Schizotypy Correlates with Poor Event Segmentation:

Insights for Schizophrenia Spectrum

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A senior thesis presented to the
Princeton University Department of Psychology in fulfillment
of the Undergraduate independent research requirement.

Niv Lab

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April 22nd, 2024
Acknowledgments

I would like to formally acknowledge and express my sincere gratitude to everyone who contributed to the realization of this thesis. Thank you to Princeton University’s Undergraduate Psychology Department and the Niv Lab for providing me with the necessary funding, resources, and support, without which this work could have never been completed.

I would like to express my heartfelt gratitude to Dr. Yael Niv, my faculty thesis advisor and the head of the Niv lab, for her unwavering support and expertise throughout the completion of my junior paper and senior thesis over the past two years. Your encouragement and guidance have played a pivotal role in shaping the development and successful execution of this thesis project, and I am profoundly grateful for the opportunity to have joined your lab and to have benefited from your wisdom and experience. To you and the members of the Niv lab, I owe a debt of gratitude for your contributions, collaboration, and camaraderie throughout this journey. Thank you, Dr. Niv, for your outstanding mentorship and support. I am immensely grateful for everything you have done to support my academic, career, and personal development.

A special acknowledgment and my deepest gratitude goes to Dr. Oded Bein, my postdoctoral thesis advisor. Navigating the ever-turning and tumultuous life of an undergraduate Princeton student can be challenging, but you have been a constant source of empathy, kindness, and encouragement. I have always felt that I was not navigating this journey alone, knowing that you were there as an anchor of support. Your belief in my abilities has been a constant source of motivation, pushing me to strive for excellence in my research and academic pursuits. Throughout this research, your guidance and support have been invaluable as you spent countless hours patiently explaining complex concepts, ensuring that I understood each aspect thoroughly. Your ability to make me laugh during our thesis meetings has lightened many stressful days and
made the long process enjoyable. I will deeply miss our weekly meetings. Thank you for always making yourself available, and generously sharing your time, energy, and expertise. Dr. Bein, your constructive feedback and insightful advice have been instrumental in refining my ideas and methodologies, contributing to the overall quality of this work. Your dedication to my academic and professional growth has been unwavering, and I have gained an endless amount of knowledge and confidence through our sessions, which will undoubtedly benefit me in my future endeavors. Thank you once again, Dr. Bein, for your exceptional guidance and support.
Dedication

I dedicate this work to my family. Your love and encouragement have been the foundation of this journey. Without you and your ongoing support, completing this work would have been impossible. I love you; you mean everything to me.

To my father, Suliman, you are the embodiment of resilience and strength. Your diagnosis of paranoid schizophrenia was a turning point that shaped not only your path but also mine. It was witnessing your journey and resilience that ignited my passion for psychology and mental health advocacy. Your support has been unwavering—from helping me move in and out of boarding school and college dorms to courageously volunteering as a practice subject for my phlebotomy class, despite your fear of needles. Amidst the recent dehumanization of Palestinian men, it's even more important for me to honor and acknowledge you today and always. Baba, this work is a tribute and a testament to the profound influence you've had on shaping my understanding of psychology and mental health, and I dedicate this thesis to you with my utmost love, admiration, and eternal gratitude.

To my mother, Zuhour, your commitment to my education has been the cornerstone of my life’s journey. From a young age, you instilled in me the belief that education could turn dreams into reality, allowing me to dream fearlessly. Thank you for letting me chase those dreams and push the limits, even when you were scared for your little girl. Your support and belief in me have been the driving force behind my achievements, leading me to Princeton University and guiding me through the completion of this thesis. Mama, thank you for dealing with my stress, excusing my absences at family events, and always cooking me delicious home-cooked meals to get me through this process.
To my eldest sister, Samira, you have been much more than a sister to me; you've been my best friend and role model throughout my life. Thank you for believing in me and my future and for supporting my large dreams and aspirations with unwavering encouragement. Your sacrifices have been both numerous and profound, from the early days of changing my diapers to the countless hours you spent driving me to interviews, program events, internships, and moving me in and out of boarding school. Your support and kindness have not gone unnoticed. From my earliest memories, I have looked up to you with admiration and the desire to emulate your strength and grace. Your guidance and example have been instrumental in shaping who I am today. Thank you, Samira, for being my guiding light and inspiration.

To my brother, Samir, it is from you that I have learned the true meaning of patience and generosity. You stand as the epitome of selflessness, always placing others' needs ahead of your own, even when it comes at a personal cost. I recall your wise words from my younger days: "Why spend time complaining about the things you have to do in life? Why not just do them?" Your philosophy has instilled in me the value of action over procrastination. Thank you, Samir, for teaching me the importance of empathy and action, and for always leading by example. Your influence on my life is immeasurable, and I am forever grateful for your support, love, and chocolate bars.

To my sister, Sukayna, since we were children, you have championed the value of education, going so far as to create makeshift classrooms and play pretend school to teach me my ABCs. While your constant rants often distracted me from my work, they have also refocused my energy, particularly when I needed it most. Thank you for teaching me the value of balance; it has been instrumental in completing this thesis. Your advocacy and encouragement have empowered me to push boundaries and advocate for myself. It was your belief in me that laid the
foundation for my participation in the NJSEEDS program, a pivotal moment that set me on my current path. Thank you, Sukayna, for being my biggest cheerleader. Your impact on my life is indefinite, and I am forever grateful for your love, guidance, and belief in me.

To my cousin, Ayah, you have endured my crankiness, unavailability, and endless amounts of panic and stress with your beautiful smile and kind words. Your presence has been a silent source of support, even when you did not realize it. Thank you for making me laugh during those long nights and for filling me with confidence when I was riddled with self-doubt.

