Bipolar Disorder Modifies the Relationship between Inter-key Delays and Sample Entropy of Typing

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Background

• Typing kinematics and keystroke meta data are associated with social, cognitive, and mood outcomes in bipolar disorder (Stange et al., 2018; Zulueta et al., 2018).

• Dynamical systems allow for the measurement of how systems "change in time. Our goal is to extract meaningful information from seemingly random (stochastic) processes such as typing speed. Sample entropy examines the degree of complexity or self-similarity in a time series (Richman & Moorman, 2000). We examined how sample entropy of typing speed is altered in bipolar disorder.

Methods

• Participants enrolled by downloading BiAffect, a crowd-sourced ResearchKit study and iOS/Android app whose core technology is a custom keyboard that collects metadata consisting of keystroke time and type.

• We extracted typing keystrokes (e.g., alphanumeric, backspace, autocorrects) and keypress timestamps for participants with a self-reported diagnosis of Bipolar Affective Disorder (BPAD) 1, 2, or not otherwise specified (n=183). They were collapsed into one single group in subsequent analyses. To focus on conversational typing behaviors, we filtered out autocorrects and interkey time delays (ITD) <0.10 or >9 seconds.

• Using logistic regression models, we evaluated the likelihood that those who self-reported a history of bipolar disorder diagnosis would screen positive on the Mood Disorder Questionnaire (MDQ) for BPAD.

• Using hierarchical linear models, we calculated the main effects of BPAD diagnosis, gender, age, and median ITD as well as the interactive effects of BPAD and median ITD on sample entropy.

**Table 1.** Summary table of demographics, MDQ, sample entropy, and median ITD.

Table Legend:
Acronyms: MDQ = Mood Disorder Questionnaire; BPAD = Bipolar Affective Disorder, ITD = interkey time delay

|	Control (N=83)	BPAD (N=100)	P-value
Age, years (mean±SD)	39.3±13.8	32.1±9.3	p<0.001
Gender (% Female)	60.2%	71%	p=0.169
MDQ (% + screen for BPAD)	24.1%	82.8%	p<0.001
Sample Entropy (mean±SD)	0.86±0.27	0.77±0.21	p=0.02
Median ITD (mean±SD)	0.30±0.15	0.26±0.07	p=0.007
Bipolar Disorder (% BPAD+)			
Bipolar Disorder I	-	36%	-
Bipolar Disorder II	-	50%	-
Bipolar Disorder - Other	-	14%	-

