a sixth sense?

55. Have you ever felt that you are communicating with another person telepathically (by mind-reading)?

Unusual Perceptual Experiences

4. Have you often mistaken objects or shadows for people, or noises for voices?

13. Have you ever had the sense that some person or force is around you, even though you cannot see anyone?

22. When you look at a person, or yourself in a mirror, have you ever seen the face change right before your eyes?

31. I often hear a voice speaking my thoughts aloud.

40. Have you ever seen things invisible to other people?

48. Do everyday things seem unusually large or small?

56. Does your sense of smell sometimes become unusually strong?

61. Do you ever suddenly feel distracted by distant sounds that you are not normally aware of?

64. Are your thoughts some-times so strong that you can almost hear them?

Odd or Eccentric Behavior

5. Other people see me as slightly eccentric (odd).

14. People sometimes comment on my unusual mannerisms and habits.

23. Sometimes other people think that I am a little strange.

32. Some people think that I am a very bizarre person.

67. I am an odd, unusual person.

70. I have some eccentric (odd) habits.

74. People sometimes stare at me because of my odd appearance.

No Close Friends

6. I have little interest in get-ting to know other people.

15. I prefer to keep myself to myself.

24. I am mostly quiet when with other people.

33. I find it hard to be emotion-ally close to other people.

41. Do you feel that there is no one you are really close to outside of your immediate family, or people you can confide in or talk to about personal problems?

49. Writing letters to friends is more trouble than it is worth.

57. I tend to keep in the back-ground on social occasions.

62. I attach little importance to having close friends.

66. Do you feel that you cannot get "close" to people?

Odd Speech

7. People sometimes find it hard to understand what I am saying.

16. I sometimes jump quickly from one topic to another when speaking.

25. I sometimes forget what I am trying to say.

34. I often ramble on too much when speaking.

42. Some people find me a bit vague and elusive during a conversation.

50. I sometimes use words in unusual ways.

58. Do you tend to wander off the topic when having a conversation?

69. I find it hard to communicate clearly what I want to say to people.

72. People occasionally comment that my conversation is confusing.

Constricted Affect

8. People sometimes find me aloof and distant.

17. I am not good at expressing my true feelings by the way I talk and look.

26. I rarely laugh and smile.

35. My "nonverbal" communication (smiling and nodding during a conversation) is not very good.

43. I am poor at returning social courtesies and gestures.

51. I tend to avoid eye contact when conversing with others.

68. I do not have an expressive and lively way of speaking.

73. I tend to keep my feelings to myself.

Suspiciousness

9. I am sure I am being talked about behind my back.

18. Do you often feel that other people have it in for you?

27. Do you sometimes get concerned that friends or co-workers are not really loyal or trustworthy?

36. I feel I have to be on my guard even with friends.

44. Do you often pick up hid-den threats or put-downs from what people say or do?

52. Have you found that it is best not to let other people know too much about you?

59. I often feel that others have it in for me.

65. Do you often have to keep an eye out to stop people from taking advantage of you?

Note.—The response format is "yes/no." All items endorsed "yes" score 1 point

Appendix E

Supplementary Material for Chapter 2

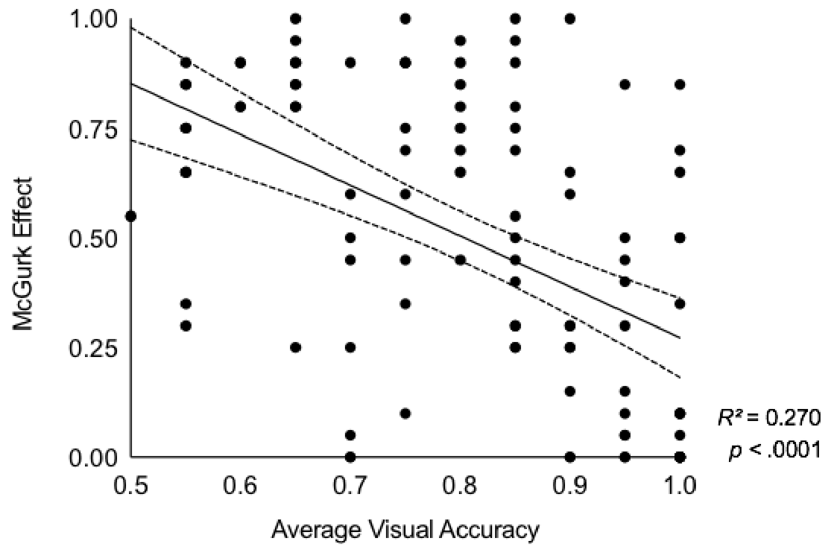

Figure S1. Scatterplot showing correlation between average visual accuracy and McGurk effect (*N* = 105).