To my dear friends and colleagues, Sofi and Toru, thank you for keeping me sane and for lending me your ears and shoulders. You have been my anchors. You have contributed so much light and warmth to my Princeton experience, each in different and beautiful ways. Thank you for your constant presence, encouragement, and the countless memorable moments we've shared. I will cherish them forever.

Lastly, I dedicate this thesis to all the Palestinians who tragically lost their lives in recent months. You have not left my mind during the completion of this work. Your voices, filled with anguish and sorrow, echo constantly in my thoughts. This thesis stands as a testament to your unrealized dreams, your injustice, and to the enduring and inspirational resilience of our people. It is a tribute to the innocent men, women, and children who were taken from us before they could realize their potential.
Abstract

Schizophrenia is a spectrum of mental disorders that impair individuals' ability to perceive and understand their environment. A critical aspect of understanding our environment is our ability to parse continuous experiences into discrete events in our minds, a process termed ‘event segmentation.’ Understanding segmentation along the spectrum of schizophrenia severity (i.e., schizotypy) and symptoms can facilitate our understanding of the mechanisms underlying disorganized perception in schizophrenia. To that end, online participants (N=483) completed a task in which they segmented short movie clips into discrete units by indicating when in their mind one unit ends and another begins. Participants with higher levels of schizotypy (based on self-report) indicated segments in less typical time points, as reflected by less agreement with the group’s segmentation norm. That is even though they had the same number of segments. These results reflect a disorganized and less structured perception of events in schizotypy. Additionally, symptoms of perceptual dysregulation specifically, more so than eccentricity and unusual beliefs, correlated with poorer segmentation. This study contributes to our understanding of the relationship between schizotypy and perceptual organization, shedding light on potential cognitive mechanisms underlying psychotic experiences.

Keywords: Event segmentation, schizophrenia, schizotypy, psychotic symptoms, perceptual dysregulation, context
Introduction

The Role of Event Segmentation in Perceptual Processing.

Human thinking happens within a constant flow of sensory information (i.e. what we see, hear, taste, smell). Despite this constant flow, our brains parse continuous experiences into distinct clusters or episodes, a process termed ‘event segmentation’ (Zacks et al., 2007). This breaking-up of events is triggered by event boundaries, which are shifts in situational context (Clewett et al., 2019; Zacks, 2020; Zacks et al., 2007). For example, when I’m walking my dog, walking out of the door to the street is a change of context from my home to the street, which signals a clear beginning of a new event – that of walking the dog. Likewise, walking through the door when coming back home signals an ending. By breaking down continuous experiences into discrete events, individuals can organize complex information into manageable parts and comprehend their surroundings effectively to make context-appropriate decisions and actions (Zacks & Sargent, 2010). Segmentation also allows for the extraction of meaningful information by enabling individuals to focus attention on specific aspects of each segment, discern patterns, and understand the significance of events within their context (Zacks, 2020). Moreover, segmentation facilitates memory encoding by creating distinct memory traces (Clewett et al., 2019). Thus, event segmentation serves as a fundamental mechanism for navigating and making sense of our dynamic environment.

Neurotypical individuals tend to agree about where event boundaries occur (Baldwin & Baird, 2001). This shared agreement depends on using similar sensory cues and shared semantic knowledge that represents previously learned information about event parts and the perception of boundaries, which arises from ongoing perceptual processing and regulates attention and memory (Zacks et al., 2007). Sensory cues, such as changes in visual or auditory stimuli, serve as perceptual anchors that signal transitions between events. Additionally, semantic knowledge,
acquired through shared experiences and cultural norms, shapes individuals' understanding of how events are structured and organized; therefore, they can agree about where event boundaries occur. This shared understanding of event boundaries is essential for effective social interaction, as it enables individuals to interpret others' actions and intentions accurately (Baldwin & Baird, 2001). For instance, recognizing the end of a conversation segment might signal that it's appropriate to respond with empathy or offer support to a friend who has just shared a personal experience. By aligning their perceptions of events, individuals can engage in effective communication, fostering social cohesion and mutual understanding between individuals (Boggia & Ristic, 2015).

In addition, event segmentation theory (EST) and empirical findings suggest that events are segmented hierarchically (Baldassano et al., 2017; Kurby & Zacks, 2008; Zacks et al., 2001). Events are segmented at multiple levels, encompassing small, fine-grained events that are nested within larger, more abstract events. Fine segmentation (i.e., into small events), is thought to be based on sensory information like changes in sound, color, or shape, and might be mediated by early visual and auditory processing areas in the brain (Baldassano et al., 2017; Zacks, 2020). Coarse segmentation of large, high-order events is thought to be driven by a combination of bottom-up processing of sensory features and top-down processing of conceptual features and is potentially mediated by the ventromedial prefrontal cortex (vmPFC) as lesions to this region have been shown to selectively impair coarse segmentation (Zacks et al., 2016). For example, walking my dog would be a large event containing smaller events such as grabbing my house key, putting on my dog’s leash, and locking the door on my way out. Small events help me to complete the larger goal of walking my dog. In this way, the integration of various levels of abstraction allows humans to analyze and understand their experiences as meaningful events.
A Spectrum of Schizophrenia Disorders

Schizophrenia encompasses a spectrum of disorders characterized by disturbances in thought, perception, and behavior. Central to the experience of schizophrenia is the disruption of cognitive processes, including perception, attention, memory, and executive function (Green, 2006) as well as difficulty in understanding others’ behavior and intentions (Eisenberg & Berman, 2009; Orellana & Slachevsky, 2013). Individuals with schizophrenia often struggle to maintain coherence in their thoughts and may experience hallucinations (false perceptions, i.e., seeing, hearing, or feeling things that are not grounded in reality), delusions, or confabulations (false memories or stories that individuals believe to be true), which further exacerbate their difficulties in distinguishing reality from internal experiences (Marder & Freedman, 2014). The neurobiological underpinnings of schizophrenia involve dysregulation in various neurotransmitter systems as well as structural and functional abnormalities in brain regions implicated in executive function, such as the prefrontal cortex (Howes & Kapur, 2009; Lewis & Lieberman, 2000; Orellana & Slachevsky, 2013). Importantly, these same prefrontal regions are also implicated in event segmentation (DuBrow & Davachi, 2016; Ezzyat & Davachi, 2011; Zacks, 2020).

