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Liberal Acceptance Bias, Momentary Aberrant Salience, and Psychosis: An Experimental Experience Sampling Study

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Cognitive models of psychosis posit that reasoning biases are an important mechanism contributing to the formation of psychotic symptoms, in part through transforming anomalous experiences of aberrant salience into frank psychotic symptoms. This study aimed to investigate the interplay of liberal acceptance (LA) bias, which is a specific type of reasoning bias, and momentary aberrant salience in the development of paranoid and psychotic experiences in daily life in first-episode psychosis patients (FEP), at-risk mental state participants (ARMS), and controls. We used a novel experimental Experience Sampling Methodology (eESM) task for measuring LA bias (ie, decisions based on low probability estimates) and ESM measures of momentary aberrant salience and paranoid and psychotic experiences in 51 FEP, 46 ARMS, and 53 controls. We found evidence that LA bias was more likely to occur in FEP than in controls. Further, LA bias was associated with psychotic and paranoid experiences (all $P < .007$) and modified the association between momentary aberrant salience and psychotic experiences ($\chi^2(df) = 7.4(2)$, $P = .025$) in ARMS, such that momentary salience was associated with more intense psychotic experiences in the presence of LA bias in ARMS, but not in FEP and controls. Our findings suggest that LA bias may be central for anomalous experiences such as momentary aberrant salience to increase intensity of psychotic experiences in at-risk individuals. Further, LA bias appears to be more likely to be present, but not directly linked to current intensity of psychotic experiences, in treated FEP. Novel eESM tasks open new avenues for targeting psychological processes under real-world conditions.

Key words: reasoning bias/aberrant salience/experimental experience sampling methodology/prodrome/first-episode psychosis

Introduction

Schizophrenia and other psychoses are disorders with complex phenomenology and etiology. Individuals often present with multifaceted symptoms, which extend phenomenologically and temporally from subclinical psychotic experiences to psychotic disorder.[1,2] Recent factor analytic work suggests 1 transdiagnostic and 5 specific symptom dimensions of psychosis.[3–5] Arguably, this requires reducing heterogeneity by focusing on specific psychological mechanisms and psychotic symptoms[6,7] and targeting these at an early stage for achieving better outcomes of psychosis.[8–11] Cognitive models of psychosis suggest that reasoning biases are an important mechanism contributing to the formation of psychotic symptoms.[7,12,13] It has further been posited that reasoning biases distort the appraisal of disturbing anomalous experiences such as experiences of aberrant novelty and salience and, thereby, contribute to the transformation of these anomalous experiences into frank psychotic symptoms, most prominently paranoid delusions and hallucinations.[7,13]

Recently, a specific type of reasoning bias, ie, liberal acceptance (LA) bias (or, alternatively, a lowered decision threshold), has received more attention.[14–17] Although the most widely studied reasoning bias to date, ie, a tendency of jumping to conclusions, has been defined as a bias to use fewer data to reach a decision,[7,11,18–21] LA bias refers to a tendency of making premature decisions based on low subjective probability estimates.[14,16] One of the paradigms to investigate LA bias has built on a task inspired by the television show "Who Wants to Be a Millionaire" developed by Moritz et al.[16] This forced choice reasoning task requires individuals to provide probability estimates on 4 alternative response options to knowledge questions and, in a next step, asks whether or not they want to make a decision in favor of 1 of the 4 alternative responses. Reasoning bias in this task is indexed by premature decisions, defined as decisions for one of the alternative responses based on low probability estimates (ie, LA).[16] One advantage of this task may be that it is unlikely to be poor motivation that would account for premature decisions as it does not impact completion time.[16]

There is still only a limited amount of research to investigate LA bias in psychosis.[14] However, the evidence that there is suggests that LA bias is more likely to occur in patients with psychosis.[14] In our recent Experience Sampling Methodology (ESM) study,[9] we found that momentary aberrant salience was associated with psychotic experiences in daily life, and this association was greatest in individuals with an at-risk mental state for psychosis (ARMS).[2,9,22] However, whether or not, and if so how exactly, reasoning biases such as LA may interact with, and modify, experiences of aberrant salience to transform them into psychotic symptoms, remains to be elucidated.[7,23,24] Although affective disturbances are given an increasingly prominent role in cognitive models of psychosis,[7,23] mood does not seem to be directly linked to LA bias.[15] Also, the role of LA bias has yet to be examined in individuals with ARMS or first-episode psychosis (FEP), which would allow us to minimize the consequences of illness chronicity and elucidate the influence of LA bias across different stages of early psychosis.

Even though several studies have examined reasoning biases in psychosis, no study that we are aware of has investigated what role these biases play in individuals' daily life, outside the research laboratory. This may be particularly relevant given reasoning biases may potentially vary within individuals over time and across different contexts. Hence, the generalizability of findings from research conducted to date to real-world contexts remains limited. This is, however, key if we are to better understand which psychological mechanisms to target in individuals' real lives as a basis for achieving more sustainable change and improving outcomes under real-world conditions.[8]

We used a novel experimental Experience Sampling Methodology (eESM) design that would allow us to administer a forced choice reasoning task to assess presence of, and fluctuations in, LA bias over time under real-world conditions (using a modified version of the task developed by Moritz et al.[16]) and, thereby, advance on previous research by simultaneously optimizing both internal and external validity.[8] Our aim was to investigate the interplay of LA bias[16] and momentary aberrant salience in the development of paranoid and psychotic experiences in daily life using this eESM task for measuring presence of, and fluctuations in, LA bias in FEP, ARMS, and controls. To this end, we sought to test the following hypotheses:

1. LA bias in daily life is more likely to be present and fluctuate in FEP and ARMS than in controls.
2. (1) Within each group (FEP, ARMS, and controls), presence of, and fluctuations in, LA bias is associated with more intense (a) psychotic experiences and (b) paranoid experiences in daily life, and (2) these associations are greater in (a) FEP than in controls, (b) ARMS than controls, and (c) FEP than ARMS.
3. The association of experiences of momentary aberrant salience with more intense (1) psychotic experiences (as previously reported[8]) and (2) paranoid experiences is modified by presence of, and fluctuations in, LA bias in daily life, such that (1) within each group (FEP, ARMS, controls), these associations are greater in the presence vs absence of (and high vs low fluctuations in) LA bias, and (2) this difference in associations in the presence vs absence of (and high vs low fluctuations in) LA bias is greater still in (a) FEP than in controls, (b) ARMS than controls, and (c) ARMS than FEP.
4. Presence of, and fluctuations in, LA bias is not associated with affective disturbance in any one group.

Method

Sample

We recruited a sample of FEP, ARMS, and controls identified in the London center of European Network of National Networks studying Gene-Environment Interactions in Schizophrenia (EU-GEI)[25] and the Childhood Adversity and Psychosis study.

First-episode psychosis. Individuals with FEP were recruited from mental health services in defined catchment areas in South-East London, United Kingdom.[9] Inclusion criteria were resident in defined catchment areas; aged 18–64; presence of an FEP, based on the OPerational CRITeria system (OPCRIT);[3,26] and adequate command of the English language. Exclusion criteria were psychotic symptoms precipitated by an organic cause and transient psychotic symptoms resulting from acute intoxication. Participants in hospital at time of consent completed ESM assessments after discharge.

At-risk mental state for psychosis. Individuals with ARMS were recruited from South London and Maudsley NHS Foundation Trust, West London Mental Health NHS Trust, and a community survey of general practitioner (GP) practices.[9] Inclusion criteria were presence of an ARMS based on the Comprehensive Assessment of At-Risk Mental States (CAARMS)[2,9] or the schizophrenia proneness instrument, adult version[9,27–29] (see Supplementary Table 1); aged 18–35; and adequate command of the English language. Exclusion criteria were psychotic episode for more than 1 week as determined by the CAARMS and *Structured Clinical Interview for DSM Disorders* (SCID)[30]; previous treatment with an antipsychotic for a psychotic episode; and IQ < 60, measured with an adapted version of the Wechsler adult intelligence scale.[25,31]

Controls. Controls were recruited using the national postal address file and GP lists as sampling frames. Inclusion criteria were resident in the same areas as FEP, aged 18–64, and adequate command of the English language. Exclusion criteria for controls were the same as for FEP with the addition of the following: personal/family history of psychotic disorder[32]; presence of psychotic symptoms, assessed with the Psychosis Screening Questionnaire[33]; and presence of an ARMS (see earlier criteria).[9]

Data Collection

Basic Sample Characteristics. Data on sociodemographic characteristics were collected using a sociodemographic schedule.[25,34] *Diagnostic and Statistical Manual of Mental Disorders-IV* diagnoses of psychotic disorder were made based on structured examination of case records using OPCRIT[3,26] as part of the EU-GEI "Functional Enviromics" study.[25] The SCID was used in the ARMS sample to assess current comorbid affective disorders[30] as part of the EU-GEI High-Risk study.[25]

ESM Measures. Data on psychotic experiences, paranoia, momentary aberrant salience, and negative affect were collected using a time-based ESM design with 10 assessments scheduled at random within set blocks of time over 6 consecutive days.[9] All participants were given an electronic device (PsyMate®). A detailed description of the ESM procedure and measures[9,16,35–43] is shown in table 1.

eESM Task: LA Bias. We used a novel eESM task for measuring presence of, and fluctuations in, LA bias in individuals' daily life based on a modified version of the task developed by Moritz et al.[16] The eESM task is described in detail in table 1. LA bias was defined as a bias toward making premature decisions and, more specifically, as making any decision and, in its more marked form, an incorrect decision based on a deviation in participants' likelihood estimations of a given response being correct from the "rational" estimate (or, in other words, a lowered decision threshold), consistent with event probability estimation tasks.[36] The task was scheduled at the end of the ESM assessment of other ESM measures using the same time-based design with assessments scheduled at random within set blocks of time.

Statistical Analysis

ESM data have a multilevel structure with multiple observations (level-1) nested within participants (level-2). We used the "melogit" and "mixed" commands in Stata 14[44] to estimate mixed effects models for binary and continuous outcomes with random slopes, respectively, while controlling for potential confounders (ie, age, gender, and level of education). These models were estimated using restricted maximum likelihood estimation, which provides unbiased estimates using all available data under the assumption that data is missing at random and if all variables associated with missing values are included in the model.[9,45,46] First, in order to investigate whether LA bias in daily life is more likely to be present in FEP and ARMS than in controls (hypothesis 1), we fitted models with group as the independent variable and presence (vs absence) of LA bias as the binary outcome variable. We next fitted separate mixed effects models with (1) psychotic experiences and (2) paranoid experiences as continuous outcome variables and presence of LA bias as binary independent variable, and added 2-way LA bias × group interactions to test hypothesis 2. We further estimated models with momentary aberrant salience as independent variable and psychotic experiences as continuous outcome variable and added 2-way (aberrant salience × LA bias, aberrant salience × group, LA bias × group) and 3-way (aberrant salience × LA bias × group) interactions to test hypothesis 3. Finally, we fitted mixed effects models with negative affect as continuous outcome variable and presence of LA bias as binary independent variable to test hypothesis 4.