Results

Figure 1: Logistic regression models were conducted using the MDQ as the dependent variable and history of BPAD diagnosis as the independent variables. Significance set at p<.05.
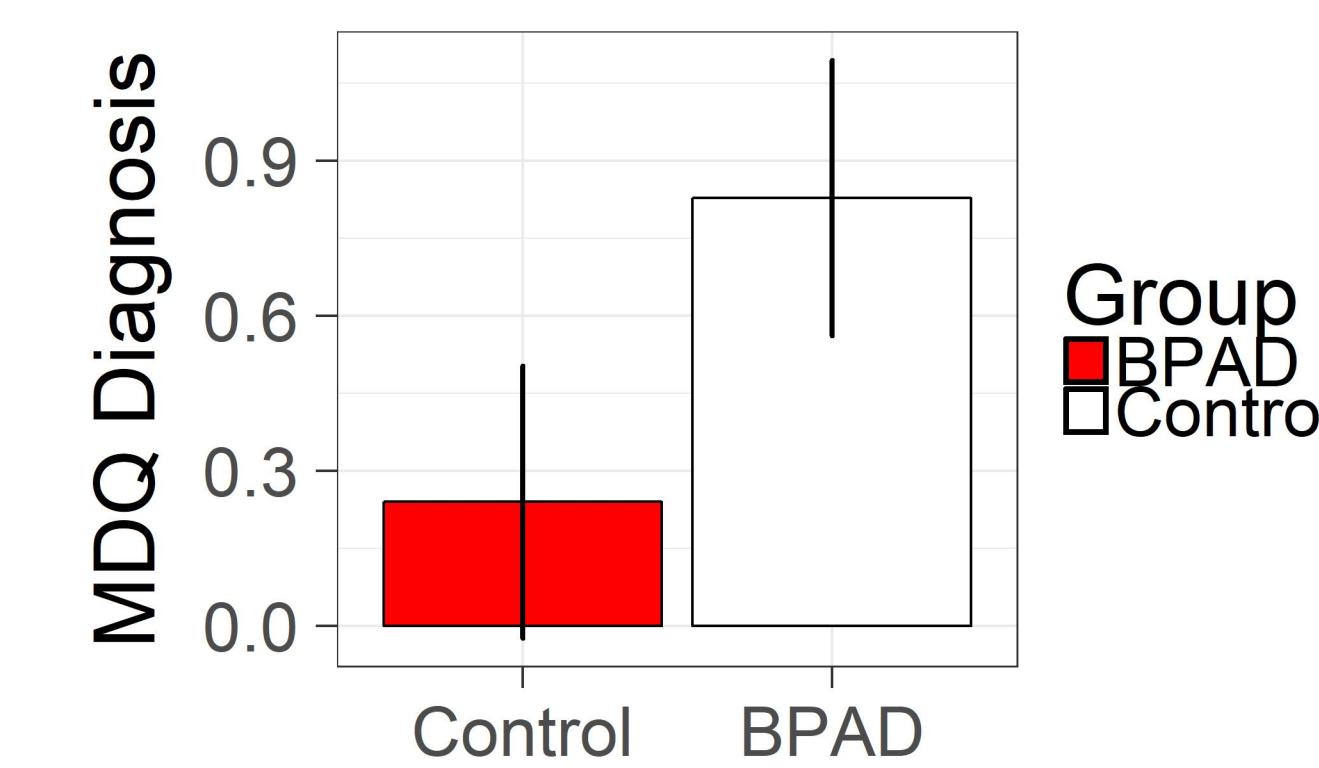

• Those who report having received a diagnosis of bipolar disorder (1, 2, and other) are