Impairments in executive function, here defined as the ability to organize a sequence of actions in time to achieve a goal, are common in both schizophrenia and individuals with prefrontal cortex lesions (Zacks & Sargent, 2010). These deficits may contribute to challenges in event segmentation, particularly coarse segmentation, in schizophrenia (Zalla et al., 2006). Individuals with poor executive function find it difficult to stay focused and motivated when working towards their goals, which could lead to the disorganization of sequences toward the
goal. This would predict that schizophrenic participants could still segment small events, for which goal maintenance might be less important, but have particular difficulties identifying larger event boundaries and events. Indeed, in a study that asked schizophrenia patients to identify fine or coarse event boundaries, schizophrenia patients identified coarse boundaries less accurately but showed no impairments in fine segmentation (Zalla et al., 2004).

In addition, a lack of integration of bottom-up (sensory-driven) and top-down (concept-driven) information processing in individuals with schizophrenia (de Boer et al., 2019; Karbakhsh et al., 2023) can exacerbate segmentation impairments. One possibility is that in schizophrenia, the brain fails to chunk sensory information into events and potentially interprets a large event as multiple smaller events, but with no cohesive conceptual organization of the small events, and this could lead to disorganized thinking and confusion. For example, picking up my toothbrush, wetting my toothbrush, and putting toothpaste on my toothbrush are all small events, but some individuals with dysfunctional segmentation may fail to construct these small events under one larger event. When such a disconnect occurs, individuals may struggle to segment actions into larger, coarse-grained events, which could lead to difficulty in comprehending the purpose behind their actions.

While the past research above focused on schizophrenia patients, schizophrenia exists along a spectrum. It includes a wide range of symptoms, severity levels, and functional impairments. Schizotypy often refers to a personality organization characterized by behaviors, thoughts, and emotions that resemble those seen in schizophrenia but appear to a lesser extent. Thus, schizotypy reflects a susceptibility to schizophrenia spectrum disorders (Barrantes-Vidal et al., 2015; Ettinger et al., 2014; Lenzenweger, 2018), and research highlights significant overlap between the two across behavioral, brain structural, and functional, as well as molecular levels
Like schizophrenia patients, individuals with schizotypy may exhibit deficits in recognizing contextual changes and forming coherent mental representations crucial for daily functioning (Phillips et al., 2016). While event segmentation has been studied to some extent in schizophrenic patients (Zalla et al., 2004; 2006), no study has specifically investigated how schizotypal traits influence event segmentation. Addressing this gap can help our understanding of the cognitive mechanisms underlying schizotypy and schizophrenia and potentially identify early markers of vulnerability to psychosis. Further, by looking at symptoms of schizotypy continuously, we can potentially discern nuanced effects like how different symptoms are associated with event segmentation. That might be obscured in patients because of the high severity of all symptoms.

To that end, in this study, we ask, 1) What is the relationship between event segmentation and schizotypy? and 2) How does this relationship relate to specific schizotypal symptoms? To address these questions, participants viewed and segmented movie clips into discrete events based on their subjective perception of meaningful boundaries, a paradigm that has been extensively used before to study event segmentation (Newtson, 1973; Swallow et al., 2009; Zacks et al., 2007). They also completed a validated self-report questionnaire that assessed the severity of schizotypal symptoms along a continuum (PID-5: Personality Inventory of the DSM-5; Krueger et al., 2012). We hypothesize that schizotypy will correlate with less appropriate segmentation of coarse events, i.e., indicating boundaries in uncommon time points, reflected in lower segmentation agreement. We will further test specifically which symptoms of schizotypy correlate with altered segmentation.

**Methods**

**Participants.**
**Recruitment and Compensation:** We enlisted participants through Prolific (www.prolific.co), specifically including native English speakers aged 18 and above from the United States. Participants received $15.00 for each 75-minute session dedicated to the segmentation task, equivalent to a rate of $12.00 per hour. Incentives included $1 upon completion of both the segmentation and RT tasks (see below), and an additional $0.50 for achieving good performance criteria, defined as surpassing 75% accuracy in memory questions about movie clips, completion of all cognitive tasks, and scoring above 85% accuracy in the symmetry span task (as per Kane et al., 2004; Unsworth et al., 2005). A $3.00 compensation was provided for an additional questionnaire session taking approximately 10 minutes, with a bonus of 30 cents for completing the entire session. Informed consent was obtained in accordance with procedures approved by the Princeton University Institutional Review Board.

**Invitations and Eligibility Criteria:** We extended invitations to the initial session of the experiment to individuals who had successfully completed and passed quality control in a mental health symptoms questionnaires section of another lab study that was ongoing approximately at the same time. Quality control measures for the questionnaires included screening for no zigzag response patterns, avoidance of consistent straight-line responses, and making no more than two errors in attention check questions (Zorowitz et al., 2023). Attention check questions were designed to be straightforward and embedded within the questionnaires, mirroring the phrasing of the questionnaire questions but having an obvious and highly probable answer (e.g., endorsing "I avoid walking in front of a speeding car" with 'definitely agree'). Regarding the main segmentation task, exclusion criteria for the current experiment were (1) achieving below 75% accuracy in attention checks during the movie segmentation, and (2) having less fine segments compared to coarse segments, indicating poor compliance with the task (see below).
A total of 660 participants initiated the initial movie segmentation session. Among them, 10 did not complete the session, and an additional 3 repeated at least a portion of it due to technical issues. Out of the remaining 647 participants, 640 surpassed the 75% attention-check accuracy threshold, qualifying them for an invitation to the second segmentation session and an additional questionnaire session (data from this session was not analyzed here and will not be further discussed).

