SUPPLEMENTAL FIGURES

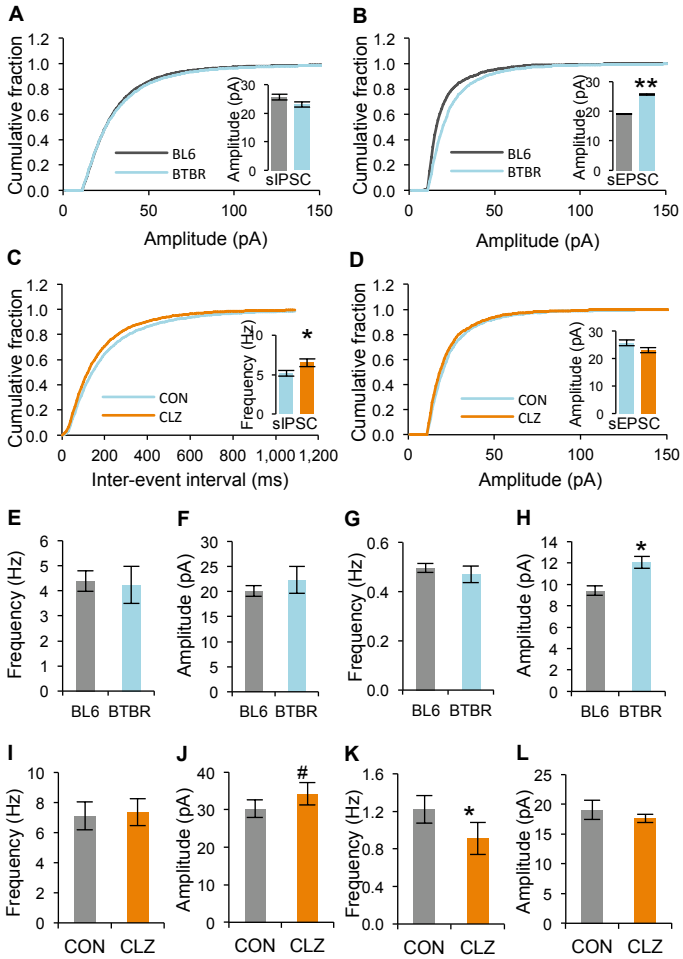

Figure S1. Effects of low-dose clonazepam treatment on GABAergic neurotransmission in BTBR and C57BL/6J mice. Related to Figure 1.

(**A**) Cumulative plot and average values (inset) of sIPSC amplitude was unchanged in BTBR hippocampal CA1 slices when compared to C57BL/6J (BL6) slices.

(**B**) Cumulative plot and average values (inset) of sEPSC amplitude. The amplitude of sEPSC was significantly increased in BTBR hippocampal CA1 slices when compared to C57BL/6J slices.

(**C**) Cumulative plot and average values (inset) of sIPSC frequency. The frequency of sIPSC was significantly increased by 0.5 µM clonazepam in BTBR hippocampal CA1 slices.

(**D**) Cumulative plot and average values (inset) of sEPSC amplitude. The amplitude of sEPSC was unchanged by clonazepam in BTBR slices.

(**E-H**) The amplitude and the frequency of miniature IPSC and miniature EPSC were measured in BTBR and C57BL/6J hippocampal CA1 slices. (**E and F**) the frequency (**E**) and the amplitude (**F**) of miniature IPSC were unchanged in BTBR slices when compared to C57BL/6J slices. (**G and H**) the frequency of miniature EPSC was unchanged (**G**), but the amplitude of miniature EPSC was significantly increased (**H**) in BTBR slices when compared to C57BL/6J slices.

(**I-L**) The frequency and amplitude of spontaneous IPSC and spontaneous EPSC in C57BL/6J. (**I and J**) the frequency (**I**) and the amplitude (**J**) of spontaneous IPSC were not changed by the bath application of 0.5 µM clonazepam in C57BL/6J hippocampal CA1 slices. (**K and L**) the frequency of spontaneous EPSC was decreased (**K**), but the amplitude of spontaneous EPSC was not changed (**L**) by 0.55 µM clonazepam treatment in C57BL/6J hippocampal CA1 slices.

CON, Control. CLZ, Clonazepam. All data shown are means ± s.e.m. from 15 - 19 recordings per strain. #, $P = 0.054$; *, $P < 0.05$, **, $P < 0.01$, ***, $P < 0.001$.