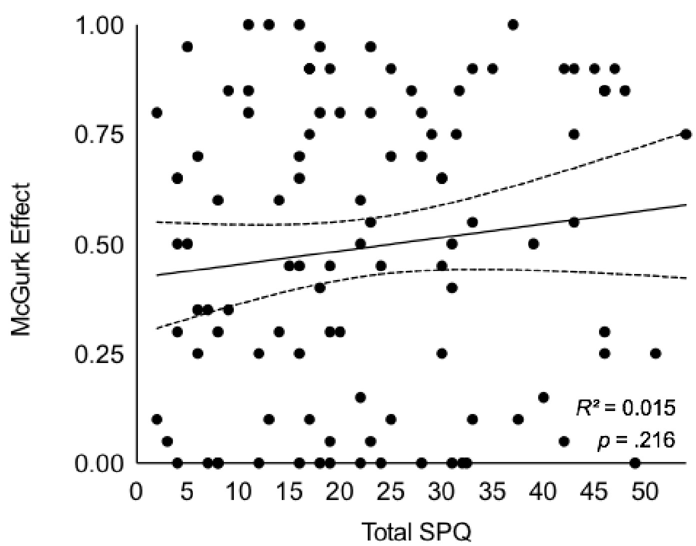

Figure S2. Scatterplot showing correlation between the McGurk effect and the Total SPQ score (*N* = 105).

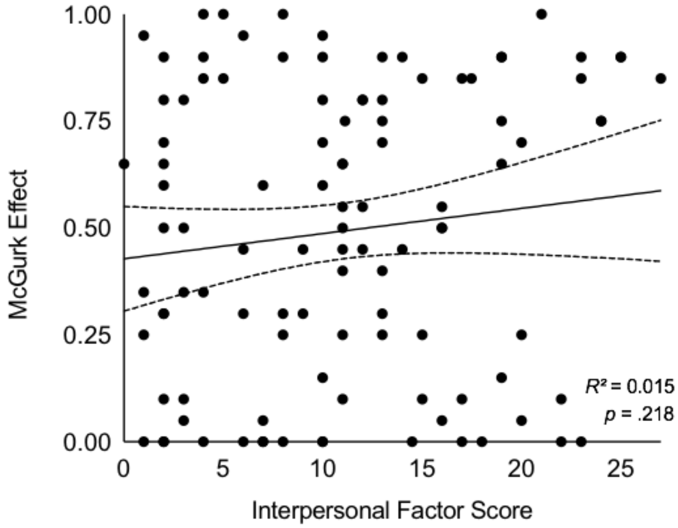

Figure S3. Scatterplot showing correlation between the McGurk effect and the Interpersonal Factor score (N = 105).

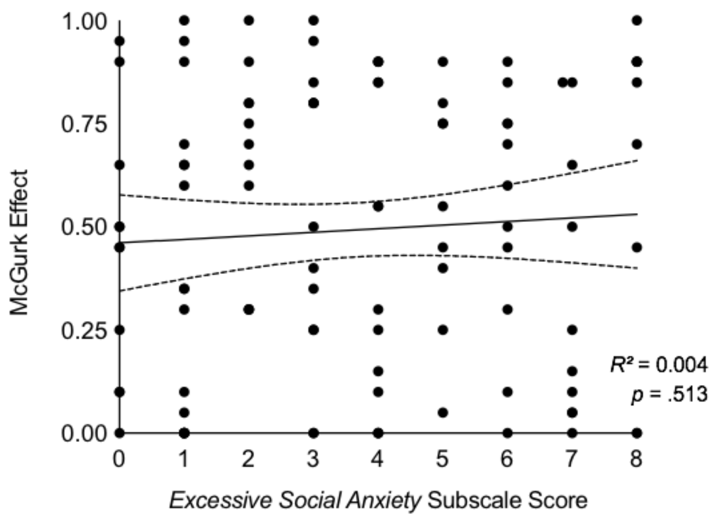

Figure S4. Scatterplot showing correlation between the McGurk effect and the *Excessive Social Anxiety* subscale score (N = 105).