Invitations for the first session simply informed participants that they were invited based on their performance in a previous lab study, without specifying the study name. Invitations for the second session explicitly mentioned it was the second part of the same study, acknowledging the similarity in tasks between the two sessions and participants' general awareness that repeating the same experiment is discouraged. Five days after the first session, invitations were extended for the second session of the movie segmentation task, allowing completion within eight days after the initial session.

**Participant and Sample Size Characteristics:** We based our sample size on a power analysis using the effect size obtained in a similar online study, Experiment 2 from Gillan et al. (2016), which tested correlations between a cognitive task and mental health symptoms, and controlling for several nuisance covariates. The effect size for the coefficient of partial determination was $f^2 = 0.018$ (a “small” effect; Cohen, 1988; Lakens, 2013). For $p < .05$, testing schizotypy (see below) as a predictor of interest and including age and gender as additional covariates, implies 80% power at N=438 and 90% at N=586 (G*Power a-priori power analyses for an F-test, multiple regression: Fixed model, $R^2$ increase). This study was run in parallel to an additional study in the lab.
We aimed to reach a sample size that would give us at least 80% power. Of the 530 participants who initiated the second session after the first session (82% retention), 5 did not complete it, and an additional 1 participant did not meet the attention check threshold. An additional 22 participants (4%) were excluded for having fewer fine segments compared to coarse segments, indicating poor compliance with the task (see below). One additional participant did not complete the RT task both before and after the task in the second session and was excluded from the analysis. Among the remaining 501 participants, 17 participants were removed due to outlier segmentation behavior (> 3 SD of the mean). Another participant was removed for not providing demographic information due to a technical error; complete data for age and gender are necessary to ensure accurate analysis when controlling for these variables. In sum, a total of 483 participants were included in the main analysis (190 women, 9 non-binary, 284 men; ages 18-73, M = 37.9, SD = 13.1) that had all tasks and questionnaires data, passed all quality control thresholds, and had demographic data. This gives us 84% power to discover an effect of \( f^2 = 0.018 \).

**Materials.**

*Self-report instruments for assessing mental health symptoms in online participants:*

Participants completed a subset of the PID-5 (Krueger et al., 2012) questionnaire, a tool previously employed in studies investigating latent cause inference in the Niv lab. This questionnaire, which usually consists of 220 items, required participants to rate the extent to which they identified with each statement on a Likert scale, indicating the degree of agreement with the statements (Krueger et al., 2012). In the current study, this assessment was conducted on a reduced subset of items, and the data from subscales addressing schizotypal symptoms - unusual beliefs, perceptual dysregulation, and eccentricity - was used. This self-report
questionnaire was administered using the NivTurk software in JsPsych (Zorowitz & Bennett, 2022).

**Movie clips for movie segmentation:** During the task, participants viewed eight movie clips that were, on average, 144 seconds long, ranging from 90 to 179 seconds each, with a total duration of 1152 seconds. The audiovisual stimuli consisted of eight movie clips taken from a previous segmentation study (Baldassano et al., 2018) and from the internet. All eight movies showed scenes representing goal-directed events that follow a natural chronological order on a color screen with matching audio. These movies have already been piloted to achieve a range of prior knowledge regarding the typical unfolding of events in that context. For example, a date in a restaurant (high knowledge) vs. astronaut training (low knowledge). The 8 movies were: a fishing scene (A River Runs Through, 90 s), a supermarket scene (Home Alone, 146 s), a heist scene (Ocean’s Eight, 168 s), a scene including breaking of code (The Imitation Game, 121 s), a laundry scene (Friends, 179 s), a law lecture (How to Get Away from Murder, 178 s), a date in a restaurant (Derek, 157 s), and an astronaut training scene (First Man, 113 s). An additional two short clips were included for practice. They have different plots and narratives that vary in content. Five of the clips were cut from longer full-length movies (A River Runs Through It, Home Alone, Ocean’s Eight, The Imitation Game, First Man). Three of the clips were cut from episodes from television shows (Friends, How to Get Away with Murder, Derek). Each movie clip was preceded by a 5-second countdown (Baldassano et al., 2018) in which black numbers appeared at the center of the screen and decreased in numeral order.

**Experimental procedure.**

For each of the eight clips, participants were tasked with indicating the points where one meaningful unit concluded and another commenced by clicking the space bar. This task was
performed twice, with a 5-8 day interval (Sargent et al., 2013). Participants initially focused on the identification of larger meaningful units (coarse segmentation) and subsequently on smaller meaningful units (fine segmentation; Sargent et al., 2013). The sequencing and timing were determined based on a prior study examining segmentation in PTSD patients (Eisenberg et al., 2016).

Prior to engaging in the segmentation task, participants received instructions and had the opportunity to practice to ensure a clear understanding of the task. Participants were instructed to “press the space bar when, in your judgment, one meaningful and natural unit ends, and another begins. There are no right or wrong answers, we want to know how you do it” (Michelmann et al., 2021; Newtson, 1973; Sargent et al., 2013). Participants were informed that they could segment the movies based on either small or large events and were given practice in both types of segmentation. They were then directed, "Today, you will indicate the largest units that seem meaningful to you" (with the word 'largest' replaced by 'smallest' in the second session). To ensure the attentiveness and comprehension of online participants regarding the level of segmentation in each session, they were prompted to type whether they intended to segment based on the largest or smallest units in the current session. Task progression was contingent on providing the correct response. Subsequently, participants practiced the segmentation task once more, focusing on the granularity specified for that particular session. This final practice round also encompassed knowledge and emotion questions (see below). The segmentation tasks were coded using Inquisit 6.6.1 (2021; www.millisecond.com) and were run on participants’ desktops using Inquisit 6.