more likely to screen positive on the MDQ (OR=15.23, z=7.27, p < 0.0001)

Figure 2: The predicted fit of Model 1 (see Table 2). Hierarchical linear models were conducted using sample entropy as the dependent variable and BPAD as the independent variable. Significance set at p<.05.
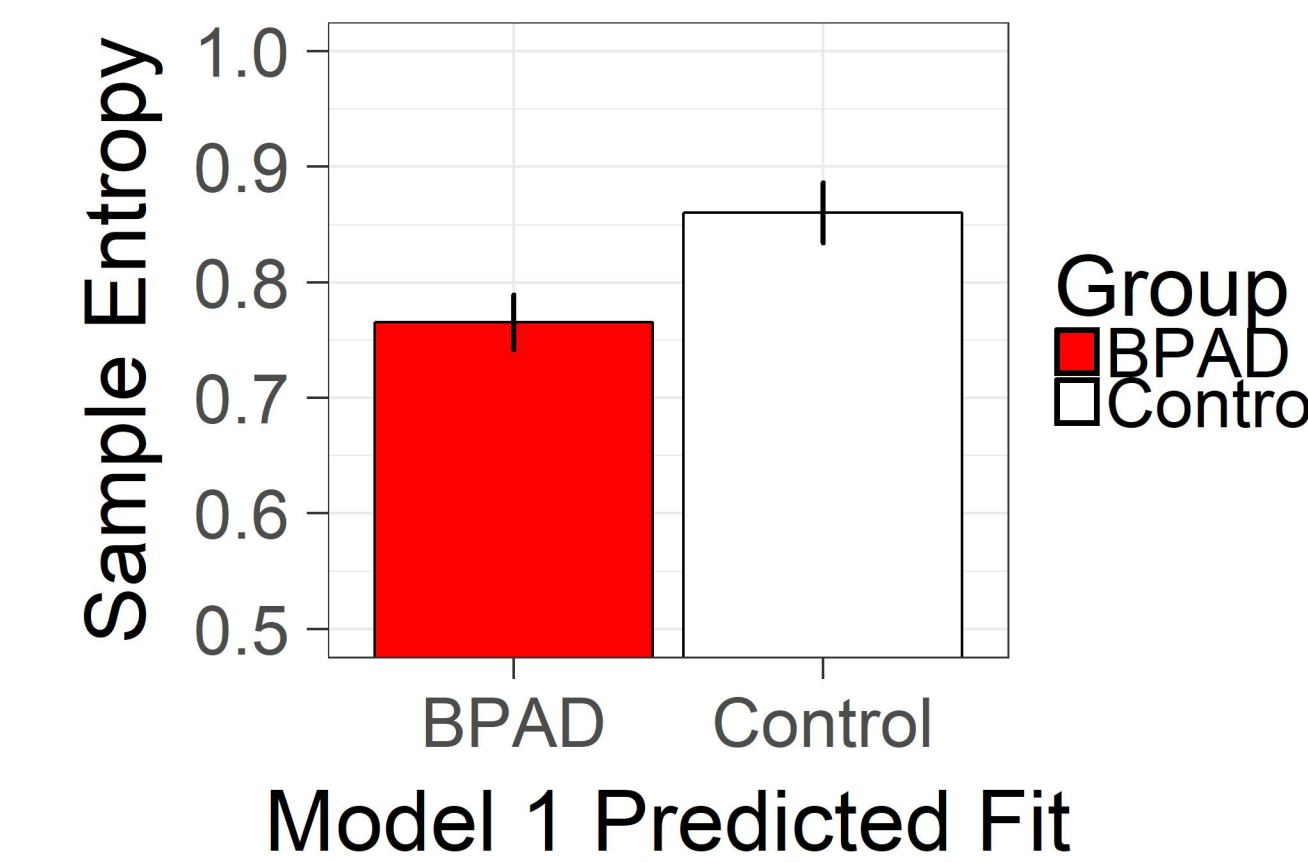

