Overestimated Environmental Volatility Underpins Aberrant Decision Making in Type-I Bipolar Disorder

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Introduction

- Bipolar Disorder (BD) is a severe mood disorder characterized by recurrent mood episodes of mania and depression.
- Recent studies suggest that mood instability in BD may arise from altered reward perception and learning during decision making [1], [2].
- One key component of decision making is the inference of **environmental volatility** — how rapidly the environment changes.
- However, only one study [3] has investigated volatility inference in BD, and it examined only a simple environmental structure in euthymic individuals.

Aim & Research Questions

Here, we tested whether individuals with BD show altered volatility inference across diverse environmental structures and whether it is associated with clinical symptoms.

RQ 1. Do individuals with BD show differences in behavioral patterns?
RQ 2. Do individuals with BD show altered volatility inference?
RQ 3. How do clinical symptoms relate to individual differences in volatility inference?

Method

Participants

HC (N=40)

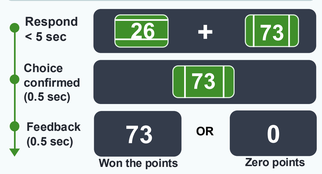
Type-I BD (N=32)

		HC	Type-I BD	*p*-value
Demographic Information	Age (yrs)	35.5±9.73	39.78±10.84	ns
	Gender (female)	18 (45%)	15 (46.9%)	ns
Mood (Depression)	BDI	2.48±3.96	17.26±14.7	$p < .001$
	MADRS	-	12.06±9.98	-
Mood (Mania)	YMRS	-	8.25±7.99	-
Personality trait	HPS	11.58±7.26	23.8±8.22	$p < .001$
Motivation System	BIS	53.48±9.59	75.54±13.7	ns
	BAS	37.73±5.85	39.84±7.46	ns
Impulsivity	BIS-11	53.48±9.59	75.54±13.7	$p < .001$

Note. Values are presented as **mean ± SD** or **n (%)**. **BDI** = Beck Depression Inventory; **MADRS** = Montgomery–Åsberg Depression Rating Scale; **YMRS** = Young Mania Rating Scale; **HPS** = Hypomanic Personality Scale; **BIS** = Behavioral Inhibition System; **BAS** = Behavioral Activation System; **BIS-11** = Barratt Impulsiveness Scale–11; **ns** = not significant.

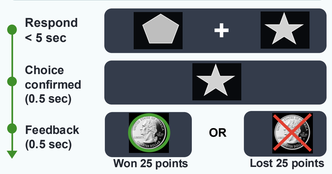
Task

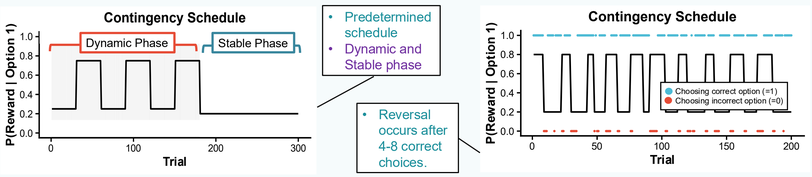
PTT (Probability Tracking Task) [4]



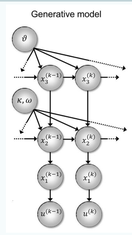
Different Pattern & Source of Environmental Change

PRL (Probabilistic Reversal Task) [5]





Hierarchical Gaussian Filter [6] **Computational Modeling**



Level	State of the world	Variable	Possible values	Generative model
3	Log-volatility of tendency	x_3	Real number	Gaussian random walk with constant step size ϑ
2	Tendency towards category "1"	x_2	Real number	Gaussian random walk with step size $\exp(\kappa x_3 + \omega)$
1	Stimulus category	x_1	"1", "0"	Sigmoid transformation of x_2

Parameters of interest

μ_3^0 Prior Belief about Environmental Volatility

ζ Behavioral Stochasticity

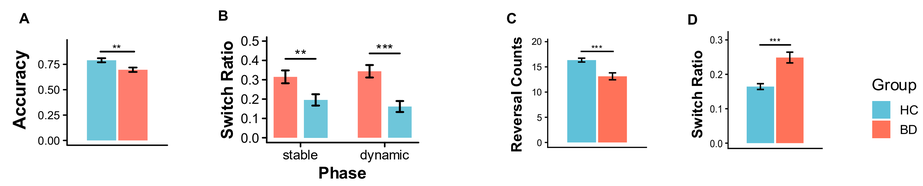
- Infer trial-wise hierarchical belief of the participant from behavioral data.

