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Momentary Assessment of Aberrant Salience, Anomalous Self-Experiences, and Psychotic-Like Experiences

Monet S. Meyer[1], Jonathan R. Cohn[2], Kentaro Hayashi[1], and David C. Cicero[2]

[1] Department of Psychology, University of Hawai'i at Mānoa

[2] Department of Psychology, University of North Texas

To improve understanding of emerging psychosis, researchers have identified potential precursory mechanisms that may momentarily precede psychotic-like experiences, including aberrant salience and anomalous self-experiences. Aberrant salience is the misattribution of significance to neutral stimuli and may be linked to atypical dopamine transmission. Anomalous self-experiences include changes in the experience of the self, which may alter top-down cognitive processes. The present study extends previous research on these phenomena by examining the momentary dynamics of aberrant salience, anomalous self-experiences, and psychotic-like experiences in daily life. Participants were 246 young adults who were prompted to complete 6 smartphone surveys daily for 7 days. Baseline measures of aberrant salience and anomalous self-experiences each predicted occurrence of the same phenomena in daily life, supporting the use of these measures to examine within-subject changes. Dynamic structural equation modeling was used to examine lagged effects. Both aberrant salience and anomalous self-experiences exhibited carryover effects across timepoints. Furthermore, aberrant salience and anomalous self-experiences were each associated with psychotic-like experiences at subsequent timepoints, above and beyond the carryover effects of psychotic-like experiences. These temporal relationships provide preliminary support consistent with social-cognitive models of psychosis and support further examination of the within-subject dynamics of aberrant salience and anomalous self-experiences at the momentary scale.

Keywords: schizotypy, aberrant salience, anomalous self-experiences, experience sampling methodology, emerging psychosis

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Psychosis-spectrum disorders are characterized by symptoms organized into positive (e.g., perceptual abnormalities and delusional thinking), negative (e.g., anhedonia and flat affect), and disorganized (e.g., disorganized speech and odd behavior) clusters. These symptoms exist on a continuum, ranging from highly distressing and impairing clinical symptoms to more subtle experiences associated with schizotypy or schizotypal personality disorder (van Os & Reininghaus, 2016). Schizotypy is a latent psychological organization that manifests as a variety of phenotypes including schizotypal personality traits, psychotic-like phenomenology, and cognitive deficits that reflect a genetic vulnerability for the development of schizophrenia (Barrantes-Vidal et al., 2015; Lenzenweger, 2006; Meehl, 1962; Rado, 1960). Thus, some people with schizotypy may exhibit symptoms consistent with diagnosable disorders such as schizophrenia and schizotypal personality disorder, whereas others in the general population may experience less severe subclinical psychotic-like experiences (van Os et al., 2009). Indeed, the majority of people with high levels of schizotypy do not go on to develop full-blown schizophrenia (Chapman et al., 1994). Recent research supports the idea that psychotic symptoms, schizotypy, and personality traits such as low extraversion share common underlying dimensions (Cicero et al., 2019), and new measures of schizotypy have eliminated cut-scores (Kwapil et al., 2020), supporting the notion that schizotypy is prevalent in the general population.

Psychotic-like experiences are unusual thoughts or perceptual experiences that may represent momentary manifestations of trait schizotypy. An estimated 5% to 10% of the general population experience reoccurring psychotic-like experiences (Lenzenweger & Korfine, 1992; van Os et al., 2009), and self-reported psychotic-like experiences in the general population are associated with increased risk for psychosis and related outcomes (van der Steen et al., 2019). Studying schizotypy and psychotic-like experiences in the general population removes confounds often associated with patient research, such as effects of antipsychotic medication, loss of insight, and functional impairment (Barrantes-Vidal et al., 2015; Lenzenweger, 2010; Meehl, 1962), and may capture unique facets of premorbid signs of psychosis, including mechanisms involved in the emergence of unusual thoughts and experiences.

Monet S. Meyer https://orcid.org/0000-0003-4523-9114

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Correspondence concerning this article should be addressed to David C. Cicero, Department of Psychology, University of North Texas, 1150 Union Circle #311280, Denton, TX 76203-5017, United States. Email: david.cicero@unt.edu

Social-cognitive models of psychosis have been proposed (Broyd et al., 2017; Freeman, 2007; Garety et al., 2001; Howes & Murray, 2014), in which psychotic-like experiences are thought to evolve from initial perceptions, derived from either external experiences or internal sensations (bottom-up processing) before they are molded to be consistent with prior knowledge (top-down processing; Freeman et al., 2004; Hohwy, 2004). Common to most of these models are two key components: (a) aberrant salience, the misassignment of significance to neutral stimuli, and (b) impaired self-processing, which may include fluctuations in self-concept or the occurrence of anomalous self-experiences. Both aberrant salience and anomalous self-experiences are associated with trait schizotypy (Cicero et al., 2010, 2017) and are conceptualized in the present article as precursory mechanisms to psychotic-like experiences (Figure A1).

Aberrant salience is the unusual or incorrect assignment of significance to otherwise innocuous stimuli and is thought to be associated with dysregulated dopamine transmission (Kapur, 2003). Dopamine is a neurotransmitter associated with the prediction of significant events—it is involved in the assignment of value to encountered stimuli, driving motivation and behaviors to seek reward (Berridge, 2007; Grace et al., 2007). Dopamine has long been implicated in the etiology of psychosis, and the aberrant salience hypothesis may provide a link between neurochemistry and phenomenology (Howes & Kapur, 2009). Aberrant salience may represent a complex cluster of processes across multiple levels of cognitive functioning (Chun et al., 2019) and can be experienced as sharpened senses, increased attention capture, difficulty screening out irrelevant details, or increased feelings of importance (Cicero et al., 2010).

Aberrant salience provides an explanation for the initial driver of a psychotic-like experience, but the interpretation of these unusually significant stimuli determines whether the experience results in a meaningful psychotic-like experience, hallucination, or delusion. Humans constantly seek meaning; we construct frameworks to describe relationships between stimuli, identify inconsistencies, and relate these frameworks to ourselves and our schemas (Heine et al., 2006). If strange experiences occur only rarely, they are unlikely to be accommodated into our belief system—they are rejected as anomalous and quickly forgotten. However, if these unusual experiences persist, an individual may seek external explanations about why they continue to occur (Kapur, 2003). The process by which an explanation is chosen, and how idiosyncratic that selection is, may be impacted by how a person draws information about themselves and the world around them. Thus, a second aspect of most social-cognitive models of psychosis is self-relevant information processing.

