Mechanisms of social dysfunction and treatment-related change in Veterans with posttraumatic stress disorder (PTSD)

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ABSTRACT

Introduction:

Many Veterans with PTSD struggle with symptoms of social dysfunction, including isolation [1] and physical violence [2]. Current Veterans Affairs (VA) treatments effectively decrease posttraumatic stress symptoms (PTSS) [3, 4, 5, 6], but do not directly target social dysfunction. In the current study, we investigate deficits in two potential mechanisms: trust and social responsiveness. We propose to use the iterated Trust Game [7, 8]– an economic exchange task that operationalizes trust and social responsiveness– to investigate differences due to PTSS severity. We will also investigate changes after treatment using the Trust Game in a dataset of Veterans undergoing residential treatment for PTSD at a VA Medical Center. We hypothesize that those with greater PTSS severity will show deficits in trust or social responsiveness, and these deficits will assuage with PTSS improvement after treatment.

Methods:

We analyze a cross-sectional dataset of combat-exposed Veterans ($n = 153$) and a dataset undergoing residential treatment for PTSD ($n = 36$). PTSS are measured using the PTSD CheckList (PCL). Each Veteran plays a ten-round variant of the iterated Trust Game. Each

round involves exchange between the Veteran (or "investor") who is endowed $20 each round, and a "trustee", in whom the investor may entrust any portion of the $20. The investment is tripled before being sent to the trustee, and the trustee may return any proportion. Trust is operationalized as investment, and social responsiveness is operationalized as the ability of the trustee's changes in response to the investor—"trustee reciprocity"—to predict changes in the investor's next round investment.

We investigate the two potential mechanisms in the cross-sectional dataset. To determine the relationship between trust and PTSS, we regress investment onto PCL. To investigate the relationship between social responsiveness and PTSS, we regress round change in investment onto the interaction of PCL and trustee reciprocity. We next investigate the impact of treatment in the residential treatment dataset. To determine the impact of PTSS improvement on trust, we regress change in investment onto PCL score change (*posttreatment–pretreatment*). To determine the impact of treatment-related change on social responsiveness, we regress round change in investment onto the interaction of change in PCL (*posttreatment–pretreatment*), visit, and trustee reciprocity.

Results:

In the cross-sectional dataset, higher PTSS correlates with decrease in trust, operationalized as investment ($\beta_1 = -0.002, p = 0.003^{**}, n = 153$). Increase in trustee reciprocity correlates with increase in round change in investment ($\beta_1 = -0.25, p < 0.001^{***}, n = 153$), indicating Veterans were socially responsive. There was no PTSS-related variation in social responsiveness ($0 < \beta_3 < 0.001, p = 0.5, n = 153$). In the residential treatment dataset, less PTSS improvement correlated with decrease in trust after treatment ($\beta_1 = -0.006, p = 0.015^{*}, n = 36$). Veterans were socially responsive ($\beta_1 = 0.39, p < 0.001^{***}, n = 36$), with a decrease in responsiveness at posttreatment ($\beta_5 = -0.29, p = 0.001^{*} n = 36$) and a greater decrease

posttreatment in those with less improvement in PTSS ($\beta_7 = -0.01, p = 0.02^*, n = 36$).

Conclusions:

In the cross-sectional dataset, trust decreased with higher PTSS, while social responsiveness did not change with PTSS severity. This suggests that Veterans with more severe PTSS show deficits in trust, but not social responsiveness, and supports deficit trust as a mechanism for the social dysfunction observed in Veterans with PTSD. In the residential treatment dataset, both trust and social responsiveness decreased with less improvement in PTSS after treatment. This suggests that Veterans whose PTSS do not improve with treatment experience further decline in mechanisms of social functioning after discharge. In the absence of a control group, it is hard to determine whether this decline is due to symptom-related order effect, or unsuccessful treatment itself.