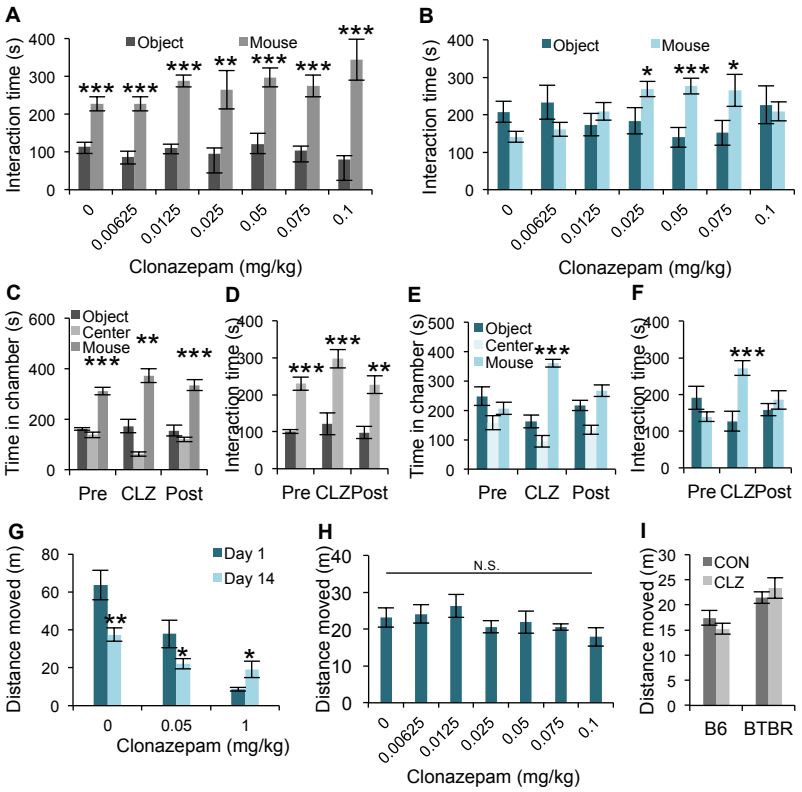

Figure S2. Low-dose clonazepam rescues social interaction and cognitive deficits in BTBR mice. Related to Figure 2.

(**A and B**) In the three-chamber social interaction test, the time spent in close interaction between the test mouse and the stranger mouse was measured. (**A**) Close interaction behavior of C57BL/6J mice (n = 6; each group) was not altered by a single injection of clonazepam, dose range from 0 - 0.1 mg/kg. (**B**) Clonazepam treatment rescued the decreased closed interaction behavior in BTBR mice (n = 9; each group) in a dose-dependent manner. Interestingly, the rescuing effect was not observed at higher than maximally effective concentration (0.05 mg/kg).

(**C-F**) In the three-chamber test, social deficits in BTBR mice (n = 8) were reversibly rescued by treatment with low-dose clonazepam. The social interaction preference in C57BL/6J mice (n = 7) was not changed by low-dose clonazepam, measured by time spent in the chamber (**C**), or by time spent in close interaction (**D**), but BTBR mice showed recovered social interaction behaviors after clonazepam treatment, measured by time spent in the chamber (**E**), or by time spent in close interaction (**F**), and the clonazepam effect disappeared after a 1-week clearance period in the same mice. (**G**) To test tolerance to the effects of clonazepam on locomotor and social behaviors, BTBR mice (n = 10; each group) were treated with low-dose (0.05 mg/kg), and high-dose (1 mg/kg) clonazepam for 14 days. Total distance moved during open field test at Day 1 and at Day 14 were measured. Whereas chronic high-dose clonazepam treatment caused significantly increased locomotor activity after drug treatment on Day 14 compared to Day 1, chronic low-dose clonazepam did not cause any increase in locomotor activity after drug treatment on either day. .

(**H and I**) To monitor the sedative effect of clonazepam, total distance moved was measured during the three-chamber social interaction test in BTBR mice (n = 9; each group) (**H**) and during the elevated plus maze test in BTBR mice (n = 10) and C57BL/6J mice (n = 10) (**I**). The clonazepam treatment did not cause sedation during the three-chamber test and the elevated plus maze test.