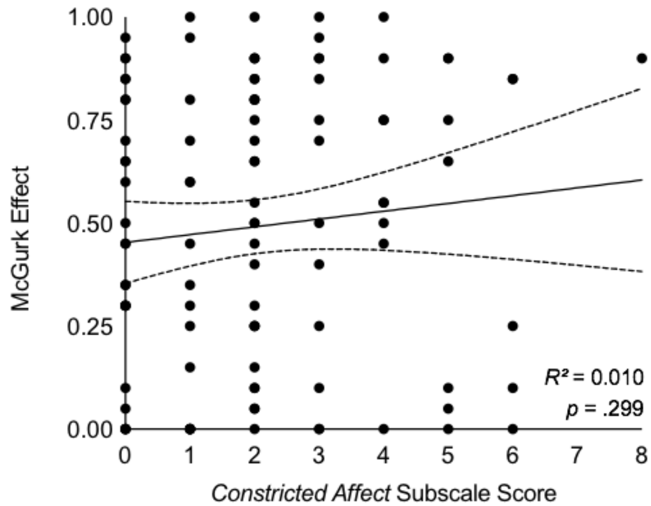

Figure S5. Scatterplot showing correlation between the McGurk effect and the *Constricted Affect* subscale score (N = 105).

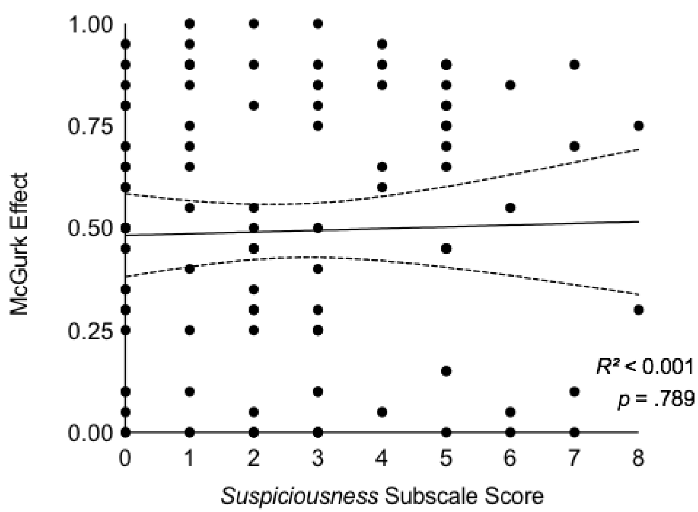

Figure S6. Scatterplot showing correlation between the McGurk effect and the *Suspiciousness* subscale score (N = 105).

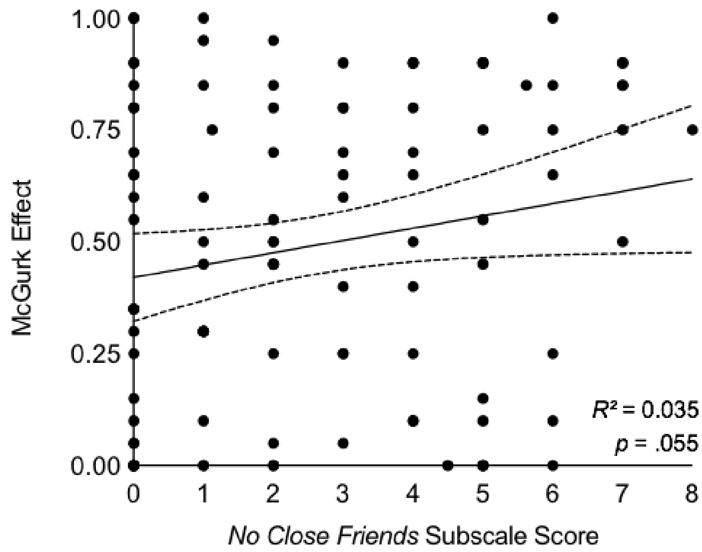

Figure S7. Scatterplot showing correlation between the McGurk effect and the *No Close Friends* subscale score (N = 105).