These findings suggest decreased trust, but not social responsiveness, is a mechanism of social dysfunction observed in PTSD. Further investigation into mechanisms of social dysfunction and treatment-related change in Veterans with PTSD, the iatrogenic effects described, and the way these effects can be minimized is also necessary. These findings lend support to treatments that directly target social dysfunction in the context of treatment-resistant post-traumatic stress disorder.

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GENERAL AUDIENCE ABSTRACT

Introduction: Posttraumatic stress disorder (PTSD) is a debilitating mental illness that develops after exposure to life-threatening or traumatic situations. Symptoms can include flashbacks, changes in mood and sleep, and feeling constantly "on-edge". Many Veterans develop PTSD after returning from combat, and in addition to the aforementioned symptoms, can struggle with social difficulties, including isolation [1] and physical violence [2]. Current Veterans Affairs (VA) treatments effectively decrease PTSD symptoms [3, 4, 5, 6], but do not directly target social difficulties.

In the current study, we investigate two potential reasons Veterans might struggle with social situations: trust and social responsiveness. We propose to use the Trust Game[7, 8], which measures representations of trust and social responsiveness, to investigate differences in behavior due to PTSD symptoms. We will also investigate changes in behavior and symptoms after treatment using the Trust Game in a dataset of Veterans undergoing residential treatment for PTSD in a VA hospital. We believe that those with more PTSD symptoms will have either less trust or social responsiveness, and after treatment, any differences will have decreased.

Methods: We analyze one dataset of 153 combat-exposed Veterans with varying PTSD symptoms (the "cross-sectional" dataset), and a second dataset of 36 Veterans undergoing

residential treatment for PTSD ("treatment dataset"). Each Veteran plays ten rounds of the Trust Game. Each round, the Veteran (or "investor") is given $20 and can entrust any whole dollar amount in a "trustee". The trustee receives triple the investment, and the trustee may return any whole dollar amount. The amount sent by the investor is considered a measure of "trust", and the relationship between changes in the investor's behavior and changes in the trustee's behavior is considered a measure of "social responsiveness".

We investigate trust and social responsiveness in the cross-sectional dataset. To determine the relationship between trust and symptom severity, we measure the correlation between the two variables using a linear regression. To investigate the relationship between social responsiveness and symptom severity, we measure how the relationship between change in investment between rounds and change in trustee behavior is related to symptom severity.

We next investigate the impact of treatment. To determine the impact of improvement in symptom severity on trust, we measured the relationship between the change in symptom severity (*posttreatment–pretreatment*) and change in investment. Social responsiveness is considered to be the relationship between change in investment between rounds and change in trustee behavior. To determine the impact of improvement in symptom severity on social responsiveness, we determined differences in this relationship before and after treatment and by change in symptom severity.

Results: In the cross-sectional dataset, more severe PTSD symptoms was related to less investment, suggesting less trust ($\beta_1 = -0.002, p = 0.003^{**}, n = 153$). Investment between rounds changed with change in trustee behavior, ($\beta_1 = -0.25, p < 0.001^{***}, n = 153$), and was not different dependent on PTSD symptom severity ($0 < \beta_3 < 0.001, p = 0.5, n = 153$), suggesting social responsiveness was not related to PTSD symptom severity.

In the residential treatment dataset, less PTSD symptom improvement was related to less in-

vestment after treatment ($\beta_1 = -0.006, p = 0.015^*, n = 36$), suggesting those who improved less also decreased trust after treatment. There was still a relationship between change in investment between rounds and change in trustee behavior ($\beta_1 = 0.39, p < 0.001^{***}, n = 36$). This relationship was less significant after treatment($\beta_5 = -0.29, p = 0.001^* n = 36$) and even less significant with less improvement in symptoms ($\beta_7 = -0.01, p = 0.02^*, n = 36$). This suggests that while there was no real difference in social responsiveness in Veterans before treatment, less improvement in symptoms was related to a decrease in social responsiveness after treatment.