Hierarchical Bayesian analysis for estimating and comparing group level parameter [7].

Results

Result 1. Group Differences in Behavioral Patterns

Task 1: PTT



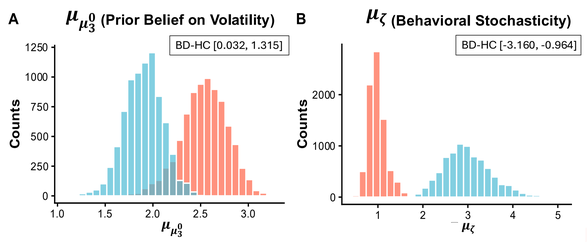
Task 2: PRL

Fig 1. The individuals with BD showed :
- **Poorer performance** (A&C)
- **Higher option switching** (B&D)

Note. $p<.05$ *, $p<.01$ **, $p<.001$ ***, Error bars indicate SEM.

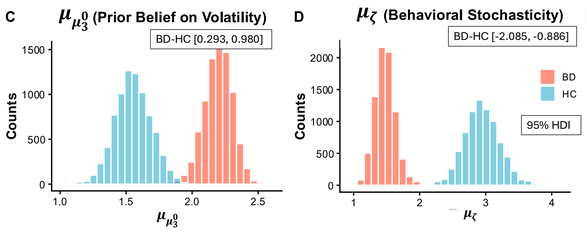
Result 2. Group Differences in Perceptual Parameter

Task 1: PTT



Task 2: PRL

* The lower the ζ is, the higher the choice randomness.



Note. 95% Higher Density Intervals of posterior group differences (BD-HC) are noted.

Fig 2. Group posterior distributions of HGF parameters
The individuals with BD exhibited :
- **Higher priors on volatility**
- **Higher choice randomness**

Higher volatility estimates across trials in BD

Greater overall uncertainty (∝ learning rates)

More frequent belief fluctuation

Higher switch rates at behavioral level

How do differences in HGF parameters shape belief updating across trials and give rise to distinct behavior patterns?

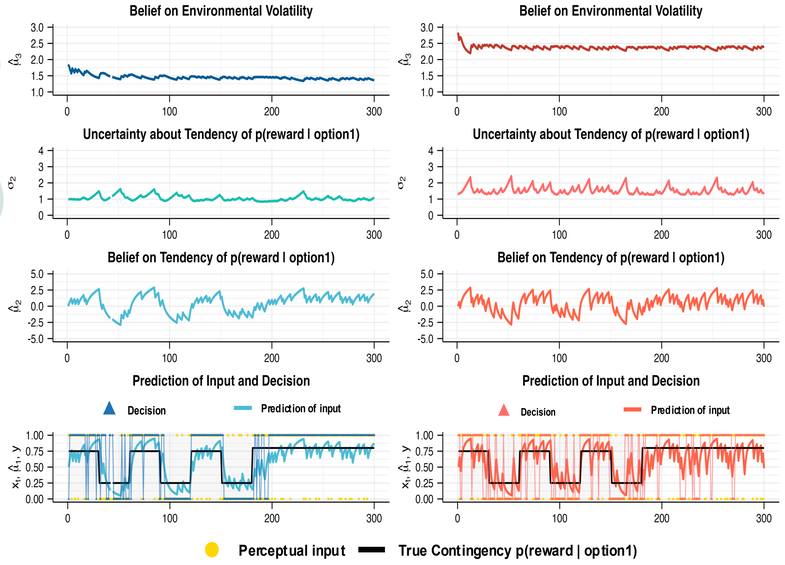


Fig 3. Belief trajectories and decisions in PTT of two representative participants whose posterior means are close to the group posterior means from each group; HC (left); BD(right).

Result 3. Association with Clinical Variables

The mania (YMRS) and depression symptoms (MADRS) were not associated with HGF parameters within BD.

Conclusion

Key Takeaway Type-I BD is characterized by heightened volatility beliefs and increased behavioral stochasticity, independent of current manic and depressive symptoms, suggesting that these computational alterations may represent trait-like features.

Clinical Implication

Explaining Clinical Symptoms Heightened volatility beliefs may lead individuals to interpret ordinary life events as signals of environmental change, potentially explaining why specific life events (e.g., personal achievements) trigger mood episodes (e.g., manic episode).

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