Results

Basic Sample Characteristics

We assessed a total of 165 participants (59 FEP, 51 ARMS, and 55 controls) with the ESM during the study period. ESM assessment (with ≥20 valid responses) was completed by 150 participants (51 FEP, 46 ARMS, and 53 controls) (table 2). Psychotic experiences, paranoid experiences, experiences of momentary aberrant salience, and affective disturbances were more common in FEP and ARMS than in controls (Supplementary Table 2).

LA Bias in FEP, ARMS, and Controls

Table 3 shows findings on LA bias as measured with the eESM task in FEP, ARMS, and controls. We found evidence that LA bias, characterized by making decisions based on probability estimates that deviate below rational

Table 1. Experience Sampling Methodology (ESM) Procedure[a], experimental Experience Sampling Methodology (eESM) Task for Measuring Liberal Acceptance Bias, and ESM Measures of Momentary Aberrant Salience, Negative Affect, and Psychotic and Paranoid Experiences

Domain	eESM task
Liberal acceptance (LA) bias	We used an eESM task for measuring LA bias, asking individuals to provide probability estimates on four alternative response options to one knowledge question each time when an ESM assessment was scheduled. The probability estimates ranged from 0% to 100% and were grouped and presented as categorical variable (0%, 1%–9%, 10%–19%, 20%–29%, … , 90%–99%, 100%) to reduce complexity and the potential impact of poor task comprehension. In a next step, participants were asked whether or not they want to make a decision and select one of the four alternative responses. The questions were designed to be similar to those asked in the television show "Who Wants to Be a Millionaire," but selected based on their property that the likelihood for a response option being correct would seem equal across all four options (eg, question: "What would be the colour of Coca-Cola without colouring?"; response options: "A: orange, B: green, C: brown, D: colourless"). Hence, in line with the rational estimate of 50% for first estimations in the beads task (with no evidence on which to base estimations),[36] the rational estimate would be 25% for any set of 4 response options in this eESM LA task (ie, an estimate of <20%–29% on the simplified, categorical variable)
LA bias (any decision)	*Presence of liberal acceptance bias* was *defined as (1) any decisions made based on estimates* of the *likelihood of a selected response being correct below 20%–29% and thus deviating below the rational estimate* (in the absence of evidence on which to base estimations), whereas absence of LA bias was defined as decisions made based on likelihood estimates equal to or above 20%–29% (on the simplified, categorical variable) or not wanting to make a decision
LA bias (incorrect decision)	Consistent with Moritz et al.,[16] *incorrect decisions based on low probability estimates* were also *considered to be indexing presence of* (more marked) *liberal acceptance bias*, defined as *(2) making an incorrect decision based on estimates* of the *likelihood of a selected response being correct below the rational estimate* (ie, an estimate <20%–29% on the categorical probability estimate variable)
Fluctuations in LA bias (variability, instability)	In line with previous experience sampling research,[38] *fluctuations in liberal acceptance bias* were operationalized as *variability* (ie, differences between LA bias in the moment and the average LA bias within individuals over the 6-day assessment period, calculated as the squared difference between LA bias at each timepoint and mean LA bias within subjects over time) and *instability* (ie, differences in LA bias from one moment to the next, calculated as the squared difference between LA bias at timepoint t and LA bias at timepoint t-1 within subjects and days)
	ESM measures
Experiences of aberrant novelty and salience	A modified version of the 3-item ESM measure of momentary aberrant salience by So[42] was employed, asking participants to rate the following items on a 7-point Likert scale (ranging from 1 [not at all] to 7 [very much]): "Everything grabs my attention right now," "Everything seems to have meaning right now," and "I notice things that I haven't noticed before"[42]
Negative affect	We used a 5-item ESM measure for assessing negative affect. This measure asks participants to rate the following items at each entry point on a 7-point Likert scale: "I feel anxious," "I feel down," "I feel lonely," "I feel insecure," and "I feel annoyed" (Cronbach's $\alpha = 0.86$)[39]
Psychotic experiences	The ESM psychosis measure was used to assess intensity of psychotic experiences. It consists of 8 items (ie, "I feel paranoid," "I feel unreal," "I hear things that aren't really there," "I see things that aren't really there," "I can't get these thoughts out of my head," "My thoughts are influenced by others," "It's hard to express my thoughts in words," "I feel like I am losing control") rated on a 7-point Likert scale (Cronbach's $\alpha = 0.90$).[38,39,43] We observed good concurrent validity of ESM measures of negative affect and psychotic experiences ($r = .68$, $P < .001$)
Paranoid experiences	The item "I feel paranoid" of the ESM psychosis measure was used to assess paranoid experiences. There was good concurrent validity for this measure of paranoid experiences with ESM measures of psychotic experiences (score calculated excluding the item "I feel paranoid"; $r = .78$, $P < .001$), negative affect ($r = .67$, $P < .001$) and threat anticipation ($r = .54$, $P < .001$)