An altered awareness of one's presence and changes in the first-person view of the world may be some of the most fundamental early signs of psychosis (Brent et al., 2014; Møller & Husby, 2000; Nelson et al., 2009; Parnas & Handest, 2003; Schultze-Lutter & Theodoridou, 2017). Phenomenological studies of individuals with recent-onset psychosis describe weakened experiences of the self (e.g., "[I] almost didn't know who I was"; Møller & Husby, 2000, p. 228) combined with an increase in drive to scrutinize one's inner world (e.g., "I thought understanding myself better would help me with conflicts I felt compelled to resolve"; Bowers, 1968, p. 352), which is often followed by a period of elaboration (e.g., "He had to find the hidden meaning of things"; Boisen, 1947). Self-processing disturbances linked to psychotic-spectrum disorders can occur across levels of processing: changes in somatosensation (perception of the body based on internal sensations), anomalous self-experiences (changes in first-person experiences), and fluctuations in self-concept (instable self-identity; Klaunig et al., 2018). Previous research suggests that lowered self-concept interacts with aberrant salience to predict reports of psychotic-like experiences (Cicero et al., 2013, 2015), and recent studies have focused on the occurrence of anomalous self-experiences across the psychosis spectrum (Gawęda et al., 2019).

This research has provided theoretical insights into proposed social-cognitive mechanisms associated with psychosis-spectrum symptoms. However, most studies have collected cross-sectional data about lifetime experiences, so it is unclear how frequently or intensely these experiences occur in daily life. In addition, cross-sectional analyses preclude the possibility of examining momentary temporal relationships, which may be especially important for studying how psychotic-like experiences are formed. Intensive longitudinal methods such as experience sampling methodology (ESM) enable analysis of these temporal relationships by collecting data at numerous timepoints over a relatively short period. In the present study, growth is not expected to occur across the week; rather, the data are expected to reflect a sample of relatively stable processes during a typical week in the lives of our participants. Fluctuations are expected to occur within individuals across timepoints, but mean scores should remain stable from the beginning of the week to the end. Thus, the current study is more similar to a cross-sectional than a longitudinal study. ESM also has the added benefit of collecting data in the context of participants' daily lives and addresses recall bias by reducing the gap between experience and recall, particularly useful for recording fleeting thoughts and moods. ESM has been used widely in studies of psychopathology to elucidate the dynamics of symptoms and the internal mechanisms or external determinants driving them (Myin-Germeys et al., 2018).

Previous studies have used ESM to measure schizotypy in daily life, providing support for relationships between trait schizotypy and expressions of psychotic-like experiences, negative affect, and low desire for social contact in the daily lives of nonclinical undergraduate students (Barrantes-Vidal et al., 2013; Kwapil et al., 2012, 2020). Aberrant salience has also been examined in daily life. One study examined real-world correlates of aberrant salience in undergraduates and found that trait aberrant salience was associated with momentary psychotic-like experiences, disorganized symptoms, and suspiciousness (Chun et al., 2020). Another study used ESM to survey levels of aberrant salience, stress sensitivity, and psychotic-like experiences, and found a stronger association between aberrant salience and psychotic-like experiences in clinical high-risk individuals compared with individuals who had already experienced a first episode, indicating that aberrant salience could play a stronger role in unusual belief formation before psychotic symptoms are fully formed (Reininghaus et al., 2016). In a third study, individuals with psychosis in an inpatient setting completed ESM surveys. Time-lagged analyses revealed that aberrant salience and negative affect predicted paranoia at the next timepoint, but paranoia did not predict aberrant salience, providing support that aberrant salience may represent a causal mechanism (So et al., 2018). However, to our knowledge, no studies to date have examined the momentary expression of anomalous self-experiences nor a cross-lagged analysis of aberrant salience and psychotic-like experiences.

The present study aimed to examine the momentary expression of aberrant salience, anomalous self-experiences, and psychotic-like experiences in the daily lives of a nonclinical sample of undergraduates over a period of 7 days. The use of intensive longitudinal methods and dynamic structural equation modeling (DSEM) allowed us to address four primary goals. First, we investigated the relationship between trait baseline measures and the expression of these phenomena in daily life to examine ecological validity. We expected to find that trait schizotypy measured at baseline would be associated with an increase occurrence of psychotic-like experiences, aberrant salience, and anomalous self-experiences as measured with ESM. We also expected to find that trait aberrant salience and anomalous self-experiences at baseline would be associated with reports of aberrant salience and anomalous self-experiences as measured using ESM, respectively. Our second, third, and fourth aims involved surveying temporal patterns in the ESM-obtained measures to test hypotheses about the pathogenesis of psychotic-like experiences. One preliminary method for providing evidence consistent with causal relationships is to examine whether the proposed causal variables occur before the outcome variables, above and beyond autoregressive effects of the outcome variables. In our second aim, we expected that there would be an autoregressive structure to the data (i.e., consecutive measurements are more correlated than nonconsecutive measurements) for psychotic-like experiences, aberrant salience, and anomalous self-experiences, a common concept in emotion research that is also referred to as "inertia" or "carryover effects" (Hamaker et al., 2018). In Aims 3 and 4, we expected to find that aberrant salience (Aim 3) and anomalous self-experiences (Aim 4) would occur prior to psychotic-like experiences, above and beyond the carryover effects of each variable.

Method

Participants

Participants were 246 undergraduates attending a large public, Pacific university from September 2016 to December 2018. The mean age of the sample was 19.64 (*SD* = 4.04) and 64% of the sample identified as female. The sample reflected the demographics of the region: 18.3% identified as White, 30.5% as East Asian, 16.7% as Southeast Asian, 8.5% as Pacific Islander, 4.9% as Hispanic, 0.4% as Native American or Alaskan Native, 0.0% as Black, and 19.5% identified with more than one race.