Conclusions: In the cross-sectional dataset, more severe PTSD symptoms was related to less trust but no difference in social responsiveness. This suggests less trust is a potential cause of social difficulties in Veterans with PTSD. In the treatment dataset, both trust and social responsiveness decreased with less improvement in symptoms after treatment. This suggests that Veterans whose symptoms do not improve with treatment have a decline in trust and social responsiveness after treatment. In the absence of a control group, it is hard to determine whether this decline is due to the Veterans playing the game twice, or due to the lack of reduction in symptoms after treatment.

These findings suggest decreased trust, but not social responsiveness, is related to social difficulties observed in Veterans with PTSD. It is important to further look at the decline in social responsiveness and trust in Veterans whose symptoms don't improve as much after treatment and determine whether these changes are truly a harmful side effect of improving less with residential treatment. These findings lend support to PTSD treatments that directly help Veterans with social difficulties, like trauma management therapy and adapted dialectic behavioral therapy.

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List of Abbreviations

β Regression coefficient

$\Delta invest_t$ Change in investment between rounds

$\Delta invest_{t=1}$ Change in $1^s t$ round investment, $posttreatment - pretreatment$

$\Delta recip_{t-1}$ Change in trustee reciprocity, *posttreatment–pretreatment*

$\Delta severity$ Change in PCL symptom severity, *posttreatment–pretreatment*

$\overline{invest}_{t>1}$ Mean investment for rounds after 1st round

$\overline{\ invest}_{t>1}$ Change in mean investment for rounds after 1st round, $posttreatment - pretreatment$

F F statistic, output of the ANOVA

i Raw investment

$invest_t$ Investment as ratio of total possible investment, 20, in a round, t

$invest_{t=1}$ Investment in the first round.

