

Temporal Order Judgments in Schizophrenia and Bipolar Disorders — Explicit and Implicit Measures

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Supplementary Material

S1. Excluding ‘Order’ Factor from Explicit Measures

Materials and Methods

To analyze explicit measures, i.e., the rate of correct responses given on the current trials, we first conducted a three-factor mixed analysis of variance (ANOVA) with the between-factor ‘group’ [schizophrenia spectrum disorder (SZ) vs. bipolar disorder (BP) vs. healthy controls (HC)] and the within-factors ‘Stimulus Onset Asynchrony (SOA)’ (17 ms vs. 100 ms) and ‘order’ (right–left vs. left–right). Note that trials with SOA = 0 ms could not be considered in this analysis since no physical order of the stimuli is present in case of these synchronous trials.

Results

The three-factor ANOVA revealed a significant main effect of between-factor ‘group’ ($F_{2,71} = 5.74, p < 0.01, \eta_p^2 = 0.14$) and a significant main effect of within-factor ‘SOA’ ($F_{2,71} = 835.86,$

$p < 0.001$, $\eta_p^2 = 0.92$) on participants' correct response rate. No main effect of the within-factor 'order' ($F_{2,71} = 0.179$, $p > 0.05$, $\eta_p^2 = 0.003$) nor any interaction was significant. In order to simplify further analyses and increase statistical power, we averaged participants' performance on the 'order' factor.

S2. Psychometric Function Analysis

Materials and Methods

Additionally, we analyzed participants' performance by computing psychometric functions on the temporal order judgement (TOJ) data in order to measure participants' point of subjective simultaneity (PSS) and the sensitivity (Sternberg & Knoll, 1973). To do this, we used the 'quickpsy' package (Linares & López-Moliner, 2016.). We plotted the probability of 'right first' responses as a function of SOA. Negative SOAs corresponded to 'left-right' order of appearance and positive SOAs to 'right-left' order of appearance. We fitted a cumulative normal distribution function to all participants' data to obtain the mean (corresponding to the PSS) and the standard deviation of the function (SD or slope, corresponding to participants' discrimination sensitivity between left-right and right-left stimulus presentation order). These two measures were then compared separately between groups. Three participants (one HC and two patients with SZ) were excluded from these analyses because their data could not be fitted to a cumulative normal distribution function (i.e., they had flat psychometric curves).

In case of PSS, data were normally distributed and we performed frequentist as well as multivariate Bayesian analyses on the same data. A normal distribution of data was not respected for the dataset of the sensitivity measure; thus, we normalized this dataset for each group before applying the ANOVA following the same procedure as described in the main manuscript. Further, we used a beta regression to fit the raw data in the multivariate Bayesian analysis.

Results

The average psychometric functions for each group are plotted in Fig. S1 in order to illustrate the results of PSS and sensitivity.

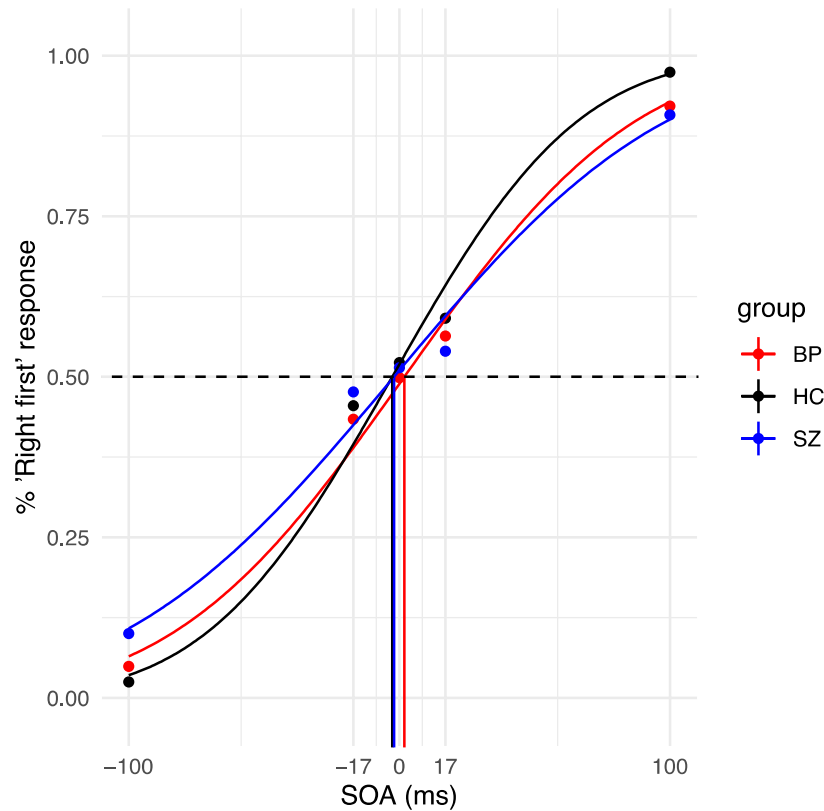


Figure S1. Psychometric functions of the three groups (BP = patients with bipolar disorder; HC = healthy controls; SZ = patients with schizophrenia spectrum disorder). Negative stimulus onset asynchronies (SOAs) correspond to the 'left–right' order of stimulus appearance and positive SOAs to the 'right–left' order of stimulus appearance. Point of subjective simultaneity (PSS) for each group is indicated on the x-axis as the SOA corresponding to a 50% 'Right first' response. Sensitivity is represented by the steepness of the slope of the individual curves.

We performed a one-way ANOVA on participants' PSS and found no significant effect of between-factor 'group' (HC vs. SZ vs. BP) ($F_{2,68} = 0.93$, $p > 0.05$, $\eta_p^2 = 0.027$). In line with this finding, we found no meaningful effect between any of the groups in the multivariate analysis [all probabilities (Pr) between 0.29 and 0.87].

A one-way ANOVA conducted on the SD of the psychometric functions revealed a significant effect of between-factor ‘group’ ($F_{2,68} = 5.19$, $p < 0.01$, $\eta_p^2 = 0.13$). Pair-wise Student t tests were performed to localize the differences and showed that the SD for the SZ group (82.04) was significantly higher, indicating lower discrimination sensitivity, than that of the HC group (48.21) ($p < 0.01$). The BP group had an intermediate SD value (62.36) and did not differ from the other two groups. The multivariate Bayesian analysis showed meaningful differences for the SD value comparing HC with SZ [odds ratio (OR) = 1.9, 95% confidence interval (CI95%): 1.23–2.94, $Pr(\text{HC} > \text{SZ}) = 0.99$], and comparing SZ with BP [OR = 0.58, CI95%: 0.36–0.94, $Pr(\text{SZ} > \text{BP}) = 0.03$], but no meaningful difference comparing HC with BP ($Pr = 0.65$).

Discussion

Our results indicate that while patients with SZ do not present a different bias as compared to HC and patients with BP (similar PSS), they have worse sensitivity for discriminating the temporal order of stimulus presentations correctly (compared to HC according to frequentist analyses, and compared to both HC and patients with BP according to Bayesian analyses). These results are consistent with the results on explicit measures in the main manuscript, showing altered order processing in patients with SZ as compared to HC and patients with BP.

References

- Linares, D., and López-Moliner, J. (2016). quickpsy: An R package to fit psychometric functions for multiple groups. *R J.* 8, 122–131.
- Sternberg, S., & Knoll, R. L. (1973). The perception of temporal order: fundamental issues and a general model. In S. Kornblum (Ed.), *Attention and Performance IV* (pp. 625–685). New York, NY, USA: Academic Press.