Procedure

The present study was not preregistered, but we report how we determined our sample size, all exclusions, and we report all manipulations and measures in the study. The study was approved by the University of Hawaii Institutional Review Board (#2016–30069). Participants initially completed a baseline survey through Qualtrics in exchange for course credit. Participants were instructed not to consider experiences they had only under the influence of drugs or alcohol during the baseline survey. Upon completion of this initial 1-hr study, they had the option to register for the ESM portion for additional credit, and 246 of the 1,148 students elected to participate in the present study. Participants registered for a 15-min in-person orientation session to install the application (LifeData) on their personal smartphone and receive instructions about study completion from a trained research assistant. Participants were offered electronic tablets to use if they did not have access to or feel comfortable using a personal smartphone, but all participants declined this option.

Once enrolled, participants received notifications on their smartphones six times a day for 7 days, prompting them to fill out a survey composed of 26 questions about aberrant salience, anomalous self-experiences, psychotic-like experiences, mood, and substance use (Table S1 in the online supplemental materials). To maximize response rate, notifications were set to occur in random intervals between 10:00 and 22:00, with at least 30 min between each survey. In addition, ESM questions were randomized in blocks to reduce the effects of habituation to the questionnaires. Participants were encouraged to respond immediately, but they were allowed 1 hr to respond to the notification in case they were unable to use their phone at that moment. To guard against careless, invalid, or invariant responding, participants' data were retroactively removed from the study if they answered "true" or "false" to 44 or 45 of 45 questions on the baseline schizotypy scales or if they completed the entire baseline study in less than 15 min. This resulted in 106 participants being removed from the baseline study and 16 from the ESM portion of the study.

Material

Baseline Measures

Short Form of the Wisconsin Schizotypy Scale. The Wisconsin Schizotypy Scales were developed as a true–false measurement of domains of schizotypy: magical ideation, perceptual aberration, social anhedonia, and physical anhedonia. More recently, short forms each containing 15 items were created to ease administration and improve psychometric quality (Winterstein et al., 2011). Prior research has suggested adequate reliability and validity for use of the short forms in nonclinical student populations (Gross et al., 2015). Participants completed the Magical Ideation, Perceptual Aberration, and Social Anhedonia short scales through Qualtrics. Previous structural research with the Wisconsin Schizotypy Scales has consistently found that the Magical Ideation and Perceptual Aberration Scales load on a single factor (Cicero & Kerns, 2010; Gross et al., 2015; Wuthrich & Bates, 2006). Thus, following most schizotypy research, scores from the magical ideation and perceptual aberration subscales were summed to produce a positive schizotypy score for each participant. The current research showed good internal consistency for both magical ideation ($\alpha = .81$) and perceptual aberration ($\alpha = .88$) subscales.

Aberrant Salience Inventory. The Aberrant Salience Inventory (ASI) is a self-report questionnaire designed to measure lifetime occurrence of aberrant salience in nonclinical samples (Cicero et al., 2010). The full version includes 29 "yes/no" questions, loading onto a five-factor structure: increased significance, sharpened senses, impending understanding, heightened emotionality, and heightened cognition. Construct validity has been supported through significant associations with measures of positive schizotypy and Behavioral Activation System, but weak association with measures of negative schizotypy and Behavioral Inhibition System, as would be expected (Chun et al., 2020; Cicero et al., 2010). Participants completed the full version at baseline on Qualtrics. The ASI showed excellent internal consistency ($\alpha = .94$) in the current study.

Inventory of Psychotic-Like Anomalous Self-Experiences. The Inventory of Psychotic-Like Anomalous Self-Experiences (IPASE) was developed as a self-report measure of anomalous self-experiences (Cicero et al., 2017). The full version includes 57 questions, loading onto a five-factor structure: cognition, self-awareness and presence, consciousness, somatization, and demarcation/transitivism. Questions on the full version are answered using a 5-point Likert scale ranging from *strongly disagree* to *strongly agree*. Construct validity is supported through strong correlation with the examination for anomalous self-experiences, moderate correlations with psychosis symptom measures, and insignificant correlation with mania scales, a construct that is associated with psychosis but theoretically separate from anomalous self-experiences (Nelson et al., 2019). Participants completed the full version at baseline on Qualtrics. The IPASE showed excellent internal consistency (α = .98) in the current study. The correlations among and descriptive statistics of the baseline measures can be found in Table 1.

Experience Sampling Measures

The 26-item survey (Table S1 in the online supplemental materials) was created using items from the ASI and IPASE as well as items from previous ESM research for schizotypy (Barrantes-Vidal et al., 2013). To create short versions of the ASI and IPASE, one question from each factor was selected based on the highest factor loading, resulting in five items for each measure. All questions were converted to a 7-point Likert-like scale ranging from *not at all* to *very much* and answered using a slider in the smartphone application. Items from Barrantes-Vidal et al. (2013) were adapted to measure psychotic-like experiences, paranoia, and negative affect in daily life. Index scores for aberrant salience, anomalous self-experiences, and psychotic-like experiences were calculated by taking the mean of the relevant items at each timepoint.

Analyses

Multilevel Modeling

Data collected in ESM studies are multilevel, with experiences at each timepoint representing Level 1 data, which are nested within subjects representing Level 2 data. Multilevel modeling allows for examination of Level 2 variables (i.e., person-level variables) without inflating sample size while still maintaining the fine-grain detail of Level 1 variables (i.e., momentary variables). Two-level linear mixed modeling was used to examine relationships between baseline measures and ESM measures in Aim 1. All analyses were completed in Mplus Version 8.3 (Muthén & Muthén, 1998–2017).

Dynamic Structural Equation Modeling

DSEM represents a combination of multilevel modeling, time-series modeling, structural equation modeling, and time-varying effects modeling (Asparouhov et al., 2018). The decomposition of measured variables into both between-subjects (i.e., how each person's mean score deviates from the grand mean) and within-subject components (i.e., deviations of each person's score at time *t* from their idiographic mean) makes it ideal for intensive longitudinal data analysis and allows analysis of both within-subject and between-subjects patterns. Simulation studies with DSEM have suggested that sample sizes of 200 participants with 10 or more timepoints each results in adequate power, so we aimed for at least 200 participants from our convenience sample (Schultzberg & Muthén, 2018). In addition, previous research has suggested that the partial pooling that occurs in multilevel models resolves the need for correcting for multiple comparisons. Instead of needing to shift the confidence intervals, in multilevel modeling, the estimates are shifted toward each other via subject-mean centering (i.e., estimates that are more uncertain are pulled toward the mean; Gelman et al., 2012).