CON, Control. CLZ, Clonazepam. All data shown are means ± s.e.m. *P < 0.05, **P < 0.01, ***P < 0.001.

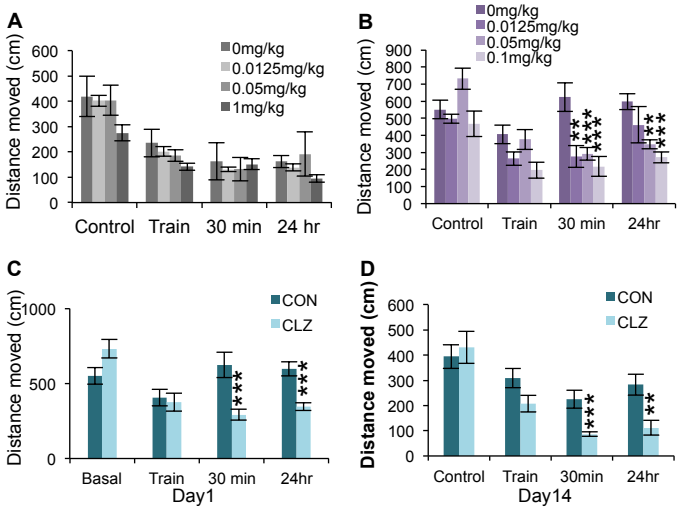

Figure S3. Total distance moved during contextual fear conditioning. Related to Figure 3.
(**A-D**) Total distance moved was measured during contextual fear conditioning, which is inversely correlated with freezing behavior.
CON, Control. CLZ, Clonazepam. All data shown are means ± s.e.m. *P < 0.05, **P < 0.01, ***P < 0.001.

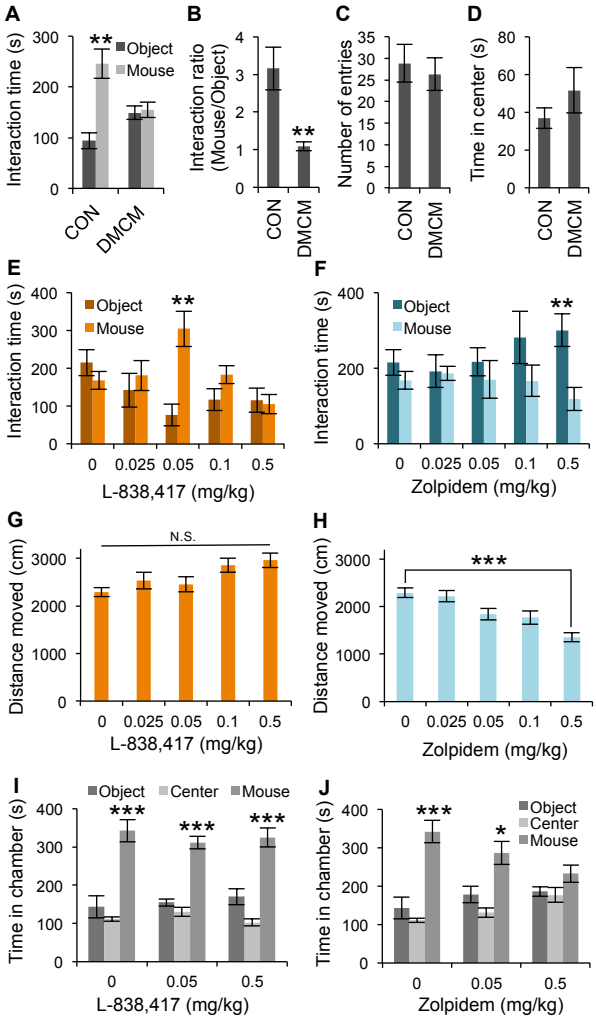

Figure S4. Rescue of social and cognitive deficits in BTBR mice by subunit-specific $GABA_A$ receptor positive allosteric modulators. Related to Figure 4.

(**A and B**) In the 3-chamber test, 0.2 mg/kg DMCM impaired the normal close interaction behavior in C57BL/6J mice (n = 8).

(**C**) In the elevated plus maze test, the number of entries in the open arms was unchanged in C57BL/6J mice (n = 7 – 8) by 0.2 mg/kg DMCM treatment.