Figure 1: Procedure for Movie Event Segmentation Task
Figure 1: Procedure for Movie Event Segmentation Task in the Online Study. Participants were asked to watch the eight movie clips twice, with a 5-8 day interval between viewings. They were prompted to press the space bar when they perceived a transition between meaningful units, first for coarse segmentation (identifying larger meaningful units), and then again, in a separate viewing, for fine segmentation (identifying smaller meaningful units). Screenshots depict an example of potential key moments from one of the movies, 'Home Alone,' as part of the segmentation task. A. Coarse events in chronological order, e.g.: 1) getting ready for the day, 2) checking out at the supermarket, and 3) walking home from the supermarket. B. Fine events within the large event of checking out at the supermarket also in chronological sequence, e.g.,: 1) waiting in line at the register, 2) placing your items on the register, and 3) paying for your items. This is an illustrative example, in the task, participants were asked to segment events based on their own judgment.

Attention checks, Emotional Response, and Knowledge: Following each movie clip, participants responded to two straightforward questions related to the clip, serving as attention checks (refer to exclusion criteria above). Additionally, participants rated valence and arousal on a 9-point scale (Bradley & Lang, 2017) to assess their emotional responses to the movies, allowing for subsequent control in the analysis. Recognizing that knowledge can impact event segmentation (Hard et al., 2006; Zacks, 2020; Zacks et al., 2001), participants were also prompted to indicate their familiarity with the general situations presented in the clips (e.g., grocery shopping in a supermarket; not specifically “Home Alone”), how frequently they
encounter such situations, and the most recent occasion on which they experienced them. The knowledge and emotion ratings were used as control (see Analysis).

**Reaction Time Task Procedure:** In each session, both before and after the segmentation task, participants engaged in a short reaction-time task. In this task, they were presented with a black fixation cross in the center of the screen, changing to a black circle (Zalla et al., 2004). Their task was to press the spacebar as soon as possible once the circle changed from the fixation cross to the circle. Participants were asked to press the spacebar as quickly and as accurately as possible once they saw the circle. They were also instructed to use the same finger they planned to use throughout all the tasks, including the segmentation task, and not to switch hands or fingers throughout the rest of the study. This task served to measure and adjust for individual differences in response times, ensuring accurate segmentation results and correcting for baseline reaction-time differences across participants (see Analysis).

**Cognitive Tasks:** In addition to the tasks above, participants engaged in short, established, and well-validated cognitive assessments, including a vocabulary test (Hartshorne & Germine, 2015), an executive function task (Bilker et al., 2012), and a working memory task (Kane et al., 2004; Unsworth et al., 2005). These supplementary tasks were conducted after the second RT task and provided a comprehensive evaluation of participants' cognitive abilities in conjunction with the primary movie segmentation task. The cognitive tasks were coded using Inquisit 6.6.1 (2021; www.millisecond.com) and were run on participants’ desktops using Inquisit 6.

**Analysis**

We assessed five segmentation measures: the number of fine segments, the number of coarse segments, fine segmentation agreement, coarse segmentation agreement, and hierarchical
segmentation. These 5 measures were assessed for each participant and for every movie clip they viewed. We then input these data into a mixed-level linear model and derived an estimate for each participant while controlling for confounds (i.e. movie order and identity of the movies). Then, this data was input into a multiple regression model to correlate segmentation with schizotypy while controlling for age and gender. The number of segments reflects how many times participants identified a boundary, computed independently for both fine and coarse segmentation. Different processes are required to generate segmentation agreement and hierarchical segmentation. These are described below.

**Segmentation agreement.**

Segmentation agreement quantifies how closely a participant's segmentation aligns with the group’s segmentation profile (Eisenberg et al., 2016; Sargent et al., 2013; Zacks et al., 2001). Initially, to adjust for inter-participant variations in reaction times, segmentation times were modified for each participant by offsetting them based on the average reaction time obtained from the pre- and post-movie reaction time tasks (Zalla et al., 2004). Subsequently, each movie clip was subdivided into 1-second intervals, and the proportion of participants identifying each interval as a boundary was computed, generating the group segmentation profile. For every participant and each movie, agreement with the group segmentation profile was determined by correlating the participant’s time series for that movie (assigning a value of 1 to time bins identified as boundaries by the participant, and 0 to all other time bins) with the group segmentation profile of the respective movie. To correct for the number of segments, these agreement values were normalized by the minimum and maximum possible correlation, given the number of segments of each participant in each movie. The maximum possible correlation was computed by aligning the time bins the participant indicated as boundaries with the time
bins with the highest proportions in the group profile and computing a correlation. The minimal correlation was the inverse – aligning the participant’s boundaries with the lowest proportions. Afterward, the agreement score underwent normalization to a feasible range using the formula: 

$$r_{\text{adjusted}} = \frac{r_{\text{observed}} - r_{\text{min}}}{r_{\text{max}} - r_{\text{min}}}.$$ 

Agreement was calculated separately for fine and coarse segmentation. As these values are between 0 and 1, they were Fisher transformed (Eisenberg et al., 2016; Sargent et al., 2013; Zacks et al., 2001).

To achieve the segmentation profile of the non-schizotypy population we used values for PID-5 facets and domains that represent values 1.5 SDs above the mean for each of the schizotypy symptoms (Miller et al., 2022; unusual beliefs < 1.59; eccentricity < 1.96; perceptual dysregulation < 1.16). To make the norm independent of each participant’s agreement score, for the participants included in the non-schizotypy group, we calculated, for each participant, the norm without that participant, and compared the participant to that norm. To complement this analysis, we also verified that the results did not change when calculating the group profile using all participants. The non-schizotypy data included 391 participants, while the total data used to compute agreement, encompassing both non-schizotypy and schizotypy participants, consisted of 501 participants.