To improve interpretation, data were both centered and standardized. The DSEM module in Mplus uses latent subject-mean centering, in which an estimated mean is used instead of the observed mean to reduce biases, reduce the effect of measurement error, and improve interpretation. Mplus also standardizes the variables using within-subject standardization, which reflects the number of *subject-specific* standard deviations that the dependent variable increases when the independent variable increases by one *subject-specific* standard deviation. These values are then averaged across the sample to create a mean within-subject standardized score. As the present study aims are primarily focused on within-subject relationships between variables, this avoids conflating within-subject with between-subjects standardization and accounts for individual differences in both parameter and variance values (Hamaker et al., 2018).

ESM data are usually autocorrelated within subjects; each variable is correlated with itself at proximate timepoints. Our analyses included an autoregressive lag-1 model (AR[1]), which allowed examination of the relationship between the measured phenomena

Table 1
Correlations Among and Descriptive Statistics for the Baseline Measures

Baseline measures	B-Mag	B-per	B-PerMag	B-ASI	B-IPASE
B-Mag	*0.80*				
B-Per	0.69*	*0.88*			
PerMag	0.94*	0.90*	*0.90*		
B-ASI	0.60*	0.41*	0.57*	*0.92*	
B-IPASE	0.53*	0.59*	0.61*	0.50*	*0.98*
M	3.21	1.36	4.51	12.79	102.31
SD	3.26	2.65	5.38	8.16	44.06
Range	0.0−14.0	0.0−15.0	0.0−29.0	0.0−29.0	57.0−233.0

Note. B-Mag = Baseline Brief Magical Ideation Scale; B-Per = Baseline Brief Perceptual Aberration Scale; B-PerMag = Combined Baseline Brief Magical Ideation and Perceptual Aberration Scales; B-ASI = Baseline Aberrant Salience Inventory; B-IPASE = Baseline Inventory of Anomalous Self-Experiences. Italicized numbers on the diagonal represent Cronbach's α.
* $p < .01$.

(e.g., psychotic-like experiences) and itself at one notification prior. An autoregressive value of zero implies a quick recovery between timepoints, whereas an autoregressive value closer to one implies a stronger carryover effect from one notification to the next. These analyses were used to test the hypotheses in Aims 2 (autoregressive relationships) and 3 (cross-lagged relationships; Figure A2).

For computational purposes, the DSEM module in Mplus uses Bayesian estimation. Because of this, there are no null hypotheses tested with *p* values as in frequentist statistics. Rather, posterior medians are reported as estimates of parameters, and to determine if an estimate is null, 95% credible intervals for the parameter of interest are reported. Using default priors, if zero falls within the interval, the estimate is null. We used Mplus defaults of 50,000 maximum computed Markov Chain Monte Carlo (MCMC) iterations with two chains and a convergence criterion of .05. Models were run with increasing levels of complexity (i.e., inclusion of additional covariance parameters), and models with the lowest deviance information criteria were retained.

Due to the complexity of DSEM, traditional power analyses are not possible. However, simulation studies with multilevel modeling and DSEM have suggested that sample sizes of 200 participants with 10 or more timepoints each results in adequate power, so we aimed for at least 200 participants with 42 timepoints from our sample (Schultzberg & Muthén, 2018). For the zero-order correlations, a sensitivity analysis suggests we have .80 to detect effect sizes of $r = .18$ or higher.

Missing Data

Notifications were set to occur at random intervals to maximize response rate, resulting in the duration between notifications varying from 30 min to over 12 hr. To accurately examine lagged relationships, the data were fit to a time grid of 24 hr, with missing data estimated using a Kalman filter, in which each missing observation is estimated based on previous observations (McNeish & Hamaker, 2020). In DSEM, missing data is estimated using the MCMC algorithm via the Gibbs sampler. The MCMC algorithm organizes all parameters, latent variables, and missing data into blocks, which are updated in a particular sequence with values adjusted based on previous blocks and the whole data set (Asparouhov et al., 2018). Simulation studies have suggested that DSEM can produce acceptable results with up to 85% missing data (Asparouhov et al., 2018), so a grid of 24 allows us to maintain the fine-grain details of momentary assessment while accounting for both missed notifications and unequal spacing between notifications. For the occasional situation in which two notifications occurred within the same hour, the mean of both reports was taken to produce one score for that hour. Across participants, survey completion rate was adequate ($M = 69.3\%$, $SD = 20.9$).

Results

Descriptive Statistics and Correlations

Table 1 includes descriptive statistics and correlations among the baseline scores of Perceptual Aberration (B-Per), Magical Ideation (B-Mag), combined Perceptual Aberration/Magical Ideation Scales (B-PerMag), Aberrant Salience Inventory (B-ASI), and Inventory of Psychotic-Like Anomalous Self-Experiences (B-IPASE). Correlations show positive, significant relationships between each of the baseline measures. Of note, B-PerMag showed a moderate to strong association with both B-ASI ($r = .57$) and B-IPASE ($r = .61$), and B-ASI was moderately correlated with B-IPASE ($r = .50$), which supports the idea that aberrant salience and anomalous self-experiences are closely related manifestations of trait schizotypy. We also examined the between- and within-level correlations of the experience sampling obtained scores of psychotic-like experiences (ES-PLE), aberrant salience (ES-ASI), and anomalous self-experiences (ES-IPASE; Table S2 in the online supplemental materials). Between-level correlations among ES-PLE, ES-ASI, and ES-IPASE each showed moderate to strong associations, suggesting that individuals who score higher on average on one variable tended to also score high on other variables. The within-level correlations between ES-PLE, ES-ASI, and ES-IPASE showed weaker associations, indicating that fluctuations across time in one variable were only somewhat associated with fluctuations across time in other variables.

Aim 1: Associations Between Baseline and Experience Sampling Measures

The first aim was to examine the relationships between the baseline scores of B-PerMag, B-ASI, and B-IPASE with the experience sampling obtained scores of ES-PLE, ES-ASI, and ES-IPASE. We ran a total of nine models. First, ES-PLE was regressed on (a) B-PerMag, (b) B-ASI, and (c) B-IPASE. Second, ES-ASI was regressed on (d) B-PerMag, (e) B-ASI, and (f) B-IPASE. Finally, ES-IPASE was regressed on (g) B-PerMag, (h) B-ASI, and (i) B-IPASE. As can be seen in Table 2, all models found significant positive relationships, which is consistent with the variables all being correlated with each other, both at baseline and in experience sampling measurements. As hypothesized, B-PerMag scores predicted ES-PLE, B-ASI predicted ES-ASI, and B-IPASE predicted ES-IPASE.