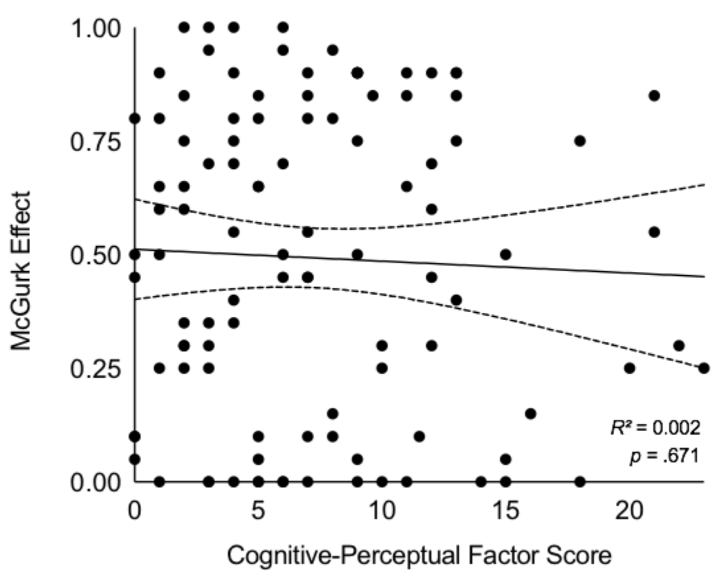

Figure S8. Scatterplot showing correlation between the McGurk effect and the Cognitive-Perceptual Factor score (N = 105).

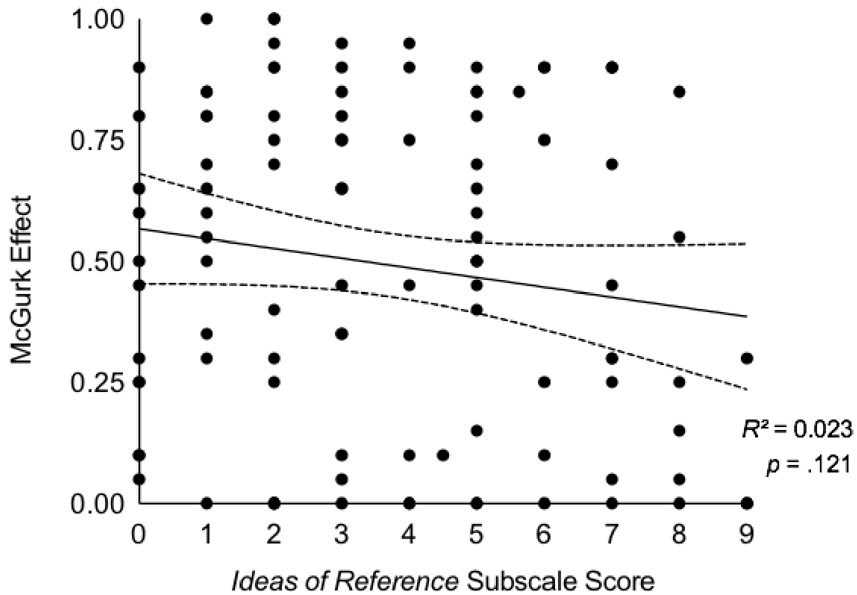

Figure S9. Scatterplot showing correlation between the McGurk effect and the *Ideas of Reference* subscale score (N = 105).