**Hierarchical segmentation.**

In a well-organized perceptual system, where events are segmented hierarchically, one would anticipate a certain degree of alignment between different levels of segmentation. This alignment reflects a systematic organization of perceptual information, where higher-level event boundaries contain lower-level segmentation cues. To test this, we measured the distance between coarse boundaries and their nearest fine boundary and compared it to the distance expected by chance for the number of fine and coarse boundaries a participant indicated (Hard et
Movies in which participants did not segment at least once for fine or coarse were excluded from the analysis, as hierarchical segmentation analysis requires segmented events. Of the 501 participants who completed both sessions, 14 (3%) participants who did not have data from at least 75% of the movie clips (i.e., less than 6 movie clips) were excluded from the analysis involving hierarchical segmentation, leaving participants with hierarchical segmentation data. First, segmentation times were adjusted as described earlier for segmentation agreement. Then, for each participant and movie clip, the average distance between each coarse boundary and its nearest fine boundaries was calculated. The actual distance was compared to the distance expected by chance, which was computed by averaging the distances between every two fine boundaries and dividing by the total number of fine boundaries (Zacks et al., 2001). To address right skewness, both the actual distance and the chance distance were log-transformed. The difference between these log-transformed distances was then taken as the measure of hierarchical segmentation (Kurby & Zacks, 2008). At the group level, we investigated the presence of hierarchical segmentation. We calculated the average hierarchical segmentation for each participant across all movies. Subsequently, we conducted a one-sample t-test to ascertain if this average differed significantly from zero, which represents the chance level.

**Preliminary analyses.**

**Segmentation measures:** Each of the five segmentation measures was included separately in a mixed-level model (implemented using the "lme4" package in R), with movies and movie order

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1 Previous research utilized a discrete measure, which bins the data into 1-second intervals, assessing the presence of both fine and coarse boundaries within each bin. However, it's acknowledged in prior studies that this binning process is arbitrary and can heavily influence the analysis. Consequently, we opted to exclusively incorporate the continuous measure previously employed, which does not encounter the same critique.
treated as fixed effects, alongside an intercept per participant and a slope per participant for movie order. Data points deviating by more than three standard deviations from the mean were excluded. As the number of fine and coarse segments are inherently non-negative and right-skewed, we addressed this non-normality by adding 1 to each count and applying a log transformation to them to mitigate the potential influence of movie order by reducing the magnitude of extreme values while accounting for individual differences in responsiveness to movie order. Consequently, the participant-specific intercepts were derived, representing each participant's segmentation score while controlling for movie order effects and individual movie variations. These intercepts for each measure were subsequently utilized in group-level analyses, as outlined below.

**Main analysis.**
We performed multiple linear regressions for each of the 5 segmentation measures. We incorporated an average of the schizotypy symptom scores from the PID-5 as predictors, along with age and gender, which were controlled for as confounding variables. A two-tailed t-test was performed on the coefficient estimate of the schizotypy score to test whether there is a significant association between schizotypy and segmentation. To correct for multiple comparisons for the 5 segmentation measures, we applied Bonferroni correction (i.e., the threshold for significance is p < .01). When the average schizotypy score yielded significant results, we conducted further analyses to investigate the specificity of the correlation with the three schizotypy symptoms. We did this by implementing an additional linear regression that included each of the sum scores from the schizotypy symptom subscales (unusual beliefs, perceptual dysregulation, and eccentricity). We also followed up with additional control analyses, explained below.

**Control analyses.**
1. To investigate segmentation measures in schizotypy while controlling for the influence of emotional responses and prior knowledge, participants rated their emotional responses to the movies (i.e. valence and arousal) on a 9-point scale (Bradley & Lang, 2017) for each movie clip. Participants were also asked how familiar they were with the situation presented in the movies, how often they experienced it, and when was the last time they did so to assess their knowledge and familiarity with the movie clips and the situations shown in the movies. We did not design the study to examine how emotional content and prior knowledge might influence segmentation in schizotypy, we used these ratings as controls. These ratings and their interaction (z-scored within participants) were added as fixed effects and slopes per participant to the linear regression model described in the preliminary analysis. That means that the intercept per participant in this control model reflects the segmentation measure for the average emotion rating, accounting for within-participant variance due to emotion. Then, the group-level analyses (a linear regression correlating average schizotypy with segmentation while controlling for age and gender, as above) were repeated with these intercepts.

2. To control for general cognitive function, the main multiple regressions above were repeated including participants' accuracy in each of the three cognitive tasks (see Methods) as covariates. Of note, although participants are required to keep their accuracy above 85% in the additional ‘processing’ task in the symmetry span (namely, the indication of symmetrical pattern or not; Kane et al., 2004; Unsworth et al., 2005), we did not omit participants that did not reach that score, to be conservative with exclusion, and following research showing that exclusion based on this score does not impact the
reliability of the working memory score from the main task (i.e., remembering the order and location of a sequence of squares on the screen; Đokić et al., 2018).

**Results**

At the group level, with 501 participants, segmentation agreement was comparable to previous studies (fine: $M = .55, SD = .11$; coarse: $M = .43, SD = .12$). Also consistent with prior studies, we obtained robust hierarchical segmentation, significantly different from zero which reflects chance-level segmentation ($M = .44, SD = .44; t_{(486)} = 21.98, p < .0001;$ Cohen’s $d = 1.00$).

**Schizotypy Correlates with Poor Event Segmentation**

In our primary analyses, coarse agreement, fine agreement, and hierarchical segmentation significantly correlated with schizotypy ($p’s < .025$; Table 1). Specifically, participants who reported higher scores of schizotypy symptoms differed more from the neurotypical group segmentation profile (Table 1; Figure 2) and also showed less hierarchical segmentation. This suggests a less structured organization of perception. Of these, only coarse segmentation agreement survived Bonferroni correction for 5 comparisons ($p < .01$). Thus, follow-up analyses were conducted only on coarse segmentation agreement. Coarse segmentation agreement also correlated with schizotypy when controlling for cognitive functions, the knowledge participants had about the situations in the clips, and emotional response to the movies and remained significant when calculating agreement with the entire group’s profile rather than just non-schizotypy (see Methods; $p’s < .006$). There was no significant relationship between schizotypy and the number of either coarse or fine segments ($p’s > .28$; Table 1).