Aims 2 to 4: Autoregressive and Cross-Lagged Analyses

We ran two separate models to examine Aims 2 to 4. First, we fit a model that included an autoregressive effect for aberrant salience, an autoregressive effect for psychotic-like experiences, and a cross-lagged relationship of aberrant salience and psychotic-like experiences in which aberrant salience at time *t*-1 predicted psychotic-like experiences at time *t* (Table 3). This model revealed a significant autoregressive relationship for aberrant salience at times *t* and *t*-1 across participants, indicating a nonnull carryover effect (i.e., aberrant salience experiences at each timepoint were correlated with aberrant salience experiences at the previous timepoint). Similarly, the autoregressive term for psychotic-like experiences was also significant. For the cross-lagged effect, aberrant salience at *t*-1 was significantly correlated with psychotic-like experiences at time *t*, above and beyond the autoregressive effects of both variables, suggesting that aberrant salience is uniquely associated with future psychotic-like experiences. Significant between-subjects variances and covariances indicated that autoregressive and cross-lagged relationships varied across participants, supporting evidence of individual differences in the presentation of aberrant salience and psychotic-like experiences, as well as in

Table 2
Experience Sampling Reports of Psychotic-Like Experiences, Aberrant Salience, and Anomalous Self-Experiences as a Standardized Function of Baseline Measures

	Baseline measures		
Experience sampling measures	PerMag	B-ASI	B-IPASE
ES-PLE	0.512 (0.049)**	0.268 (0.063)*	0.447 (0.056)**
ES-ASI	0.359 (0.059)**	0.323 (0.061)*	0.236 (0.068)**
ES-IPASE	0.532 (0.047)**	0.320 (0.061)*	0.511 (0.051)**

Note. ES = experience sampling; B = baseline; PLE = psychotic-like experiences; PerMag = perceptual aberration and magical ideation subscales of the Wisconsin Schizotypy Scales Short Form; IPASE = Inventory of Psychotic-Like Anomalous Self-Experiences; ASI = Aberrant Salience Inventory.
* Credible interval does not contain 0.

the amounts of unexplained variance (i.e., LogV ES-PLE, LogV ES-ASI, respectively).

We fit a second model that included an autoregressive effect for anomalous self-experiences, an autoregressive effect for psychotic-like experiences, and a cross-lagged relationship of anomalous self-experiences and psychotic-like experiences in which anomalous self-experiences at *t*-1 predicted psychotic-like experiences at *t* (Table 4). This model revealed autoregressive effects for both anomalous self-experiences and psychotic-like experiences, indicating nonnull carry-over effects from one timepoint to the next. Thus, in this model, reported anomalous self-experiences at one timepoint were significantly correlated with the previously reported anomalous self-

Table 3
Cross-Lagged Analysis of Experience-Sampling Reports: Psychotic-Like Experiences as a Function of Aberrant Salience

Intercepts						
					95% credible interval	
	Effect	Notation	Estimate	Posterior *SD*	LL	UL
	Int (ASI)[a]	α_{1i}	7.957**	0.258	7.454	8.460
	Int (PLE)[a]	α_{2i}	1.162**	0.084	1.043	1.349
	Ln (Var [ASI])[b]	w_0	0.841**	0.011	0.819	0.861
	Ln (Var [PLE])[b]	w_1	0.792**	0.030	0.751	0.858
Regression path intercepts[b]						
					95% credible interval	
Predictor at time *t*-1	Outcome at time *t*	Notation	Estimate	Posterior *SD*	LL	UL
ASI	ASI	φ_{1i}	0.289**	0.015	0.261	0.319
PLE	PLE	φ_{2i}	0.236**	0.038	0.149	0.285
ASI	PLE	φ_{3i}	0.041**	0.014	0.012	0.068
Between-subject residual variances[b]						
	Effect		Notation		Estimate	
	$Var(u_{0i})$		τ_{00}		2.264**	
	$Var(u_{1i})$		τ_{11}		6.050**	
	$Var(u_{2i})$		τ_{22}		1.034**	
	$Var(u_{3i})$		τ_{33}		0.719**	
	$Var(u_{4i})$		τ_{44}		0.141	
	$Var(u_{5i})$		τ_{55}		−1.357**	
	$Var(u_{6i})$		τ_{66}		0.362**	
	$Cov(u_{0i}, u_{1i})$		τ_{10}		0.911**	
	$Cov(u_{0i}, u_{2i})$		τ_{20}		0.083	
	$Cov(u_{1i}, u_{2i})$		τ_{21}		0.043	
	$Cov(u_{0i}, u_{3i})$		τ_{30}		0.705**	
	$Cov(u_{1i}, u_{3i})$		τ_{31}		0.793**	
	$Cov(u_{2i}, u_{3i})$		τ_{32}		−0.080	
	$Cov(u_{0i}, u_{4i})$		τ_{40}		−0.445**	
	$Cov(u_{1i}, u_{4i})$		τ_{41}		−0.320**	
	$Cov(u_{2i}, u_{4i})$		τ_{42}		0.297*	
	$Cov(u_{3i}, u_{4i})$		τ_{43}		−0.381**	

Note. PLE = psychotic-like experiences; ASI = aberrant salience inventory; CI = credible interval; LL = lower limit; UL = upper limit.
[a] Unstandardized. [b] Within-level standardized estimates averaged over clusters.
* 95% credible interval does not contain 0. ** 99% Credible interval does not contain zero.