(**D**) In the open field test, the time spent in center was unaltered in C57BL/6J mice (n = 8) by 0.2 mg/kg

(**E and F**) In the 3-chamber test, impaired social behavior, measured by the time spent in close interaction between the test mouse and the stranger mouse, was rescued at the doses of 0.05 mg/kg L-838,417, but the rescuing effect was disappeared at the dose of 0.5 mg/kg (**E**). Zolpidem failed to rescue social deficit in BTBR mice (n = 6 - 8; each group), rather it made social behavior worse at the dose of 0.5 mg/kg (**F**).

(**G and H**) The total distance moved during the 3-chamber test, was unchanged by L-838,417 with the dose range from 0 to 0.5 mg/kg (**G**), whereas the total distance moved during the 3-chamber test was dose-dependently decreased by zolpidem with the dose range from 0 to 0.5 mg/kg (**H**).

(**I and J**) In the 3-chamber test, the social behavior was not changed by L-838,417 in C57BL/6J mice (**I**). Zolpidem dose-dependently impaired the normal social behaviors in C57BL/6J mice (n = 7) (**J**). Test mice were not reused, different group of mice were used for each dose of drug treatments.

CON, Control. All data shown are means ± s.e.m. *P < 0.05, **P < 0.01, ***P < 0.001.

SUPPLEMENTAL EXPERIMENTAL PROCEDURES

Mice

The mice used for all behavioral analyses were 6-10 month-old adult male mice. As required for stable recordings of spontaneous synaptic activity, brain slices from 3-4 week-old mice were used for electrophysiological studies. All mice were singly housed at least 1 week before the behavioral tests. All experiments with animals were performed according to the National Institutes of Health Guide for Care and Use of Laboratory Animals and were approved by the University of Washington Institutional Animal Care and Use Committee.

Control Mouse Strain

We chose the C57BL/6J line as our control strain for comparison with BTBR based on precedents in the literature. At least fifty studies have used this mouse line as the primary control strain (Amodeo et al., 2012; Babineau et al., 2013; Benno et al., 2009; Blanchard et al., 2012; Bolivar et al., 2007; Cao et al., 2012; Chadman, 2011; Corley et al., 2012; Defensor et al., 2011; Ellegood et al., 2013; Frye and Llaneza, 2010; Gould et al., 2011; Heo et al., 2011; Jones-Davis et al., 2013; Karvat and Kimchi, 2012; Lipina and Roder, 2013; McFarlane et al., 2008; McTighe et al., 2013; Mercier et al., 2012; Meyza et al., 2012; Meyza et al., 2013; Miller et al., 2013; Moy et al., 2008; Moy et al., 2007; Onaivi et al., 2011; Pearson et al., 2012; Pearson et al., 2011; Pobbe et al., 2011; Pobbe et al., 2010; Roullet et al., 2011; Rutz and Rothblat, 2012; Scattoni et al., 2008; Scattoni et al., 2013; Scattoni et al., 2011; Schwartzer et al., 2013; Shah et al., 2013; Silverman et al., 2013a; Silverman et al., 2013b; Silverman et al., 2012; Silverman et al., 2010a; Silverman et al., 2010b; Stephenson et al., 2011; Wohr et al., 2011; Yang et al., 2012; Yang et al., 2009; Yang et al., 2011; Yang et al., 2007a; Yang et al., 2007b; Zhang et al., 2012; Zhang et al., 2013), whereas no other strain has emerged as a preferred alternative. The second most common type of control mouse strain, used in addition to C57BL/6J in five of these fifty studies, is the 129 mouse strain; however, different substrains of 129 mice were used in those five studies. We repeated our experiment with DMCM induction of autistic-like behaviors using 129SvJ mice and found comparable results to C57BL/6J (Figure 4).

Open-field Test

Open field test was performed as previously described (Han et al., 2012). 50 x 50 cm square open field arena with non-transparent white Plexiglas was used in this study. During the 10 min of trial, total distance moved, circling behavior (a complete 360-degree turn of nose angle with respect to the body center) and time in center (20 x 20 cm imaginary square) were measured by the video-tracking software (EthoVision XT 8.5, Noldus Technology). All data shown are means ± s.e.m. and analyzed using Student's two-tailed, unpaired t-test.