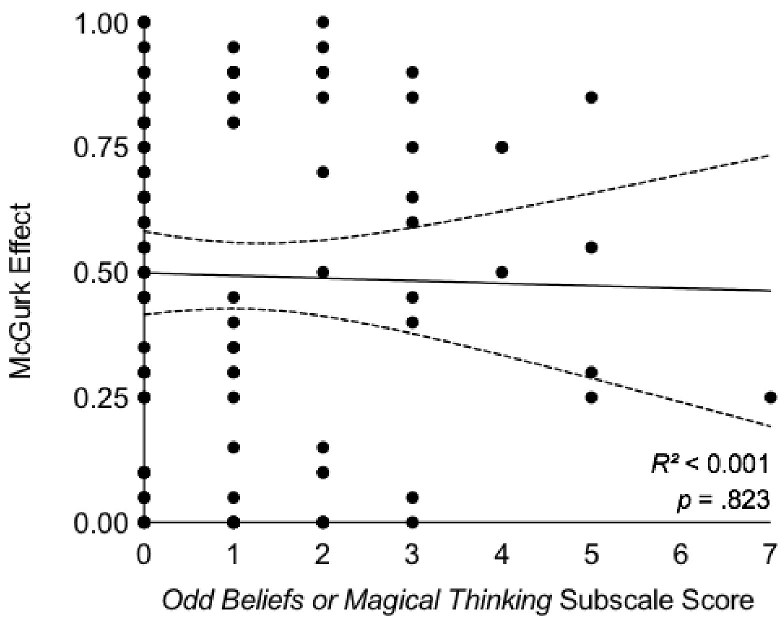

Figure S10. Scatterplot showing correlation between the McGurk effect and the *Odd Beliefs or Magical Thinking* subscale score (N = 105).

Table S1

Summary of mediational analysis for perceived McGurk effect predicting Odd Speech subscale scores with average visual accuracy as a mediator

Mediation Estimates

Effect	Label	Estimate	SE	Z	p	% Mediation
Indirect	a × b	0.382	0.359	1.064	0.287	27.089
Direct	c	1.029	0.682	1.509	0.131	72.911
Total	c + a × b	1.411	0.586	2.409	0.016	100.000

Path Estimates

	Label	Estimate	SE	Z	p
Average Visual Accuracy → McGurk Effect	a	-0.233	0.037	-6.225	< .001
McGurk Effect → Odd Speech	b	-1.643	1.521	-1.080	0.280
Average Visual Accuracy → Odd Speech	c	1.029	0.682	1.509	0.131

Table S2

Summary of mediational analysis for average visual accuracy predicting Odd Speech subscale scores with perceived McGurk effect as a mediator

Mediation Estimates

Effect	Label	Estimate	SE	Z	p	% Mediation
Indirect	a × b	-1.192	0.813	-1.467	0.142	42.050
Direct	c	-1.643	1.521	-1.080	0.280	57.950
Total	c + a × b	-2.835	1.314	-2.157	0.031	100.000

Path Estimates

	Label	Estimate	SE	Z	p
Average Visual Accuracy → McGurk Effect	a	-1.159	0.186	-6.225	< .001
McGurk Effect → Odd Speech	b	1.029	0.682	1.509	0.131
Average Visual Accuracy → Odd Speech	c	-1.643	1.521	-1.080	0.280

Table S3

Summary of mediational analysis for perceived McGurk effect predicting Disorganized factor scores with average visual accuracy as a mediator

Mediation Estimates

Effect	Label	Estimate	SE	Z	p	% Mediation
Indirect	a × b	1.045	0.596	1.752	0.080	34.575
Direct	c	1.977	1.102	1.794	0.073	65.425
Total	c + a × b	3.022	0.957	3.158	0.002	100.000

Path Estimates

	Label	Estimate	SE	Z	p
McGurk Effect → Average Visual Accuracy	a	-0.233	0.037	-6.225	< .001
Average Visual Accuracy → Disorganized Factor	b	-4.490	2.460	-1.825	0.068
McGurk Effect → Disorganized Factor	c	1.977	1.102	1.794	0.073

Table S4

Summary of mediational analysis for average visual accuracy predicting Disorganized factor scores with perceived McGurk effect as a mediator

Mediation Estimates

Effect	Label	Estimate	SE	Z	p	% Mediation
Indirect	a × b	-2.291	1.329	-1.723	0.085	33.781
Direct	c	-4.490	2.460	-1.825	0.068	66.219
Total	c + a × b	-6.781	2.134	-3.177	0.001	100.000

Path Estimates

	Label	Estimate	SE	Z	p
Average Visual Accuracy → McGurk Effect	a	-1.159	0.186	-6.225	< .001
McGurk Effect → Disorganized Factor	b	1.977	1.102	1.794	0.073
Average Visual Accuracy → Disorganized Factor	c	-4.490	2.460	-1.825	0.068