$invest_{t>1}$ Investment in a round after the 1^{st} round

j Raw trustee return

k Raw amount kept by trustee

$recip_{t-1}$ Trustee reciprocity in the prior round

$symptoms$ Posttraumatic stress symptom severity measured by PCL

visit Variable representative of variation at posttreatment in regression

Z Fisher's Z-test statistic

ANOVA Analysis of Variance

AUD Alcohol Use Disorder

AUDIT Alcohol Use Disorder Identification Test

BDI Beck depression inventory

BSL Borderline symptom list

CAPS Clinician Administered PTSD Schedule, DSM-IV version

CAPS-5 Clinician Administered PTSD Schedule, DSM-5 version

DSM-5 Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition

DSM-5 Diagnostic and Statistical Manual of Mental Disorders, fifth edition

DSM-IV Diagnostic and Statistical Manual of Mental Disorders, fourth edition

DUD Drug Use Disorder

DUDIT Drug Use Disorder Identification Test

IRB Institutional Review Board

OEF Operation Enduring Freedom

OIF Operation Iraqi Freedom

OND Operation New Dawn

PCL-5 PTSD CheckList for DSM-5

PCL-M PTSD CheckList for DSM-IV, Military Edition

PTSD Posttraumatic stress disorder

SCID Structured clinical interview for DSM-IV

SCID-5 Structured clinical interview for DSM-5

SD Standard deviation

U Random variation due to subject

VA Veterans Affairs

VAMC Veterans Affairs Medical Center

Chapter 1

Introduction

1.1 Background

Social isolation, relationship difficulties, and uncontrollable anger are intrusive examples of social dysfunction observed in many Veterans with PTSD [2]. Veterans with PTSD exhibit higher rates of physical violence [1], aggression [1, 9, 10, 11, 12, 13, 14] and decreased work, social, and parental functioning [15, 16, 17], especially when PTSD is comorbid with substance use disorder [18]. In addition to these direct effects, social dysfunction can decrease social connectedness [19, 20, 21], which is thought to moderate suicidal ideation and attempts [22, 23, 24]). Social dysfunction is also associated with less treatment-seeking behavior [25], adherence [26, 27], and outcomes [5, 28, 29, 30, 31, 32]. Current Veterans Affairs (VA) first-line treatments effectively decrease many symptoms of PTSD [3, 4, 5, 6], but do not directly target social dysfunction. Of note, there are emerging treatments targeting social dysfunction: prior randomized controlled trials (RCTs) of Trauma Management Therapy in Veterans with PTSD have found that social and emotional rehabilitation components specifically impact subjective measures of social engagement, and suggest multicomponent treatments may successfully target social dysfunction [33, 34, 35, 36, 37]. In the current study, we evaluate two potential mechanisms associated with social dysfunction in Veterans with PTSD, and assess whether each is associated with response to treatment.

1.1.1 Potential Mechanism 1: Disruption in Trust

One construct hypothesized to be both disrupted by trauma as well as important for social functioning is trust. Trust is the belief in another's positive intentions and subsequent willingness to accept social risk. Lower subjective trust has been associated with higher post-traumatic stress symptoms in Veterans and active servicemembers [38], and also has been found to predict less social engagement [19]. Higher levels of subjective trust correlate with viewing friends and family as more supportive, more social support-seeking and less dysfunctional coping behavior [39]. Reduced trust is one potential mechanism of social dysfunction in those with PTSD, as those who do not invest as much in interpersonal interactions may benefit less from relationships and instead solve or cope with problems using ineffective or harmful mechanisms.

Recent work in behavioral economics has operationalized trust using exchange tasks including the Trust Game [7, 8]. In this game, participants are endowed with a sum of money and have the option to send a portion of it to a trustee, who may return some amount without any means of enforcement. The game is designed to capture interpersonal dynamics, including trust and cooperation. These operationalizations assess both the initial propensity to trust, reflected in the investment during the first round, and the ability to sustain cooperation over subsequent rounds, where decisions are influenced by interactions with the trustee. Measuring investment over the course of the game will allow us to determine whether decreased trust and cooperation are mechanisms of social dysfunction in Veterans with PTSD.

1.1.2 Potential Mechanism 2: Disruption in Social Responsiveness

A second potential mechanism of social dysfunction is reduced social responsiveness. Social responsiveness is the degree to which one changes in behavior in response to social signal, and

is used in social learning literature as an observable portion of the complex decision-making process in social situations [40]. Differences in social learning rate have been reported in women exposed to interpersonal violence [41, 42] but have not been studied in Veterans. In the Trust Game, partners learn about others' responses and have the opportunity to adjust their behavior accordingly; observed behavioral changes (or lack thereof) in response to social signal would therefore further motivate investigation into social learning differences in Veterans with PTSD.

Social responsiveness is operationalized in the Trust Game as response to partner reciprocity. Reciprocity is a measure of propensity to respond tit-for-tat [43], and is a strong measure of partner behavior in future rounds [7] in healthy controls. Dyadic interactions in which players respond to partner reciprocity typically develop and maintain more cooperative interactions leading to mutual benefit [44, 45], and in the iterated Trust Game, a partner's reciprocity best predicts a healthy control subject's subsequent trust [7, 46]. Furthermore, response to reciprocity is found to be disrupted in a variety of populations, including those with social anxiety disorder [47], amygdala lesions [48], and autism spectrum disorder [49]. Investigations into the impact of PTSD on reciprocity have focused on female civilians and using versions of the Trust Game with manipulated trustee returns (to be artificially "cooperative" or "uncooperative", either overall or during specific rounds of the game); there was no difference in reciprocity between controls and trauma-exposed civilians [41, 42, 50]. Our study investigates whether Veterans show altered response to partner reciprocity using a classic iterated Trust Game, and provides twofold expansion of the literature. First, it will be the first study of reciprocity in PTSD where subjects are partnered with a player simulated using healthy control data, and will give insight into the impact of PTSD on response to reciprocity in Veterans. Differences in social responsiveness in this context would suggest abnormal behavior in social situations with a healthy partner, specifically leading to less

cooperative interaction and dysfunction in social situations. Secondly, altered social responsiveness provides a behavioral correlate of social learning, and would support investigation of the impact of trauma on social learning.