• There was a main effect of BPAD diagnosis on sample entropy such that BPAD (M=0.77, SD=0.21) had lower sample entropy than controls (M=0.86, SD=0.27), t(181)=-2.68, p=0.008.

Table 2. Hierarchical linear models showing the main effects of reported history of BPAD diagnosis, gender, age, and median ITD as well as the interactive effects of BPAD diagnosis and median ITD on sample entropy.

Table Legend:
BPAD = Bipolar Affective Disorder, ITD = interkey time delay
[!]p<0.10; *p<0.05; **p<0.01; ***p<0.001

	Model 1	Model 2	Model 3	Model 4	Model 5
BPAD	-0.095**	-0.09*	-0.029	-0.018	-0.009
Gender		-0.046	-0.012	0.014	0.012
Age			0.108***	0.005	0.004
Median ITD				0.18***	0.158***
BPAD*Median ITD					0.097***
R²	0.038	0.046	0.22	0.57	0.60
ΔR²		0.008	0.18***	0.35***	0.03***

Figure 3: The predicted fit of Model 3 (see Table 2). Hierarchical linear models were conducted using sample entropy as the dependent variable as well as BPAD, Gender, and Age as the independent variables. Significance set at p<.05.
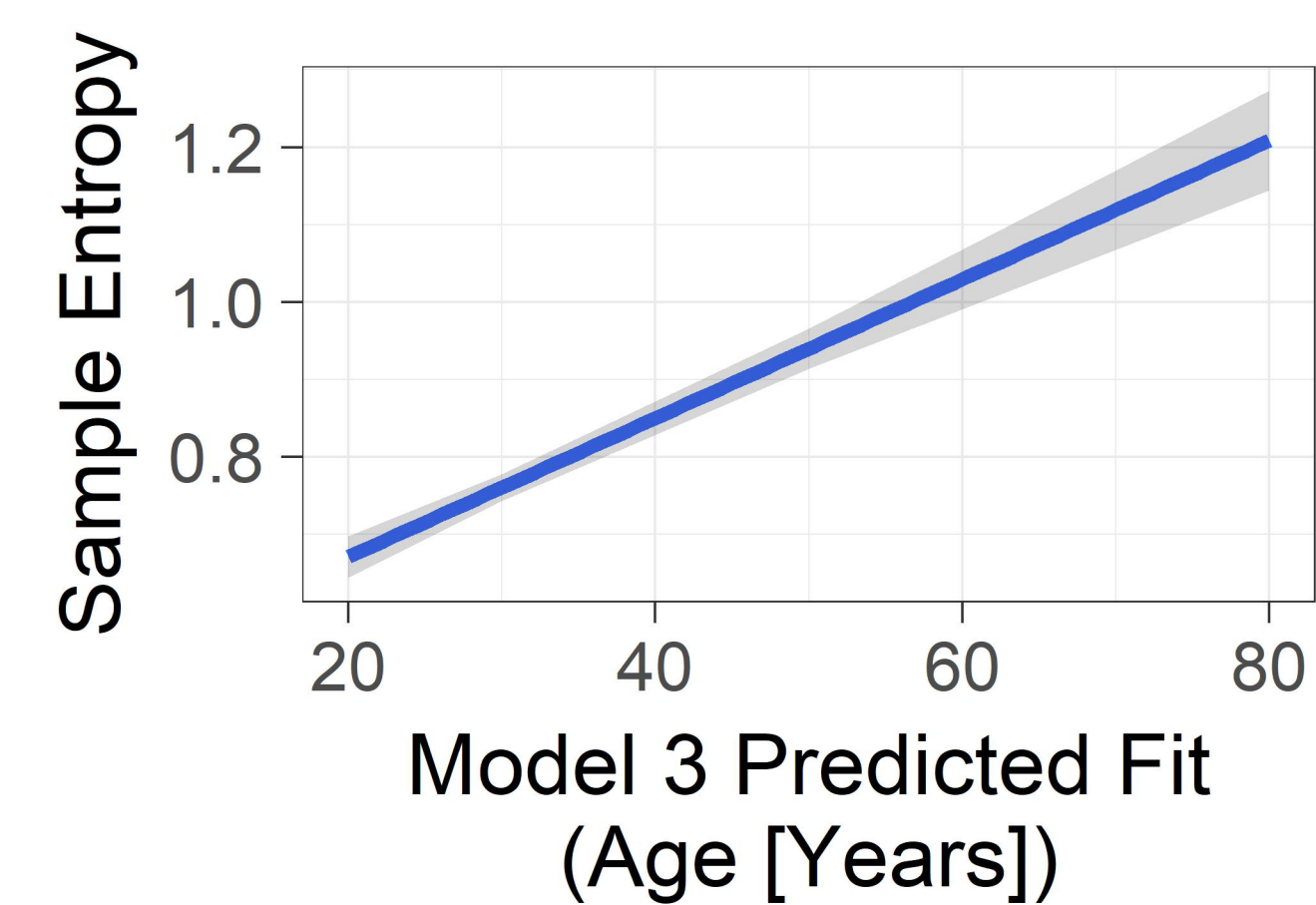

• The effect of BPAD remained significant when controlling for gender in Model 2, but was insignificant when controlling for age in Model 3. In Model 3, only age was positively correlated with sample entropy, t(179)=6.40, p<0.001.