Table S5

Summary of mediational analysis for average visual accuracy predicting Odd or Eccentric Behaviour subscale scores with perceived McGurk effect as a mediator

Mediation Estimates

Effect	Label	Estimate	SE	Z	p	% Mediation
Indirect	a × b	-1.099	0.703	-1.564	0.118	27.841
Direct	c	-2.848	1.310	-2.174	0.030	72.159
Total	c + a × b	-3.946	1.133	-3.483	< .001	100.000

Path Estimates

	Label	Estimate	SE	Z	p
Average Visual Accuracy → McGurk Effect	a	-1.159	0.186	-6.225	< .001
McGurk Effect → Odd/Eccentric Beh	b	0.948	0.587	1.616	0.106
Average Visual Accuracy → Odd/Eccentric Beh	c	-2.848	1.310	-2.174	0.030

Appendix F

Supplementary Material for Chapter 3

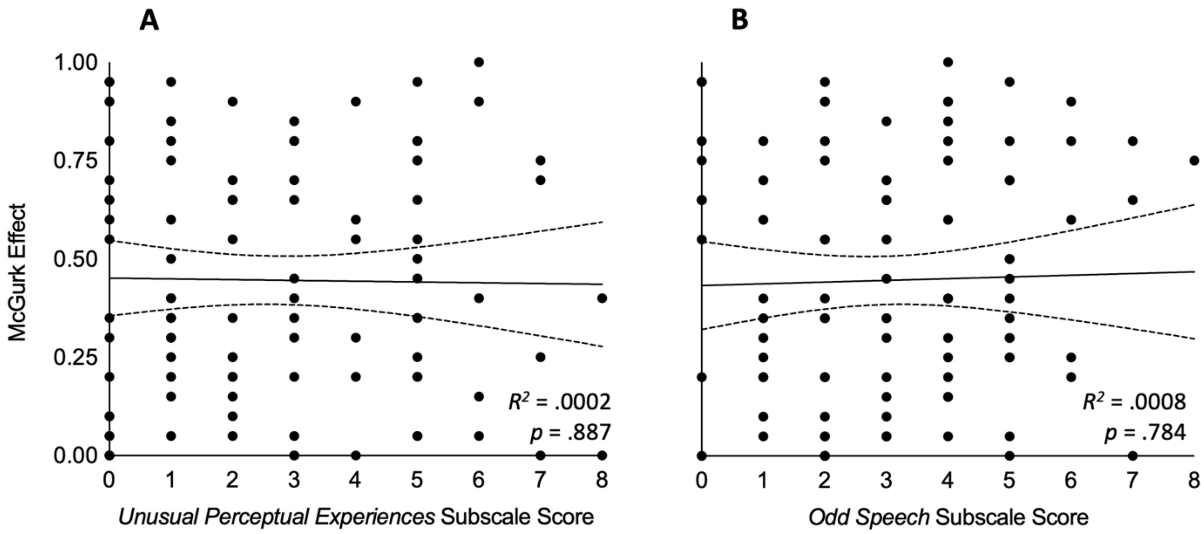

Figure S1. Scatterplots showing correlations between the McGurk effect and (A) the *Unusual Perceptual Experiences* subscale score and (B) the Odd Speech subscale score. *Note.* Dashed lines indicate 95% confidence intervals.