1.2 The Current Study

These two potential mechanisms of social dysfunction will be investigated in a cross-sectional dataset of 153 Veterans from operations in Iraq and Afghanistan . Symptom-related deficits in trust or social responsiveness specific to this population would focus further investigation into basic learning and social processes disrupted by PTSD. Our study will also measure changes in both trust and social responsiveness in 36 Veterans after 7 weeks of residential treatment for PTSD at the VA Medical Center in Salem, Virginia. It is important to determine whether social deficits moderate treatment outcomes and are still present after intensive treatment to improve high-need population outcomes.

1.2.1 Hypotheses

We propose to use the iterated Trust Game [7, 8] to investigate two potential mechanisms of social dysfunction in Veterans with PTSD: deficits in trust, and deficits in social responsiveness. First, we will investigate whether there is a symptom-related deficit in trust in Veterans with posttraumatic stress symptoms using a cross-sectional dataset. We hypothesize:

> H1) Veterans with more posttraumatic stress symptoms will show decreased trust.

(1.1)

An additional explanation for social dysfunction involves social responsiveness. We will next investigate whether Veterans with posttraumatic stress symptoms have a symptom-related deficit in social responsiveness using a cross-sectional dataset. We hypothesize:

> H2) Veterans with more severe posttraumatic stress symptoms will demonstrate less social responsiveness.

(1.2)

Next we seek to determine any changes in these mechanisms after treatment in a dataset of Veterans undergoing 7 weeks of residential treatment for PTSD. First, we will investigate whether trust and cooperation changes after treatment. We hypothesize:

> H3) Veterans with improvement in posttraumatic stress symptoms between pre- and post-treatment will show increased trust.

(1.3)

Secondly, we will investigate whether social responsiveness changes after treatment. We hypothesize:

> H4) Veterans with improvement in posttraumatic stress symptoms after treatment will demonstrate increased social responsiveness.

(1.4)

Chapter 2

Methods

2.1 Participants

Participants include Veterans from two datasets, including a cross-sectional dataset of recent Veterans that had experienced a DSM-IV Criterion A-qualifying event [51] while in service ($n = 153$), and a treatment dataset of Veterans undergoing seven weeks of residential treatment for PTSD ($n = 36$). Demographic and clinical characteristics are reported in Table 2.1.

2.1.1 Symptom Severity Measurement

Posttraumatic stress symptom severity was measured using the PTSD CheckList (PCL). For the cross-sectional cohort, the PCL-M was collected (PCL-Military Version for DSM-IV; [52]). For the treatment cohort, the PCL-5 was collected (PCL for DSM-5; [53]). PCL-5 score equivalents for the PCL-M were computed for each cross-sectional Veteran using an empirically-derived crosswalk between the two measures [54]. A diagnosis of current PTSD was additionally made using the Clinician Administered PTSD Schedule (CAPS, [55]). Further details of measurement, diagnosis, and comparison of symptom measures across groups is detailed in the Supplemental Methods.

Demographics	Cross-sectional ($n = 153$)	Treatment ($n = 36$)
Age, years	33.6 ± 9.6	49.4 ± 9.9
Sex, male, n, (%)	140 (88.6%)	14 (66.6%)
Race, white, n (%)	98 (62%)	21 (58.3%)