We were further interested in which specific schizotypy symptoms — unusual beliefs, perceptual dysregulation, and eccentricity — correlate with coarse agreement. When testing
together in one regression the scores from these three schizotypy symptom subscales, only perceptual dysregulation showed a robust significant correlation with the coarse segmentation agreement (standardized $\beta = -0.130$, $t_{(476)} = 2.15$, $p = 0.032$; controlling for cognitive function, knowledge and emotion, as above, $p = 0.037$). Unusual beliefs did initially correlate with coarse segmentation agreement ($p < 0.039$), but not after controlling for cognitive function ($p < 0.129$). Eccentricity did not correlate with coarse segmentation agreement ($p < 0.175$).

Table 1: Main Analysis Statistical Results

<table>
<thead>
<tr>
<th>Segmentation</th>
<th>Standardized $\beta$</th>
<th>$t$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Fine Segments</td>
<td>-0.051700</td>
<td>1.063</td>
<td>0.288</td>
</tr>
<tr>
<td>Number of Coarse Segments</td>
<td>0.004640</td>
<td>0.095</td>
<td>0.925</td>
</tr>
<tr>
<td>Fine Agreement</td>
<td>-0.108448</td>
<td>2.259</td>
<td>0.02430 *</td>
</tr>
<tr>
<td>Coarse Agreement</td>
<td>-0.135481</td>
<td>2.808</td>
<td>0.00519 **</td>
</tr>
<tr>
<td>Hierarchical Agreement</td>
<td>-0.115357</td>
<td>2.331</td>
<td>0.0202 *</td>
</tr>
</tbody>
</table>

Table 1: Main Analysis Statistical Results showing the correlation between segmentation measures and schizotypy. The table presents standardized $\beta$, $t$, and $p$ values for each segmentation measure, including the number of fine segments, number of coarse segments, fine agreement, coarse agreement, and hierarchical agreement. Results demonstrate significant correlations between schizotypy and coarse agreement, fine agreement, and hierarchical segmentation, while controlling for age and gender as demographic factors. Note: $p < .01$ is considered significant after applying Bonferroni correction for multiple comparisons.
**Correlation between Coarse Agreement and Schizotypy**

Figure 2: Scatter plot depicting the relationship between Coarse Agreement (z-scored) on the y-axis and Schizotypy (z-scored) on the x-axis in the participant population. Gray points represent individual data points and the black line indicates the linear regression fit to the data, with error bars denoting the confidence interval. The correlation coefficient, calculated as -0.14, is provided in the plot. The analysis controlled for potential confounding variables including gender and age.

**Discussion**

Humans parse continuous streams of perceptual information and actions into distinct clusters or episodes when the situation changes, a process termed ‘event segmentation’ (Zacks et al., 2007). In this study, we show that individuals who reported higher levels of schizotypy symptoms exhibited poor segmentation. Specifically, they showed less typical segmentation, namely, decreased agreement with the group segmentation. This was most robust for coarse segmentation, potentially reflecting pronounced difficulties in organizing perceptual experiences into meaningful high-order events.

This study extends previous work in schizophrenia patients (Zalla et al., 2004) to a community (online) sample including individuals with schizotypy. In that previous study, schizophrenia patients identified coarse boundaries less accurately (Zalla et al., 2004). Our
results are consistent with Zalla et al.’s (2004) findings, showing an impairment in coarse boundary typicality. Zalla et al. (2004) measured typicality using the percentage of correct boundaries detected, where correct was defined based on the judgment of an independent group of raters indicating boundaries. Only boundaries on which the consensus among them was equal or superior to 80% were considered as prototypical. We measured segmentation agreement by correlating our boundary identifications with a group profile as was prevalent in other studies (e.g., Zacks et al., 2001) (see Methods). Nevertheless, our results converge with Zalla et al.’s (2004) results contributing to the robustness of the findings across the studies. Our findings also parallel Zalla et al.’s (2004) findings, showing no differences in the number of segments for coarse and fine boundaries or impairments in fine segmentation. Importantly, we extend previous results to the schizotypy spectrum by examining symptom strength continuously. Taken together, the results highlight the prevalence of segmentation impairments across the schizophrenia spectrum, extending beyond clinically diagnosed patients.

One conceptual framework for interpreting these findings and their relationship with hallucinations in schizophrenia could be understanding event segmentation in the context of our prior knowledge and beliefs (shortly ‘priors,’ in Bayesian theory), and the updating of these priors given evidence (Corlett et al., 2019; Kube & Rozenkrantz, 2021). Priors lead us to make predictions or hypotheses about the source of perceived sensory information. For example, in that framework, I ‘hypothesize’ that my dog is the collection of lines and brown colors reaching the early visual cortex of my brain. Then, this prediction is compared to incoming information (i.e., is it my dog, or maybe another dog?). If there is a mismatch between our prediction and perceptual input, this is a prediction error. This prediction error can, in turn, lead to updating of
our prior beliefs, so that the next time our predictions will be more accurate (Corlett et al., 2019; Kube & Rozenkrantz, 2021).

Event models can be conceptualized as priors because they provide structured representations and expectations of potential outcomes based on past data or knowledge (Franklin et al., 2020). Like priors, event models need to be updated when surprising experience is encountered, as well as replaced at boundaries, in which perceptual information is inconsistent with the event model (Zacks, 2007; 2020). However, if the priors are very strong, they might remain unchanged, despite contradictory sensory evidence, leading to inappropriate event models.