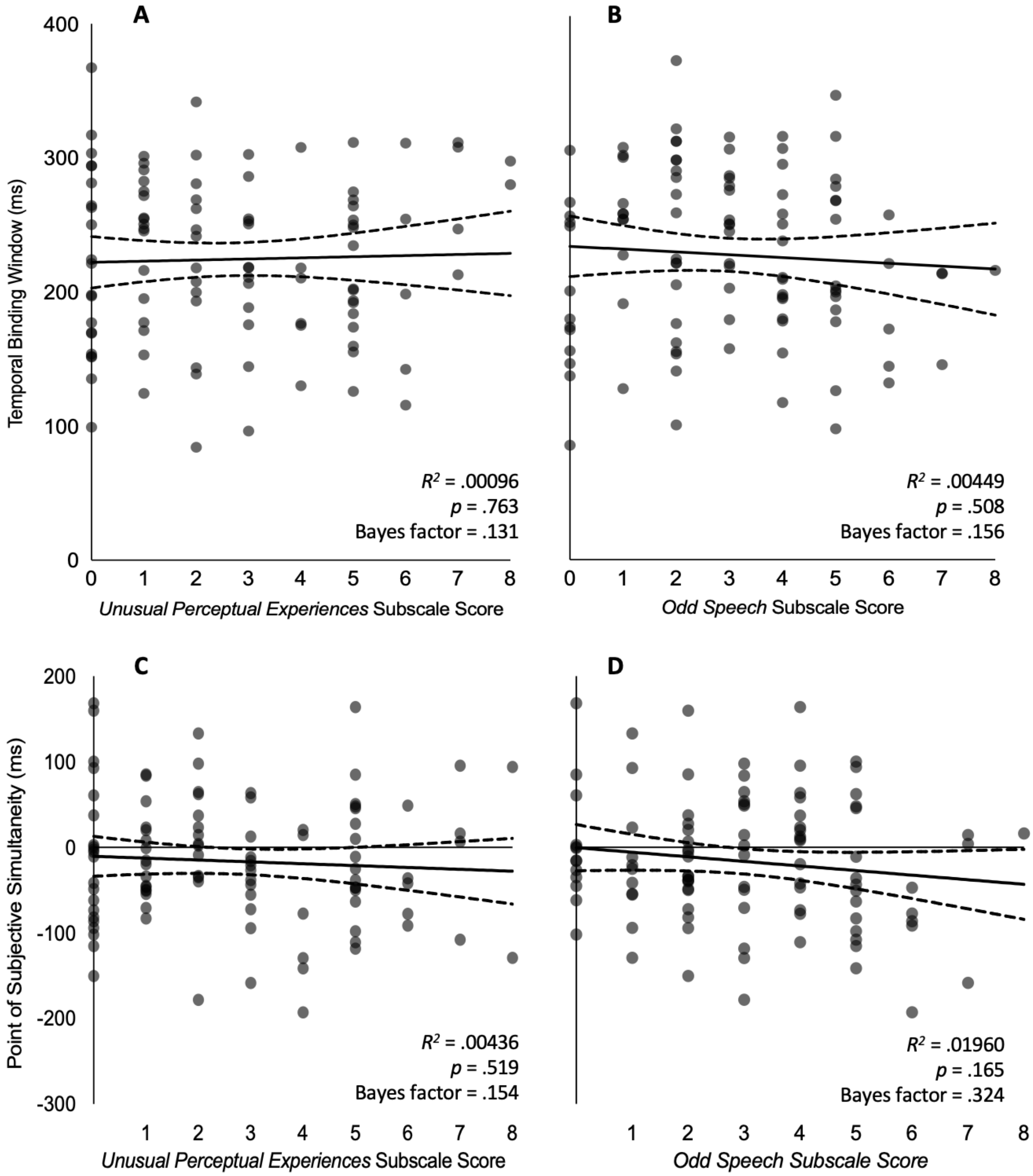

Figure S2. Scatterplots showing the correlations between the temporal binding window and (A) the *Unusual Perceptual Experiences* subscale score and (B) the Odd Speech subscale score, and the point of subjective simultaneity and (C) the *Unusual Perceptual Experiences* subscale score and (D) the Odd Speech subscale score *Note.* Darker points indicate more individual points in that location. Dashed lines indicate 95% confidence intervals.

Curriculum Vitae

CURRICULUM VITAE

Anne-Marie Muller
Department of Psychology
The University of Western Ontario

Education

2018-present Master's of Science: Clinical Psychology
University of Western Ontario
Thesis title: The Relationship Between Schizotypal Traits and the Perceptual Processes of Multisensory Integration, Temporal Processing, and Speech Perception
Advisor: Dr. Ryan Stevenson, Ph.D.

2014-2018 Bachelor of Science (Honours with Distinction): Psychology: Brain & Cognition
Minor in Neuroscience
University of Guelph

2012-2013 Bachelor of Fine Arts: Drawing and Painting
Transferred
Ontario College of Art and Design (OCAD) University

Research Experience

2018-present Research Assistant, supervised by Dr. Ryan Stevenson,
Western University.