[a]ESM procedure: On each day over an assessment period of 6 consecutive days, the PsyMate® emitted ten "beep" signals at random moments within set blocks of time. The length of time for each of these blocks was 90 minutes within which a random signal was emitted. During an initial briefing session, participants were asked to stop their activity and answer questions about thoughts, feelings, behaviors, social situations, and neighborhood surroundings each time the device emitted the beep signal. The ESM questionnaire was available to participants for the duration of 10 minutes after emission of the beep signal. Participants were not paid per completed response but contacted at least once during the assessment period to assess their adherence to instructions, identify any potential distress associated with the method, and maximize the number of observations per participant. At the end of the assessment period, participants' reactivity to, and compliance with, the method was examined in a debriefing session. Participants were required to provide valid responses to at least one-third of the emitted beeps, which is a very widely established criterion on the bare minimum of ESM completion for participants to be included in the analysis recommended in methodological guidelines on Experience Sampling Methodology[41] and used in numerous experience sampling studies to date.[35,37–40] Earlier ESM studies in samples of patients with psychotic disorder,[37–40] ARMS,[40] and controls[37–40] have demonstrated the feasibility, reliability, and validity of the assessment method.[35,37–41]

estimates, was 2 times more likely to be present in FEP than in controls (adjusted odds ratio [aOR] 2.11, $P = .043$), while controlling for age and gender. This finding broadly held, at trend level ($P = .066$), with some attenuation in magnitude (aOR 1.98), when additionally adjusting for educational level. LA bias was no more likely to occur in ARMS than in controls (OR 1.63, $P = .186$).

When we examined LA bias characterized by making *incorrect* decisions based on probability estimates that deviate below rational estimates, LA bias so defined was more than 3 times more likely to be present in FEP than in controls, while controlling for age, gender, and educational level (table 3). Further, compared with controls, LA bias (based on *incorrect* decisions) was more than 2 times more likely to be present in ARMS after adjustment for age and gender (aOR 2.51, $P = .039$), but was attenuated in magnitude (aOR 2.04) and no longer statistically significant ($P = .112$) after controlling for educational level. Overall, a very similar pattern was evident for findings on fluctuations in LA bias in FEP, ARMS, and controls over time (Supplementary Tables 3–5).

Association of LA Bias With Psychotic and Paranoid Experiences

Findings on the association between LA bias on the one hand, and psychotic and paranoid experiences on

Table 2. Basic Sample Characteristics ($n = 150$)[e]

	FEP ($n = 51$)	ARMS ($n = 46$)	Controls ($n = 53$)	Test statistic	*P*
Age (years), mean (SD)	28.3 (8.6)	23.6 (4.7)	35.0 (12.6)	F (2,147) = 18.6	<.001
Gender, *n* (%)					
Men	28 (54.9)	21 (45.7)	25 (47.2)	$\chi^2 = 1.0$, $df = 2$	.612
Women	23 (45.1)	25 (54.4)	28 (52.8)		
Level of education, *n* (%)					
School	17 (33.3)	13 (28.9)	8 (15.1)	$\chi^2 = 24.3$, $df = 4$	<.001
Further	25 (49.0)	24 (53.3)	15 (28.3)		
Higher	9 (17.7)	8 (17.8)	30 (56.6)		
OPCRIT psychotic disorder diagnosis[a,b], *n* (%)					
Schizophrenia	15 (31.3)	—	—	—	—
Delusional disorder	3 (6.3)	—	—		
Schizoaffective disorder	3 (6.3)	—	—		
Manic psychosis	7 (14.6)	—	—		
Depressive psychosis	7 (14.6)	—	—		
Psychotic disorder not otherwise specified	13 (27.1)	—	—		
SCID comorbid affective disorder diagnosis[d], *n* (%)					
Mood disorder	—	5 (10.9)	—		
Anxiety disorder	—	15 (32.6)	—	—	—
Mood and anxiety disorder	—	3 (6.5)	—		
Psychotropic medication[c], *n* (%)					
Antipsychotic	40 (81.6)	5 (11.9)	0 (0.0)	—	—
Atypical	36 (76.6)	5 (11.9)	0 (0.0)		
Typical	1 (2.1)	0 (0.0)	0 (0.0)		
Atypical and typical	1 (2.1)	0 (0.0)	0 (0.0)		
Antidepressant	11 (22.9)	17 (40.5)	0 (0.0)		
Other	12 (25.0)	4 (9.5)	9 (17.0)		
None	4 (8.2)	22 (52.4)	44 (83.0)		

Note: FEP, first-episode psychosis; ARMS, at-risk mental state for psychosis; SD, standard deviation; *df*, degrees of freedom; OPCRIT, Operational Criteria system; SCID, Structured Clinical Interview for DSM Disorders.
[a]Missing values = 3.
[b]OPCRIT diagnoses not assessed in ARMS from EU-GEI High-Risk study.
[c]Missing values = 6.
[d]SCID diagnoses not assessed in FEP and controls in the EU-GEI Functional Enviromics study.
[e]Participants included/excluded (of $n = 165$ assessed) and reasons for exclusion:

	FEP	ARMS	Controls	Test statistic	*P*
Included ($n = 150$)	51 (86.4)	46 (90.2)	53 (96.4)	$\chi^2 = 3.4$, $df = 2$	.179
Excluded ($n = 15$)	8 (13.6)	5 (9.8)	2 (3.6)		
Reasons for exclusion ($n = 15$)					
Stopped ESM assessment	1	1	2		
Did not return PsyMate	0	1	0		
Technical problems	1	0	0		
≥20 valid responses	6	3	0		

Table 3. LA Bias in FEP, ARMS, and controls

	Unadj. OR	95% CI	*P*	Adj. OR[a]	95% CI	*P*	Adj. OR[b]	95% CI	*P*
Presence of LA bias (any decision)[c]									
FEP[e]	2.17	(1.07 to 4.40)	.032	2.11	(1.02 to 4.38)	.043	1.98	(0.96 to 4.10)	.066
ARMS[f]	1.63	(0.79 to 3.40)	.186	1.52	(0.68 to 3.42)	.312	1.29	(0.57 to 2.92)	.546
Controls	1.00			1.00			1.00		
Presence of LA bias (incorrect decisions)[d]									
FEP[e]	3.44	(1.62 to 7.31)	.001	3.48	(1.60 to 7.57)	.002	3.13	(1.45 to 6.78)	.004
ARMS[f]	2.56	(1.17 to 5.59)	.019	2.51	(1.05 to 6.00)	.039	2.04	(0.85 to 4.92)	.112
Controls	1.00			1.00			1.00		

Note: FEP, first-episode psychosis; ARMS, at-risk mental state for psychosis; LA, liberal acceptance; OR, odds ratio; CI, confidence interval.
[a]Adjusted for age and gender.
[b]Adjusted for age, gender, and level of education.
[c]Presence of LA bias: making decisions based on probability estimates that deviate below rational estimates (<20%–29%); reference category: absence of LA bias defined as making decisions based on high probability estimates (≥20%–29%) or not wanting to make a decision.
[d]Presence of LA bias: making incorrect decisions based on probability estimates that deviate below rational estimates (<20%–29%); reference category: absence of LA bias defined as making incorrect or correct decisions based on high probability estimate (≥20%–29%) or not wanting to make a decision.
[e]Missing values, $n = 1$.
[f]Missing values, $n = 2$.

the other, in FEP, ARMS, and controls are displayed in table 4. There was strong evidence that LA bias (based on any decision) was associated with more intense psychotic experiences (adjusted β [aβ] = .27, $P = .005$) in ARMS. This association fell short of statistical significance in both FEP and controls. We found only some evidence that this association was greater in ARMS than in controls (aβ = .24, $P = .082$) and lower in FEP than in ARMS (adj. β = −.22, $P = .081$).

Strong evidence was observed in ARMS, but not in FEP and controls, that LA bias (based on any decision) was associated with more intense paranoid experiences (aβ = .39, $P = .009$; table 4). This association tended to be greater in ARMS than in controls (aβ = .48, $P = .026$; Wald test, $P = .080$). Again, a very similar pattern of findings was observed for the association of fluctuations in LA bias with psychotic and paranoid experiences (Supplementary Table 4).

We found no evidence that LA bias, characterized by making *incorrect* decisions based on probability estimates that deviate below rational estimates, was associated with psychotic or paranoid experiences in any one group (table 4).

Association of Momentary Aberrant Salience With Psychotic and Paranoid Experiences by LA Bias and Group

When we examined whether the previously reported association between momentary aberrant salience and psychotic experiences was modified by presence of LA bias (based on any decision) in FEP, ARMS, and controls (table 5), there was strong evidence that this association was greater in the presence vs absence of LA bias (aβ = .13, $P = .008$) in ARMS, but no evidence that this association was modified by LA bias in FEP and controls (Wald test, $P = .025$). The difference in the magnitude of associations of momentary aberrant salience with psychotic experiences in the presence vs absence of LA bias was significantly greater in ARMS than in controls (aβ = .16, $P = .034$) and in ARMS than in FEP (aβ = .17, $P = .017$). There was no evidence that the association between aberrant salience and paranoid experiences was modified by LA bias and group. The pattern of findings on associations of aberrant salience with psychotic and paranoid experiences by fluctuations in LA bias and group was very similar (Supplementary Table 5).

Association of LA Bias With Affective Disturbance

As can be seen in table 4, we found no evidence that LA bias was associated with more intense negative affect in any one group and that these associations varied across FEP, ARMS, and controls.

Discussion

Principal Findings

This study advances on previous research by using, for the first time, an eESM design to investigate LA as a specific type of reasoning bias in the daily lives of people with FEP and ARMS in comparison with controls. Our findings lent support to our first hypothesis that LA bias in daily life was more likely to occur (and fluctuate) in

Table 4. Association of LA Bias[a,b] With Psychotic Experiences, Paranoid Experiences, and Negative Affect in Daily Life by Group (FEP, ARMS, controls)[c]