Figure 4: The predicted fit of Model 4 (see Table 2). Hierarchical linear models were conducted using sample entropy as the dependent variable as well as BPAD, Gender, Age, and Median ITD as the independent variables. Significance set at p<.05.
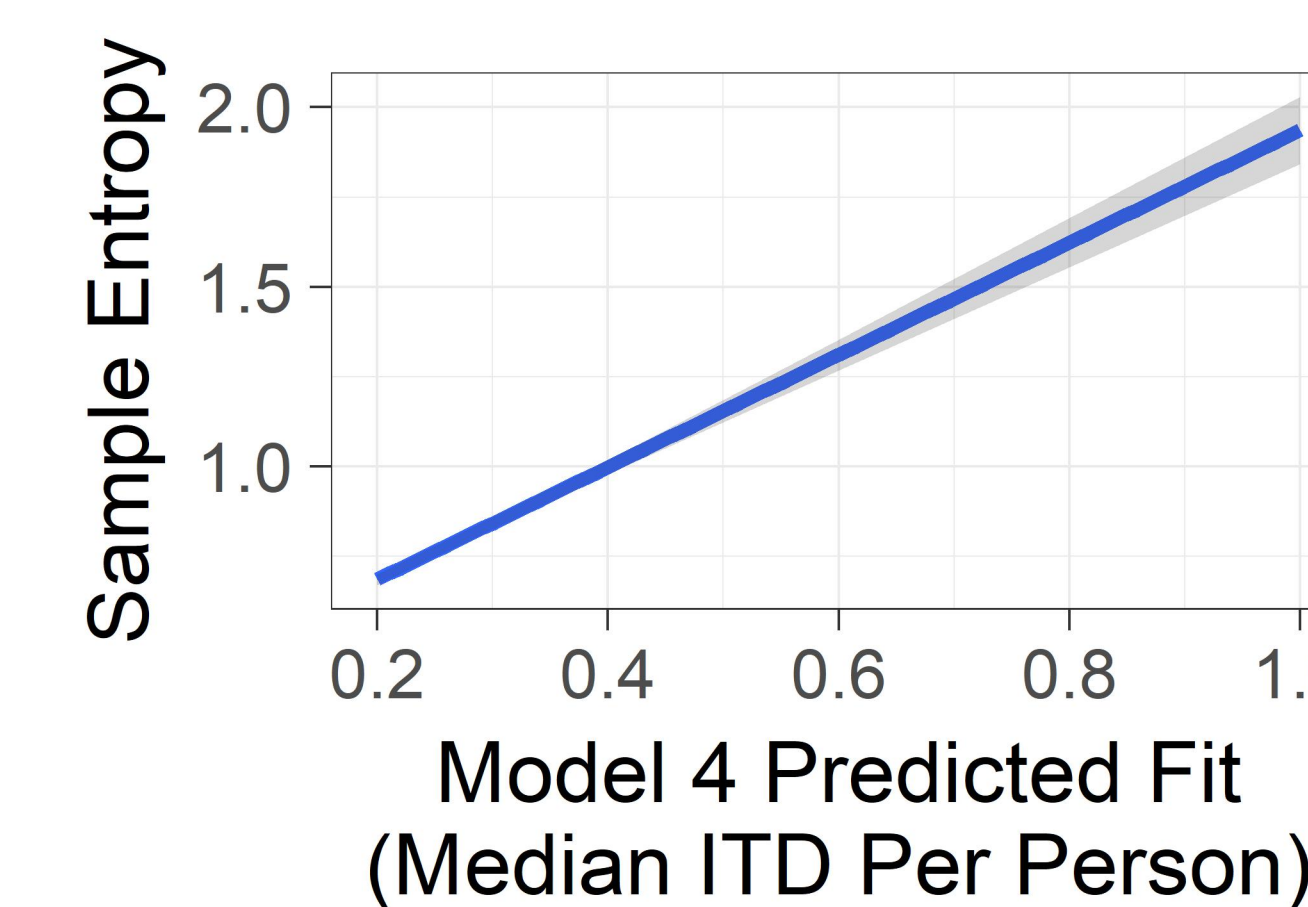
• In Model 4, we found that only typing speed was associated with sample entropy, t(178)=12.13, p<0.001, while age was not (t(178)=0.33, p=0.74).