Table 4
Cross-Lagged Analysis of Experience Sampling Reports: Psychotic-Like Experiences as a Function of Anomalous Self-Experiences

Intercepts						
					95% credible interval	
	Effect	Notation	Estimate	Posterior *SD*	LL	UL
	Int (IPASE)[a]	α_{1i}	5.016*	0.004	5.007	5.024
	Int (PLE)[a]	α_{2i}	1.028*	0.004	1.022	1.036
	Ln (Var [IPASE])[b]	w_0	0.761*	0.009	0.745	0.779
	Ln (Var [PLE])[b]	w_1	0.769*	0.008	0.752	0.786
Regression path intercepts[b]						
					95% credible interval	
Predictor at time *t*-1	Outcome at time *t*	Notation	Estimate	Posterior *SD*	LL	UL
IPASE	IPASE	φ_{1i}	0.357*	0.012	0.333	0.380
PLE	PLE	φ_{2i}	0.181*	0.016	0.149	0.209
IPASE	PLE	φ_{3i}	0.187*	0.012	0.165	0.210
Between-subject residual variances[b]						
Effect		Notation	Estimate			
$Var(u_{0i})$		τ_{00}	170.636*			
$Var(u_{1i})$		τ_{11}	33.973*			
$Var(u_{2i})$		τ_{22}	1.054*			
$Var(u_{3i})$		τ_{33}	0.695*			
$Var(u_{4i})$		τ_{44}	0.977*			
$Var(u_{5i})$		τ_{55}	−1.366*			
$Var(u_{6i})$		τ_{66}	−0.353*			

Note. PLE = psychotic-like experiences; IPASE = Inventory of Psychotic-Like Anomalous Self-Experiences; CI = credible interval; LL = lower limit; UL = upper limit.
[a] Unstandardized. [b] Within-level standardized estimates averaged over clusters.
* Credible interval does not contain 0.

experience. The same autoregressive pattern appeared for psychotic-like experiences as in Model 1. Finally, there was a significant cross-lagged relationship between anomalous self-experiences at *t*-1 and psychotic-like experiences at time *t*, above and beyond the effects of significant autoregressive relationships, suggesting that anomalous self-experiences are uniquely associated with future occurrences of psychotic-like experiences. Similar to Model 1, there was evidence of significant between-subjects variances, indicating that autoregressive and cross-lagged relationships varied across participants.

Discussion

The current study was the first to examine the momentary dynamics of aberrant salience, anomalous self-experiences, and psychotic-like experiences in the daily lives of young adults over a period of 7 days. Baseline measures of aberrant salience, anomalous self-experiences, and psychotic-like experiences were associated with ESM reports of these experiences over the course of a week, providing additional support for the ecological validity of these scales. ESM-reported aberrant salience, anomalous self-experiences, and psychotic-like experiences all showed significant autoregressive effects, indicating that measures of these phenomena are correlated with themselves at earlier timepoints. Finally, in two separate models, both anomalous self-experiences and aberrant salience predicted reports of psychotic-like experiences, over and above the effects of concurrent psychotic-like experiences, which may provide support for the theory that aberrant salience and anomalous self-experiences occur before psychotic-like experiences as suggested in social-cognitive models of psychosis.

The first aim examined the ecological validity of existing measures by testing if baseline scores are associated with daily life scores. Results reveal that baseline measures were associated with daily life scores in the predicted directions. This is important to examine because assessment efforts often only measure symptoms at one occasion but aim to reflect what is recent and recurrent for the respondent. Furthermore, psychotic-like experiences and related phenomena can be subtle and transitory, so baseline measures may not adequately capture their dynamic occurrence. This finding is consistent with previous studies on the expression of schizotypy (Kwapi et al., 2012, 2020) and aberrant salience (Chun et al., 2020) in daily life but expands to include anomalous self-experiences. Of note, the associations between positive schizotypy and expressions of anomalous self-experiences in daily life were slightly stronger than the association between positive schizotypy and psychotic-like experiences in daily life, and aberrant salience was associated with both aberrant salience and anomalous self-experiences in daily life. Although all three constructs are theorized to be expressions of positive schizotypy, these results potentially suggest low discriminant validity. Further research is warranted to examine the interplay of constructs associated with expressions of positive schizotypy.

Our results also provide supportive evidence for the use of IPASE and ASI scale scores in ESM research. The ability to obtain dynamic measurements in daily life can help expand on prior cross-sectional research on these phenomena. For example, much of the previous literature on anomalous self-experiences

uses the Examination of Anomalous Self-Experiences (EASE; Parnas et al., 2005), an unstructured phenomenological interview that requires extensive training and norming with the EASE developers. The EASE interview would not be practical in an ESM study, but the IPASE could be used in conjunction with the EASE to examine momentary changes in anomalous self-experiences in psychosis (Nelson et al., 2019). The ASI has consistently converged with measures of positive schizotypy and schizotypal personality (Chun et al., 2019; Cicero et al., 2010), but prior research has revealed mixed evidence for convergent validity between the ASI and other biological or behavioral measures of aberrant salience (Chun et al., 2019; Neumann & Linscott, 2018; Raballo et al., 2019). This may relate to the typically low reliability of behavioral measures, which are often designed to maximize within-subject variability in the context of experimental manipulation but may not be as suitable for examining between-subjects differences compared with self-report measures (Dang et al., 2020). Our finding that baseline ASI scores correlate with daily life scores indicates that self-report ASI may be a useful tool for examining both between-subjects and within-subject differences in salience. Both self-relevant information processing and salience processes are thought to occur across different domains and levels of cognitive processing (Chun et al., 2019; Klaunig et al., 2018), so it will be important to continue to study the trait-versus-state nature of these phenomena using both baseline measures and ESM.

The second aim examined the autoregressive or "inertia" relationships between each of the measured variables and themselves at different timepoints, finding significant autoregressive terms for each variable. These parameters are important to examine because they can reveal patterns of occurrence across time on a momentary scale and can contribute to the continuing debate about trait-versus-state attributes of psychopathology. Prior research has suggested that psychotic-like experiences may be discrete states that are moderated by relatively more stable traits such as schizotypy (Kwapil et al., 2012; Rössler et al., 2013), but a network model approach suggests that states and traits are not necessarily distinct and that symptoms may dynamically affect each other over time to form a causal network (van Os, 2013). With the latter theory, autoregressive relationships may play an important role in the progression of symptoms. Research in emotion regulation has considered a strong autoregressive relationship to be indicative of regulatory weakness, with a weaker autoregressive relationship indicating a quicker recovery from mood states (Hamaker et al., 2018). Stronger autoregressive relationships are associated with higher trait neuroticism (Suls et al., 1998). Given the potential relationship between schizotypy and neuroticism (Macare et al., 2012) and the role of negative affect or stress on psychotic-like experiences (Kline et al., 2012), further research would benefit from examining regulatory factors involved in moderating the autoregressive relationships of psychotic-like experiences.