	FEP[d]		ARMS[e]		Controls		LR test[d,e]	
	Adj. β (95% CI)	*P*	Adj. β (95% CI)	*P*	Adj. β (95% CI)	*P*	χ^2 (*df*)	*P*
				Outcome: psychotic experiences				
LA bias (any decision)[a] × group[f,g]								
Presence vs absence of LA bias[a]	.05 (−0.11 to 0.21)	.540	.27 (0.08 to 0.46)	.005	.03 (−0.16 to 0.23)	.736	4.0 (2)	.138
LA bias (incorrect decisions)[b] × group[f,g]								
Presence vs absence of LA bias (incorrect decisions)[b]	−.06 (−0.28 to 0.17)	.616	.07 (−0.18 to 0.33)	.569	.07 (−0.23 to 0.37)	0.645	0.7 (2)	0.691
				Outcome: paranoid experiences				
LA bias (any decision)[a] × group[f,g]								
Presence vs absence of LA bias[a]	.10 (−0.15 to 0.36)	.423	.39 (0.10 to 0.69)	.009	−.09 (−0.39 to 0.22)	.572	5.1 (2)	.080
LA bias (incorrect decisions)[b] × group[f,g]								
Presence vs absence of LA bias (incorrect decisions)[b]	−.03 (−0.30 to 0.24)	.833	.23 (−0.09 to 0.55)	.158	−.05 (−0.46 to 0.36)	.801	1.8 (2)	.407
				Outcome: negative affect				
LA bias (any decision)[a] × group[f,g]								
Presence vs absence of LA bias[a]	.06 (−0.18 to 0.30)	.633	−.10 (−0.37 to 0.18)	.486	−.17 (−0.45 to 0.11)	.237	1.6 (2)	.449
LA bias (incorrect decisions)[b] × group[f,g]								
Presence vs absence of LA bias (incorrect decisions)[b]	.06 (−0.19 to 0.32)	.626	−.19 (−0.49 to 0.12)	.236	−.20 (−0.59 to 0.18)	.299	2.0 (2)	.360

Note: FEP, first-episode psychosis; ARMS, at-risk mental state for psychosis; LA, liberal acceptance; *df*, degrees of freedom; vs, versus; CI, confidence interval; LR, likelihood ratio for interaction.

[a]Presence of LA bias (any decision): making decisions based on probability estimates that deviate below rational estimates (<20%–29%); reference category: absence of LA bias defined as making decisions based on high probability estimates (≥20%–29%) or not wanting to make a decision.

[b]Presence of LA bias (incorrect decisions): making incorrect decisions based on probability estimates that deviate below rational estimates (<20%–29%); reference category: absence of LA bias defined as making incorrect or correct decisions based on high probability estimate (≥20%–29%) or not wanting to make a decision.

[c]Adjusted for age, gender, and level of education.

[d]Missing values, $n = 1$.

[e]Missing values, $n = 2$.

[f]Two-way interaction for LA bias × group as included in the following model, with y_{ij} for psychotic or paranoid experiences or negative affect as outcome variable: $y_{ij} = \beta_0 + \beta_1 (\text{LIBERAL ACCEPTANCE BIAS}_{ij}) + \beta_2 (\text{GROUP}_j) + \beta_3 (\text{LIBERAL ACCEPTANCE BIAS}_{ij} \times \text{GROUP}_j) + \varepsilon_{ij}$ (full model not shown and available upon request).

[g]Difference in associations across groups for significant for two-way interaction for LA bias × group:

	FEP vs controls		ARMS vs controls		FEP vs ARMS	
	Adj. β (95% CI)	*P*	Adj. β (95% CI)	*P*	Adj. β (95% CI)	*P*
			Outcome: psychotic experiences			
Presence vs absence of LA bias (any decision)[a]	.02 (−0.24 to 0.27)	.890	.24 (−0.03 to 0.51)	.082	−.22 (−0.47 to 0.03)	.081
Presence vs absence of LA bias (incorrect decisions)[b]	−0.13 (−0.50 to 0.25)	.503	.00 (−0.39 to 0.40)	.986	−.13 (−0.47 to 0.21)	.448
			Outcome: paranoid experiences			
Presence vs absence of LA bias (any decision)[a]	.19 (−0.21 to 0.59)	.343	.48 (0.06 to 0.91)	.026	−.29 (−0.68 to 0.10)	.144
Presence vs absence of LA bias (incorrect decisions)[b]	.02 (−0.47 to 0.52)	.923	.28 (−0.24 to 0.81)	.286	−0.26 (−0.68 to 0.16)	.222

Table 5. Association Between Momentary Aberrant Salience, Psychotic and Paranoid Experiences by Liberal Acceptance (LA) Bias[a] and Group (FEP, ARMS, controls)[b]

	FEP[c]		ARMS[d]		Controls		LR test[c,d]	
	Adj. β (95% CI)	*P*	Adj. β (95% CI)	*P*	Adj. β (95% CI)	*P*	χ^2 (*df*)	*P*
			Outcome: psychotic experiences					
Momentary aberrant salience × LA bias (any decision)[a] × group[e,f]							7.40 (2)	.025
Association between momentary aberrant salience and psychotic experiences by LA bias								
Presence of LA bias	.16 (0.06 to 0.25)	.001	0.36 (0.27 to 0.46)	<.001	.15 (0.04 to 0.27)	.008		
Absence of LA bias	.20 (0.17 to 0.22)	<.001	.24 (0.21 to 0.26)	<.001	.18 (0.15 to 0.22)	<.001		
Presence vs absence	−.04 (−0.13 to 0.05)	0.400	.13 (0.03 to 0.22)	.008	−.03 (−0.14 to 0.08)	.600		
			Outcome: paranoid experiences					
Momentary aberrant salience × LA bias (any decision)[a] × group[e,f]							3.7 (2)	.160
Association between momentary aberrant salience and psychotic experiences by LA bias:								
Presence of LA bias	.08 (−0.07 to 0.24)	.273	.32 (0.17 to 0.47)	<.001	.10 (−0.08 to 0.28)	.291		
Absence of LA bias	.19 (0.14 to 0.23)	<.001	.23 (0.18 to 0.28)	<.001	.17 (0.11 to 0.23)	<.001		
Presence vs absence	−.10 (−0.25 to 0.05)	.188	.09 (−0.05 to 0.24)	.215	−.07 (−0.25 to 0.11)	.451		

Note: FEP, first-episode psychosis; ARMS, at-risk mental state for psychosis; LA bias, liberal acceptance bias; *df*, degrees of freedom; vs, versus; CI, confidence interval; LR, likelihood ratio for interaction.