In schizophrenia and schizotypy, it has been suggested that strong priors that remain unchanged can cause hallucinations (Corlett et al., 2019). Indeed, empirical studies have shown that strong priors can induce hallucinations in both healthy individuals and those prone to hallucinations (Powers et al., 2017). Powers and colleagues (2017) trained four different groups of participants, each with varying levels of voice-hearing to associate a tone with visual stimuli. Using functional neuroimaging and computational modeling of perception modeling, they found that participants who typically heard voices (i.e., prone to hallucinations) held strong prior beliefs about voice existence which led them to not viewing the induced auditory hallucinations as contradictory evidence. Therefore, those prone to hallucinations did not update their models. This rigidity in updating priors may explain the challenges with event segmentation observed in schizophrenia spectrum disorders if event models are not updated appropriately. Conversely, impaired event segmentation can contribute to the formation and strengthening of overly strong priors. If individuals with schizotypy have difficulty segmenting and organizing observed perceptual information into meaningful events, they may rely more heavily on their existing
priors to make sense of their surroundings. This over-reliance on strong and inflexible priors could, in turn, further hinder their ability to update their event models in response to new sensory information, creating a feedback loop that reinforces their susceptibility to hallucinations and other psychotic symptoms.

Consistent with this suggestion, in our study, we found that symptoms of perceptual dysregulation specifically correlated with impaired coarse segmentation agreement (more than eccentricity and unusual beliefs). This dysregulation includes experiences like altered object perceptions, feelings of an unreal environment, and thoughts of being controlled by others, which correspond to hallucinations and confabulations. Therefore, impaired segmentation can either lead to or result from these false perceptions, disrupting normal sensory processing and perception of reality.

**Limitations.**

Everyday life situations oftentimes involve many sensory modalities that extend beyond visual and auditory information such as touch, smell, and motion that interact to create complex and cohesive experiences. Multisensory integration (MSI), the ability to blend information from different sensory modalities, is necessary to form a coherent and comprehensive perception of our environments (Talsma et al., 2010). Individuals with schizophrenia suffer from impairments in MSI, particularly in visual, auditory, and tactile modalities (de Jong et al., 2009; Gelder et al., 2003; Liu et al., 2020). Our study focused on the visual and auditory senses. While we see no reason that these impairments would not persist across all sensory modalities, this should be empirically tested. In future studies, researchers could employ virtual reality technology to explore the impact of MSI impairments on the segmentation of events including various sensory modalities.
Here, as in previous studies (Sargent et al., 2013; Zacks et al., 2001; Zalla et al, 2004), we used rich movie stimuli. While these movies aim to capture the complexity of everyday life events, their structured narratives may not capture life’s unpredictability and complexity, where outcomes are less predictable and open to varied interpretations. This is especially relevant for individuals with schizophrenia because previous research has found that they have a difficult time forming a conceptual framework to understand ambiguous stimuli (Haut et al., 1996). Our movie clips didn't directly test this aspect, suggesting that future work could explore more unpredictable and complex stimuli to better reflect the uncertainty of everyday life.

**Future Directions.**

Emotion has been shown to alter event segmentation (Clewett et al., 2020; McClay et al., 2023; Riegel et al., 2023). Individuals with schizophrenia exhibit abnormalities in emotion perception, experience, regulation, and expression (Kring, 1999). For example, they report fewer positive experiences and exhibit less outward emotion. Also, people with disorganized symptoms exhibit a bias towards attending and remembering more negative information (Phillips et al., 2005; Hall et al., 2007; Horan et al., 2006), and in interpreting events (Phillips et al., 2000). This suggests that emotion can influence how individuals with schizotypy segment complex events. Considering this possibility, we controlled for emotional response in our analysis, and the relationship between coarse segmentation agreement and schizotypy remained significant. However, we did not measure emotion as participants watched the movie clips (only collected a rating after each clip) because we did not want it to interfere with the segmentation task.

To assess emotional response continuously without interrupting segmentation, a future study could measure pupil dilation during movie watching, as a marker of arousal signals. Salient environmental changes, such as hearing an unexpected sound, can activate central arousal
systems that regulate ongoing attention and memory processes across the brain (Berridge & Waterhouse, 2003; Bouret & Sara, 2005; Sara, 2009). Furthermore, arousal signals mediate some of the same cognitive processes that are thought to be triggered by event boundaries, including cognitive control, prediction errors, and attention re-orienting (Rouhani et al., 2020; Sara, 2009; Zacks et al., 2011; Zacks et al., 2007). Emerging evidence also suggests that arousal responses are sensitive to the structure of temporally extended experiences (Bianco et al., 2020; Zhao et al., 2019). For instance, pupil dilation occurs when a highly organized and repeated sequence of auditory tones suddenly transitions to a randomized sequence of tones (Zhao et al., 2019).

Specifically for event segmentation, one study showed that indeed pupils dilate at event boundaries, and suggested that characteristics of pupillary reflect both the stability and changes in ongoing mental context representations (Clewett et al., 2020). Together, these findings suggest that arousal dysregulation, a proposed feature of schizophrenia (Williams et al., 2004), may contribute to the segmentation deficits observed in schizophrenia spectrum disorders.

**Conclusion**

Our study investigated the relationship between event segmentation and schizotypy. Individuals reporting higher schizotypal symptoms showed less typical segmentation, as measured by lower agreement with the group segmentation profile. Furthermore, our analysis revealed that perceptual dysregulation, a specific schizotypy symptom, significantly correlated with coarse segmentation agreement, highlighting its relevance in event perception abnormalities. Our study highlights deficits in event segmentation among individuals with schizotypy and emphasizes the importance of considering perceptual organization deficits in schizophrenia spectrum disorders. More broadly, our study identifies a relationship between event segmentation research and mental health. Future research could further specify this
relationship, understand its underlying mechanisms, and explore its significance to clinical interventions and outcomes.

I pledge my honor that this paper represents my work in accordance with University regulations.

/s/ Cara Suliman Khalifeh
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