Analyses for Aim 3 examined cross-lagged effects to observe if the hypothesized precursory mechanisms occurred before psychotic-like experiences, above and beyond the effects of concurrent psychotic-like experiences. The first model found that increased reports of aberrant salience at one timepoint were associated with increased reports of psychotic-like experiences at the next timepoint. These results are consistent with a previous ESM study that found a moment-to-moment unidimensional relationship between aberrant salience and paranoia (So et al., 2018); however, the present study did not examine bidirectional relationships. Similar results were found with the second model—increased anomalous self-experiences were associated with increased psychotic-like experiences at the next timepoint, above and beyond the effects of prior psychotic-like experiences.

Overall, the findings of this study offer a novel examination of aberrant salience, anomalous self-experiences, and psychotic-like experiences. Our results are consistent with prior theories related to social-cognitive models of psychosis (Broyd et al., 2017; Freeman, 2007; Garety et al., 2001; Howes & Murray, 2014) that suggest that aberrant salience and anomalous self-experiences are distinct phenomena from psychosis and may represent mechanistic precursors to psychotic-like experiences; however, the present study is correlational, and directional causality cannot be addressed directly. Future analyses could compare bidirectional standardized coefficients to provide additional information regarding directional effects (Schuurman et al., 2016). Future experimental research may continue to examine the potential causal relationships among these variables by manipulating aberrant salience and/or anomalous self-experiences to determine whether temporary increases in these variables cause an increase in psychotic-like experiences.

Identifying the dynamics of specific mechanisms of psychotic-like experiences may be particularly important in the context of early intervention efforts. Efforts to screen for psychosis in adolescent populations have struggled with low specificity (Kline & Schiffman, 2014), potentially due in part to the transdiagnostic nature of risk factors and the heterogeneity of symptom expression. Recent efforts to improve specificity have focused on the unique subjective changes in early psychosis (i.e., 'basic symptoms'), which include early changes in perception (e.g., aberrant salience) and the self (e.g., anomalous self-experiences; Schultze-Lutter & Theodoridou, 2017). However, studies examining the clinical utility of these early signs have shown mixed results (Hengartner et al., 2017). Although self-report measures such as the IPASE (Cicero et al., 2017) or the Self-Experience Lifetime Frequency scale (Heering et al., 2016) have shown an ability to differentiate between individuals with psychosis-spectrum symptoms and individuals without, it is unclear whether they have utility for tracking within-subject changes. The present findings provide preliminary evidence that the IPASE and ASI are suitable for examining within-subject fluctuations, autoregressive relationships, and cross-lagged relationships in a nonclinical sample. Future research should examine the clinical and predictive utility of tracking these phenomena over time and whether including aberrant salience or self-experiences in conjunction with traditional criteria improves assessment efforts.

The sample of participants in this study was composed of young adults enrolled in undergraduate psychology courses, which can be viewed as both a strength and a limitation. On one hand, psychotic symptoms frequently emerge during adolescence and young adulthood, so examining the occurrence of psychotic-like experiences in college students may have direct implications for risk screening efforts (Loewy et al., 2007; Mcgorry et al., 2008). In addition, measuring schizotypy in a community sample allows researchers to examine specific facets of psychotic-like experiences without the confounds of disability or antipsychotic medications (Barrantes-Vidal et al., 2015). However, because the sample is limited to individuals who are functioning well enough to attend university, it may exclude young adults experiencing higher levels of negative or disorganized schizotypy. Prior research has

suggested that negative symptoms may preclude positive symptom formation in at-risk individuals (Carrión et al., 2016), so future studies should examine these phenomena in a broader clinical or at-risk sample.

In addition, the present sample reported relatively low levels of positive schizotypy and psychotic-like experiences. Some previous schizotypy research has enhanced samples by screening for people with high baseline schizotypy scores, resulting in higher base rates for momentary PLEs. At the same time, the present sample was larger than many schizotypy ESM samples, which may in part compensate for the lack of participant enrichment. For example, previous research has enriched the samples by inviting participants scoring 1 *SD* above the mean or more on schizotypy scales to participate. If this metric was used in the present sample, approximately 39 participants would be over 1 *SD* above the mean. Future studies may benefit from using an enriched sample of people with higher scores on baseline measures of positive schizotypy. Although participants were removed for invariant or unrealistically fast responding, an additional limitation is that we did not include validity checks for reckless, random, or disorganized responding. The current research is also not able to determine whether the momentary reports of PLEs were caused by substance use or sleep disturbances.

An additional consideration involves the timescale chosen for this study. Participants were given approximately an hour to respond to each notification before expiration, which is longer than similar studies (Kwapil et al., 2020); however, the mean lapse between notification and completion was approximately 11 min. The hourly interval allowed us to examine dynamics across waking hours in a typical week for our participants. However, different conclusions may be drawn if measures were taken weekly, daily, or moment to moment (Hamaker et al., 2018). Given that psychotic-like experiences emerge over the course of adolescent development (potentially developing across years) and may be momentarily sensitive to environmental stressors (potentially developing across seconds or minutes), further studies could examine within-subject changes across varied intervals.

An important next step in this line of research is to identify *how* aberrant salience and anomalous self-experiences evolve to produce psychotic-like experiences. The role of regulatory and affective processes may play an important role in the formation of these experiences. A recent study used similar cross-lagged methods to identify moderators of the pathway from negative affect to delusion formation in individuals with psychosis. They found that increased awareness of emotions dampened the progression to paranoia, whereas increased rumination strengthened the pathway to paranoia (Ludwig et al., 2020). Similar strategies may be used to examine the progression from aberrant salience or anomalous self-experiences to a psychotic-like experience and to examine the role of negative affect or stress. Psychotic-like experiences have been observed to fluctuate in response to minor daily stressors, and one study found that these fluctuations were associated with abnormal dopamine activity (Myin-Germeys et al., 2005). Similarly, aberrant salience has been examined in conjunction with threat anticipation and stress sensitivity (Reininghaus et al., 2016), but the momentary dynamics have yet to be examined. Including relevant measures of distress and functioning with current measures may help clarify the momentary dynamics of psychotic-like experiences in a clinical context.