[a]Presence of LA bias (any decision): making decisions based on probability estimates that deviate below rational estimates (<20%–29%); reference category: absence of LA bias defined as making decisions based on high probability estimates (≥20%–29%) or not wanting to make a decision).

[b]Adjusted for age, gender, and level of education.

[c]Missing values, $n = 1$.

[d]Missing values, $n = 2$.

[e]Three-way interaction for momentary aberrant salience × LA bias × group as included in the following model (with y_{ij} for psychotic experiences or paranoid experiences as outcome variable): $y_{ij} = \beta_0 + \beta_1$ (MOMENTARY ABERRANT SALIENCE$_{ij}$) + β_2 (LIBERAL ACCEPTANCE BIAS$_{ij}$) + β_3 (GROUP$_j$) + β_4 (MOMENTARY ABERRANT SALIENCE$_{ij}$ × LIBERAL ACCEPTANCE BIAS$_{ij}$) + β_5 (MOMENTARY ABERRANT SALIENCE$_{ij}$ × GROUP$_j$) + β_6 (LIBERAL ACCEPTANCE BIAS$_{ij}$ × GROUP$_j$) + β_7 (MOMENTARY ABERRANT SALIENCE$_{ij}$ × LIBERAL ACCEPTANCE BIAS$_{ij}$ × GROUP$_j$) + ε_{ij} (full model not shown and available upon request).

[f]Difference (Δ) in associations of momentary aberrant salience with (1) psychotic and (2) paranoid experiences in the presence vs absence of LA bias across groups:

	FEP vs controls		ARMS vs controls		ARMS vs FEP	
	Adj. β (95% CI)	*P*	Adj. β (95% CI)	*P*	Adj. β (95% CI)	*P*
	Outcome: psychotic experiences					
Δ in associations in the presence vs absence of LA bias (any decision) across groups	−.01 (−0.16 to 0.14)	.891	.16 (0.01 to 0.30)	.034	.17 (0.04 to 0.30)	.013
	Outcome: paranoid experiences					
Δ in associations in the presence vs absence of LA bias (any decision) across groups	−.03 (−0.27 to 0.20)	.781	.16 (−0.07 to 0.40)	.171	.20 (−0.02 to 0.41)	.071

FEP than in controls, but much less strong and consistent support that LA bias was more likely to occur (and fluctuate) in ARMS than in controls. When we examined our second hypothesis, we found evidence that presence of, and fluctuations in, LA bias was associated with an increased intensity of psychotic and paranoid experiences in ARMS and some evidence, at trend level, that this association was greater in ARMS than in controls. Probing these findings further, there was evidence from analyses testing our third hypothesis that LA bias modified the association between momentary aberrant salience and psychotic experiences, such that this association was greater

in the presence of, and greater fluctuations in, LA bias in ARMS, but not in FEP and controls. Finally, we found no evidence that LA bias was associated with affective disturbance in any one group.

Methodological Considerations

This study used a novel eESM task, which operationalized LA bias based on a forced choice reasoning task and, thus, did not allow for investigating other aspects of reasoning biases such as the formal criterion of draws-to-decision in the beads task. However, this task yielded several methodological advances on previous research. These included measuring LA bias repeatedly over time without learning effects, keeping the potential impact of poor motivation to a minimum (as premature decisions did not affect completion time or length of task), and probably most importantly, delivering, for the first time, an experimental task for measuring cognitive bias under real-world conditions. Although this novel task showed very good concurrent validity with psychotic experiences and clinical status, subsequent studies now need to compare eESM and conventional tasks of cognitive bias to elucidate their convergent validity.

The eESM task asked participants to provide probability estimates on response options to knowledge questions, so perhaps not unsurprisingly the magnitude of ORs was attenuated for the presence of LA bias in individuals with ARMS (and to a degree, in individuals with FEP) compared with controls when controlling for confounding by education level. We cannot rule out, however, that the latter may have indexed in part aspects of the cognitive impairments that form part of the psychopathology of psychosis and, hence, explain some of the attenuation in ORs. Future research should further investigate this link between LA bias, educational level, and IQ and what role difficulty of task, developmental age, and dosage of antipsychotics may play for the association between LA bias and psychotic experiences. Notably, the association between LA bias and psychotic experiences in ARMS held independently of, and thus was not confounded by, educational level. One reason for *P* values of interactions to reach only trend level despite differences in associations across groups being of large magnitude in the adjusted models may have been limited power.