2018 Research Assistant, supervised by Dr. Boyer Winters,
University of Guelph.

2017 Research Assistant, supervised by Dr. Benjamin Giguere,
University of Guelph.

2016 Research Assistant, supervised by Dr. Gisele LaPointe,
University of Guelph.

Scholarships and Awards

2019-2020 Canadian Institutes of Health Research Canada Graduate Scholarship – Masters (CIHR CGS-M), University of Western Ontario, total value $17,500

2019-2020 Ontario Graduate Scholarship, University of Western Ontario, total value $15,000 – declined

2019-2020 Graduate Research Awards Fund (GRAF), University of Western Ontario, total value $525

2017 CSAHS Student Volunteer Scholarship, University of Guelph, total value $1,000

2017 Undergraduate Research Award (URA), University of Guelph, total value $7,500

2016 Norma Bowen Memorial Scholarship in Psychology, University of Guelph, total value $2,000

2016 Yeandle Family Scholarship, University of Guelph, total value $2,000

2016 NSERC Undergraduate Student Research Award (USRA), University of Guelph, total value $7,500

2015 Dean's Undergraduate Scholarship, University of Guelph, total value $2,000

2012 BMO Financial Group Award, OCAD University, total value $1,000

Publications

4. **Muller, A.,** Dalal, T., & Stevenson, R.A. (Submitted). Schizotypal traits are not related to multisensory integration or audiovisual speech perception. *Consciousness and Cognition.*

3. **Muller, A.,** Dalal, T., & Stevenson, R.A. (Under Review). Schizotypal Personality Traits and Multisensory Integration: An Investigation Using the McGurk Effect. *Acta Psychologica*..

2. Dalal, T.C., **Muller, A.,** Stevenson, R.A. (Submitted). The Relationship Between Multisensory Temporal Processing and Schizotypal Traits. *Schizophrenia Research.*

1. Mitchnick, K.A., Mendel, A.L., Wideman, C.E., Jardin, K.H., Creighton, S.D., **Muller, A.,** Choleris, E., MacLusky, N.J., & Winters, B.D. (2019). 17-β Estradiol, Estrogen Receptors, and JNK Signaling in Perirhinal Cortex-mediated Object Memory in Male Rats. *Psychoneuroendocrinology.*

Conference Presentations

3. **Muller, A.,** Zhang, J., Ajao, C., Dalal, T.C., & Stevenson, R.A. (Feb 2020). Associations Between Schizotypal Personality Traits, Audiovisual Speech Perception, and Multisensory Temporal Processing. Lake Ontario Visionary Establishment (L.O.V.E.) Conference. Niagara Falls, ON.

2. **Muller, A.,** Dalal, T., Stanton, K., & Stevenson, R.A. (Sept 2019). The Relationship Between Schizotypal Personality Traits, Audiovisual Temporal Processing, and Speech Perception. Society for Research in Psychopathology (SRP) Conference. Buffalo, NY.

1. Dalal, T.C., **Muller, A.,** Brierley, N., Sehl, C., Abraham, A., Tran, B., Haque, A., Shafai, F., Gateman, E., Montenegro, J., & Stevenson, R.A. (Feb 2019). The Relationship Between Multisensory Integration and Schizotypal Personality Traits. Lake Ontario Visionary Establishment (L.O.V.E.) Conference. Niagara Falls, ON.

Certificates

Mar 2020 Certificate in Trauma-Focused Cognitive Behavioural Therapy.
Medical University of South Carolina (Online).

Aug 2019 Autism Diagnostic Observation Schedule (ADOS-2) Training.
Lifeways Community Mental Health, Jackson, MI.

Feb 2019 Dialectical Behaviour Therapy with Adolescents and Emerging Adults.
Ryerson University, Toronto, ON.

Feb 2019 Applied Suicide Intervention Skills Training (ASIST).
Toronto, ON.

Related Work and Training Experience

2020 Assessment Placement Student,
Child and Youth Development Clinic, London, ON.

2020 Research Psychometrist,
Western University.

2018 – 2019 Advocacy Through Action, Evaluations Committee,
Western University.

2018 – 2020 Teaching Assistant,
Western University.