Figure 5: The predicted fit of Model 5 (see Table 2). Hierarchical linear models were conducted using sample entropy as the dependent variable. The model included the main effects of BPAD, Gender, Age, and Median ITD as well as the interactive effects of BPAD and Median ITD as the independent variables. Significance set at p<.05.
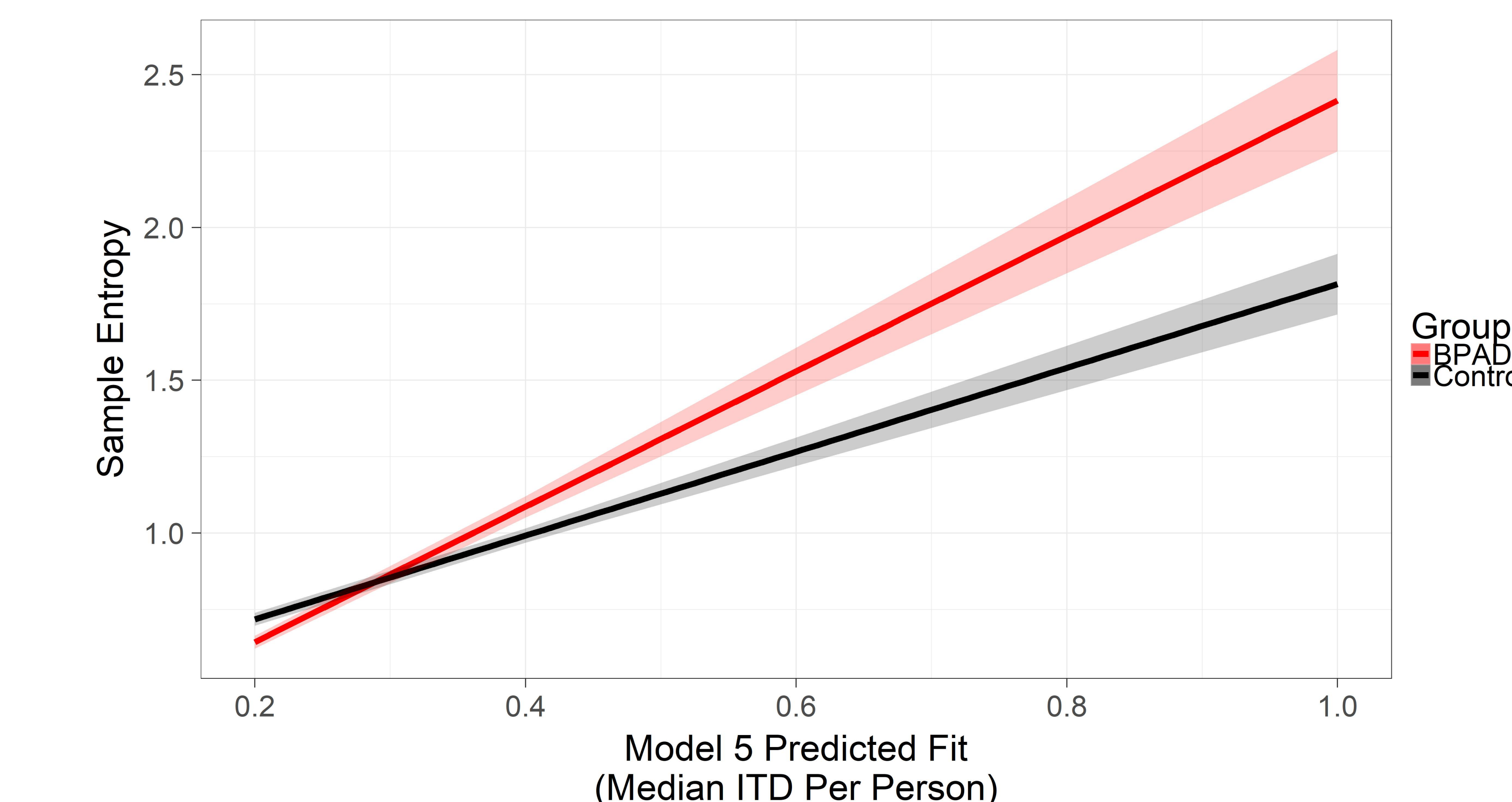
• Finally, in Model 5, we found a main effect of typing speed (t(177)=10.03, p<0.001) and a significant interaction between BPAD diagnosis and typing speed, t(177)=3.50, p<0.001. However, the main effects of BPAD (t(177)=-0.39, p=0.70), gender (t(177)=0.47, p=0.64), and age (t(177)=0.25, p=0.80) were not significant. That is, we found that a BPAD diagnosis modifies the relationship between typing speed and sample entropy.

Conclusions

• Participants with BPAD have lower ITD than controls (Table 1), but have lower sample entropy of typing speed (Figure 2), which suggests that BPAD participants have lower complexity of typing.

• Sample entropy appears to change as a function of processing speed, as the effects of gender and age are not significant when controlling for typing speed (Figure 4). BPAD diagnosis modifies the relationship between sample entropy and typing speed, perhaps because BPAD alters cognitive processing to a greater extent than in healthy controls (Figure 5).

• Future studies should examine how mania/hypomania and depression alter cognitive processing in BPAD and how this relates to typing dynamics.

References

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