ESM assessment is time intensive and data collection may be associated with assessment burden for participants. The ESM measure for assessing paranoid experiences consisted of only 1 item. Although this item did not cover the full breadth of paranoid experiences, and arguably, a clearer pattern of findings may have been observed using a more detailed measure; brevity of ESM measures allowed us to balance burden of intensive longitudinal ESM assessment. Also, good concurrent validity was observed for this measure of paranoid experiences with ESM measures of psychotic experiences, negative affect, and threat anticipation (table 1).

Comparison With Previous Research

Numerous studies have investigated reasoning biases in psychosis, but evidence on LA bias and, more generally, the role that reasoning biases play within individuals across different contexts in daily life remained limited. In the current eESM study, we found that LA as a specific type of reasoning was 2–3 times more likely to occur in the daily lives of individuals with FEP than in controls. This is in line with previous research that suggests LA bias is more likely to occur in people with psychosis compared with healthy controls.[14] We further observed that the increase in the odds of LA bias was more marked in individuals with FEP when this was characterized by making *incorrect* decisions based on low probability estimates, which is consistent with findings from the study by Moritz et al.[16] However, 95% CIs of this finding were within a broadly similar range and included the point estimate of the OR for LA bias defined as making *any* decision based on low probability estimates, and hence, differences in magnitude of ORs need to be interpreted with caution. There was much less strong and consistent evidence that LA bias was more likely to be present in individuals with ARMS. This is not too surprising given that only a proportion of those with an ARMS will go on to develop a psychotic disorder[47] and LA bias has been found to be much less relevant in people without mental health problems.[14]

Echoing previous reports in people with an elevated risk for psychosis,[48] we found momentary LA bias to be associated with increased intensity of momentary psychotic and paranoid experiences within individuals with ARMS. Our findings on the association of fluctuations in LA bias with psychotic and paranoid experiences in individuals with ARMS extended beyond previous research. Further, the absence of an association of LA bias with paranoid (and psychotic) experiences in FEP mirrors earlier findings on LA bias to be present in people with (enduring) psychotic disorder (eg, schizophrenia and delusional disorder), but not directly linked to current severity of psychotic symptoms (when LA bias was based on correct decisions).[15] A recent repeated measures online survey to investigate jumping to conclusions as another important reasoning bias did, however, report such a link in a small sample of people with enduring psychosis.[49] There was also no evidence in any one group that LA bias, characterized by making *incorrect* decisions based on low probability estimates, was associated with psychotic or paranoid experiences. Garety and Freeman[20] emphasized that probabilistic reasoning is a useful framework for investigating the nature of paranoid and psychotic symptom development precisely because "… it does not simply measure valid conclusions or errors, but assesses the way conclusions are reached" (Garety and Freeman,[20] p. 123). Our finding seems to support this point as *any*, rather than specifically incorrect, decisions

based on low probability estimates were associated with an increased intensity of paranoid and psychotic experiences in individuals with ARMS.

This finding in individuals with ARMS became even more revealing when viewed in the context of momentary aberrant salience, which we have previously reported may be particularly relevant to intensity of psychotic experiences in this population.[9] Aberrant assignment of salience to otherwise irrelevant stimuli has been theorized to be the result of excess striatal dopamine, and psychotic experiences to emerge as a "top-down" cognitive attempt to make sense of these aberrantly salient experiences, which have further been linked to altered reward processing.[50–56] Although there has been controversial debate about the number of cognitive alterations that give rise to delusions,[57,58] (some) cognitive models of psychosis[7,13] posit that the presence of reasoning biases is key for anomalous experiences of aberrant salience to transform into frank psychotic symptoms. In line with these models, we found that experiences of momentary salience were associated with more intense psychotic experiences in the presence of, and greater fluctuations in, LA bias in individuals with ARMS without any prior treatment with antipsychotics for a psychotic episode. However, there was no evidence that this association was modified by LA bias in individuals with FEP, who all but one had received treatment with antipsychotics, which have been theorized to reduce experiences of aberrant salience through their effect on elevated dopamine function.[54,59] This tentatively suggests that LA bias may be central for aberrant salience to initially increase intensity of psychotic experiences in at-risk individuals, but less relevant for aberrant salience to maintain symptoms in treated individuals with FEP.

Finally, although affective disturbances play an important role in the etiology of psychosis, as we have recently reported in daily life,[8,60] consistent with previous research,[24] we did not find negative affect to be directly linked to LA bias.

Conclusions

Our findings suggest that LA bias in daily life may be most relevant to increase intensity of psychotic experiences in individuals with ARMS and may be central for anomalous experiences such as experiences of aberrant salience to be associated with more intense psychotic experiences. Moreover, LA bias in daily life appears to be more likely to occur and, hence, to be most pronounced, in individuals with a first-episode of psychotic disorder, but, in treated individuals with FEP, does not seem to be directly linked to an increased intensity of, and maintain, psychotic experiences. The current study further illustrates that the scope of eESM tasks for measuring fluctuations in not only reasoning biases but also other psychological processes under real-world conditions is considerable and may help improve our understanding of these processes in the development of psychosis. Novel eESM tasks further open new avenues for identifying and targeting the dynamics of basic psychological dimensions in daily life. An important next step will be to conduct clinical translational research using ecological interventionist causal models for modifying reasoning bias (and other psychological processes) in daily life through novel, personalized ecological momentary interventions[8,61] in the early stages of symptom development and, thereby, prevent transformation of anomalous experiences into full-blown psychotic symptoms.

Supplementary Material

Supplementary data are available at *Schizophrenia Bulletin* online.

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