Elevated Plus Maze Test

The test was performed as previously described (Han et al., 2012). The maze used in this study has two closed arms (5.1 x 30 cm) surrounded by 20-cm high non-transparent walls and two open arms (5.1 x 30 cm). During the 10 min of trial, times spent in closed, center, and open arms, and total distance traveled during the trial were measured by the video-tracking software (EthoVision XT 8.5, Noldus Technology). All data shown are means ± s.e.m. and analyzed using Student's two-tailed, unpaired t-test.

Three-chamber Test

The test was performed as described previously (Han et al., 2012) with minor modifications. The three-chamber apparatus is a non-transparent Plexiglas box (30 x 60 cm) with two transparent partitions that make left, center, and right chambers (30 x 20 cm). In the first 10-min session, a test mouse was placed in the center of the empty three-chamber unit to habituate the test mouse. The mouse was allowed to freely explore each chamber. In the second 10-min session, an age- and gender-matched same strain mouse that had never been exposed to the test mouse, was placed in one of the two wire cages. The empty wire cage as an inanimate object cue was placed on the other side. Then, the test mouse was placed again in the center, and allowed to freely explore the chamber for 10 min. Time spent in each chamber, and time spent within a 5 cm radius proximal to each wire cage, as a close interaction were measured by the video-

tracking software (EthoVision XT 8.5, Noldus Technology). All data shown are means ± s.e.m. and analyzed using two-way ANOVA with Bonferroni's post hoc analysis and one-way ANOVA with Tukey's post hoc analysis.

Reciprocal Interaction Test

A test mouse and an age- and gender-matched stimulus mouse with a mixed C57BL/6J x 129 genetic background were introduced in an open field arena (50 x 50 cm). Mice were socially naïve with each other. The social interactions of mice were recorded by USB webcam (LifeCam HD-6000, Microsoft) and PC-based video capture software (WinAVI Video Capture, ZJMedia Digital Technology) for 10 min. Time spent in close interaction (less than 5 cm proximity from the body center of each mouse), and time spent in nose-to-nose sniffing (less than 1 cm proximity) were measured automatically by the video-tracking software (EthoVision XT 8.5, Noldus Technology). All data shown are means ± s.e.m. and analyzed using two-way ANOVA with Bonferroni's post hoc analysis.

Barnes Circular Maze Test

The test was performed as described previously (Han et al., 2012). The number of errors made and the latency to find the target hole were measured during the 3 min-training trials by video tracking software. During the 90 second-probe trial, the latency to find the target hole, % correct pokes, and % time in the target area were measured by the video-tracking software (EthoVision XT 8.5, Noldus Technology). All data shown are means ± s.e.m. and analyzed using two-way ANOVA with Bonferroni's post hoc analysis and Student's two-tailed, unpaired t-test.

Contextual Fear Conditioning Test

The test was performed as described previously (Han et al., 2012). % freeze time, and the total distance moved during each 2 min session of habituation, training, 30 min test, and 24 h test were automatically measured by the video-tracking software (EthoVision XT 8.5, Noldus Technology). Freezing behavior is defined as the period during which the velocity of the test mouse is less than 1.75 cm/s, and non-freezing behavior is defined as the period during which the velocity of the mouse is greater than 2 cm/s. All data shown are means ± s.e.m. and analyzed using Student's two-tailed, unpaired t-test.

Brain Slice Electrophysiology

Hippocampal slices preparation and whole-cell voltage-clamp recordings were performed as described previously (Han et al., 2012).

Drug Administration

Clonazepam and zolpidem tartrate (UDL Laboratories, Rockford, IL) were ground from tablets and suspended in phosphate buffered saline (PBS, Sigma), and vigorously vortexed immediately before the injection to prevent the precipitation of the drug particles. L-838,417, and DMCM (Sigma), dissolved in 100 % DMSO (sterile, Sigma) was diluted in PBS (the final concentration of DMSO was ranged from 0.005 % to 0.1 %). Drugs were administered by an intraperitoneal injection in a volume of 0.01 ml/kg 30 min before the behavioral tests.

Statistical Analysis

All data are shown as mean ± s.e.m. and analyzed using Student's t-test, one-way ANOVA with Tukey's post hoc comparison, and two-way ANOVA with Bonferroni's post hoc comparison. All the statistical analyses were done using Prism 6 (GraphPad).

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