Lastly, it may be important to consider the role of individual differences in the formation of psychotic-like experiences. As mentioned previously, the current analyses primarily focus on the within-subject dynamics of the specified phenomena, but analyses showed significant between-subjects variance. Future studies may wish to utilize the unique features of DSEM that allow for examination of between-subjects differences in within-subject processes. In our analyses, between-subjects variances (i.e., random effects) were consistently significant, indicating the presence of individual differences in each of our variables and lagged relationships of interest. In the context of clinical intervention, idiographic assessment methods may be useful in monitoring the unique within-subject processes that confer risk for psychosis-spectrum syndromes to provide intervention that targets specific mechanisms at optimal times.

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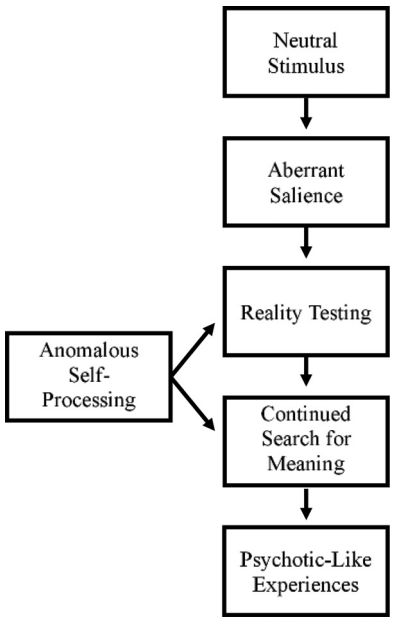
Appendix

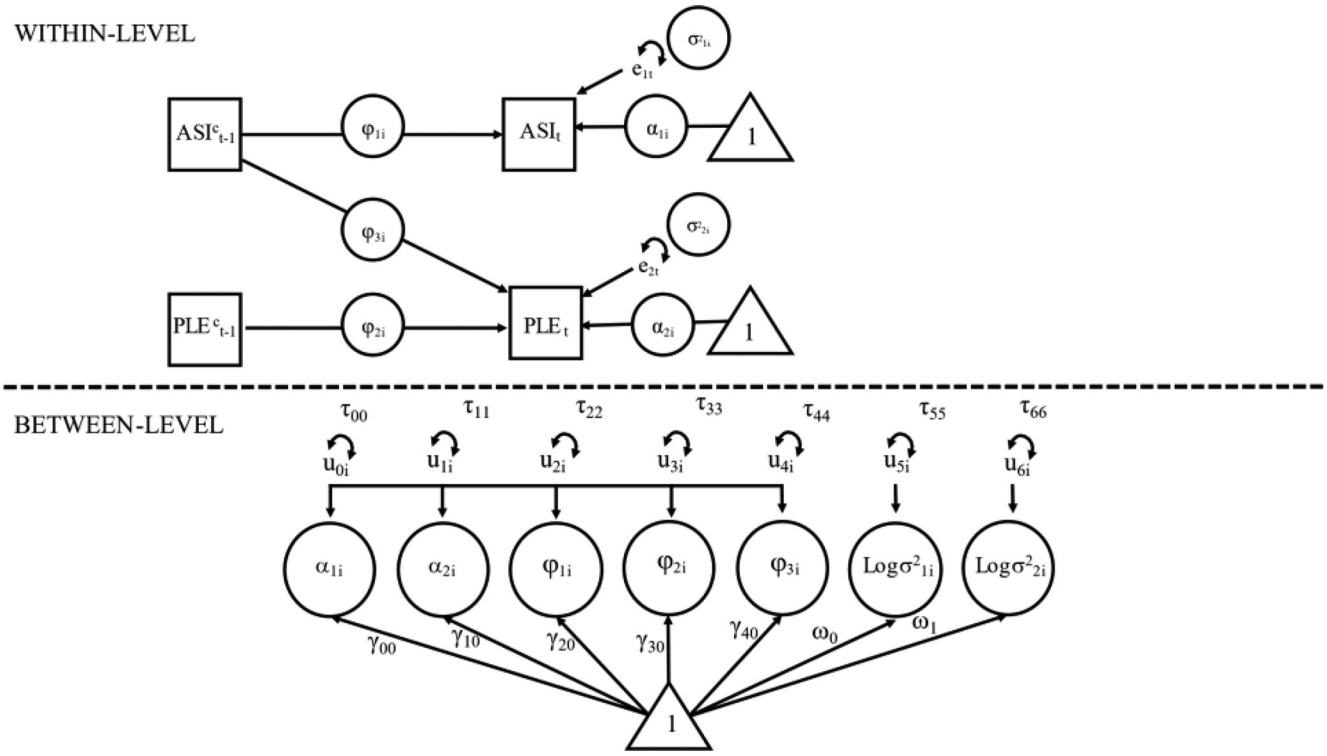
Figure A1
Social-Cognitive Model of Psychotic-Like Experience Formation



Note. As a person experiences a particularly salient sensation or perception, they attempt to relate it to prior information. If the initial experience is driven by aberrant salience (as opposed to appropriate motivational salience), it may be difficult to pinpoint its significance and meaning. For some, it may be easy to dismiss the occasional odd experience as insignificant, but for others, recurrent aberrant salience combined with anomalous self-processing may drive an increased search for meaning. Changes in the perception of the self may lead to the creation of idiosyncratic beliefs that are not based in one's sociocultural context (delusions) or perceptual experiences not occurring in the physical environment (hallucinations), both of which feel internally significant but are externally inconsistent.

Figure A2

Latent Decomposition in Dynamic Structural Equation Modeling: Aberrant Salience and Psychotic-Like Experiences.



Note. The top panel shows the within-person level model, in which latent variable Aberrant Salience Inventory (ASI) at time *t* is predicted from latent variable ASI at time *t*-1, and latent variable psychotic-like experiences (PLE) at time *t* is predicted from latent variable PLE at time *t*-1 and latent variable ASI at *t*-1. The bottom panel shows the between-person level model, which includes the between-person latent variables (mean of ASI and mean of PLE), as well as the random effects of three autoregressive parameters, and error variances and covariances in the within-person model. Note that our analyses for our second model follow a similar structure, but with anomalous self-experiences in place of aberrant salience, and no covariances due to better model fit.