Clinical Characteristics	Control ($n = 70$)[1]	PTSD ($n = 80$)[2]	Pretreatment ($n = 36$)	Posttreatment ($n = 36$)
PTSD symptom severity[3]	23.6 ± 17.0	48.1 ± 13.6	54.0 ± 14.0	40.2 ± 16.6
State Anxiety[4]	35.9 ± 9.0	48.9 ± 10.9	47.0 ± 12.0	–
Depression symptom severity [5]	7.9 ± 9.2	26.4 ± 12.2	32.2 ± 13.0	23.4 ± 16.0
DUD^+/DUD^- [6]	4/55	7/75	–	–
DUD symptoms [7]	–	–	4.6 ± 7.6	2.0 ± 6.6
AUD^+/AUD^- [8]	13/46	35/47	–	–
AUD symptoms [9]	–	–	6.6 ± 8.6	4.3 ± 6.7
Psychotropic medication/none [10]	13/46	34/49	35/0	35/0

Table 2.1: Demographics and clinical characteristics of participants in the cross-sectional and treatment datasets. Data are shown as mean ± SD unless otherwise indicated.

[1]PTSD diagnosis based on CAPS as described in Supplementary Methods

[2]PTSD symptoms calculated using the PCL as described in 2.1.1 PTSD Symptom Severity Measurement and Supplementary Methods.

[3]PTSD symptoms calculated using the PCL as described in 2.1.1 PTSD Symptom Severity Measurement and Supplementary Methods.

[4]State anxiety measured by the SAI-S/ STAI-S as described in Supplemental Methods.

[5]Depression symptoms measured by BDI as described in Supplemental Methods

[6]DUD includes SUD as determined using the SCID as as described in Supplemental Methods.

[7]DUD symptoms measured by the DUDIT as described in Supplemental Methods

[8]AUD includes SUD as determined using the SCID as as described in Supplemental Methods.

[9]AUD symptoms measured by the AUDIT as described in Supplemental Methods

[10]Psychotropic medication includes psychiatric medication and non-psychiatric medication likely to have psychiatric effects. Additional information in supplemental methods.

2.2 Experimental Procedures

2.2.1 Trust Task

Each Veteran played a ten-round variant of the iterated Trust Game, as described in King-Casas et al., 2005 and shown in Figure 2.1. The task involves ten rounds of monetary exchange between an "investor", who is initially endowed with $20 each round, and a "trustee", in whom the investor may entrust any whole dollar proportion of the $20. The investment is always tripled before being received by the trustee, and the trustee may return any proportion of this amount to the investor.

Investment ratio during any round, t, is designated $invest_t$, is the proportion of endowment the investor sends to the trustee. In this study, Veterans were always the investor. The quantity, investment in the first round, is an operationalization of "trust", and $\overline{invest}_{t>1}$ is an operationalization of cooperation. The quantity termed "trustee reciprocity", $recip_{t-1}$, is actually a measure of the trustee's deviation from reciprocity, or change that approximates the investor's change. In normative civilian populations, $\Delta invest_t$ changes in response to changes in $\Delta recip_{t-1}$ [7]; the relationship between an investor's $\Delta invest_t$ and their partner's $recip_{t-1}$ is an operationalization of the investor's social responsiveness. For further information related to these terms and their relationships, see Table 2.2.

Representation	Term	Functional Definition	Formula
$invest_t$	Investment ratio	Investor trust.	$\frac{i_t}{20}$
$return_t$	Return ratio	Trustee reciprocation of trust.	$\frac{j_t}{3*i_t}$
$\Delta invest_t$	Change in investment ratio	Responsiveness of the investor to trustee's behavior.	$invest_t - invest_{t-1}$
$recip_{t-1}$	Trustee reciprocity	Changes in the trustee's behavior relative to changes in investor behavior, in the last round.	$(return_{t-1} - return_{t-2})$ $-\Delta invest_{t-1}$
	Social responsiveness	The relationship between the trustee's reciprocity and the change in investment ratio.	$lm(\Delta invest_t \sim recip_{t-1})$

Table 2.2: Terms measured in the task as related to exchange quantities and task outlined in Figure 1. Abbreviations include i, investment; j, return; t, round.

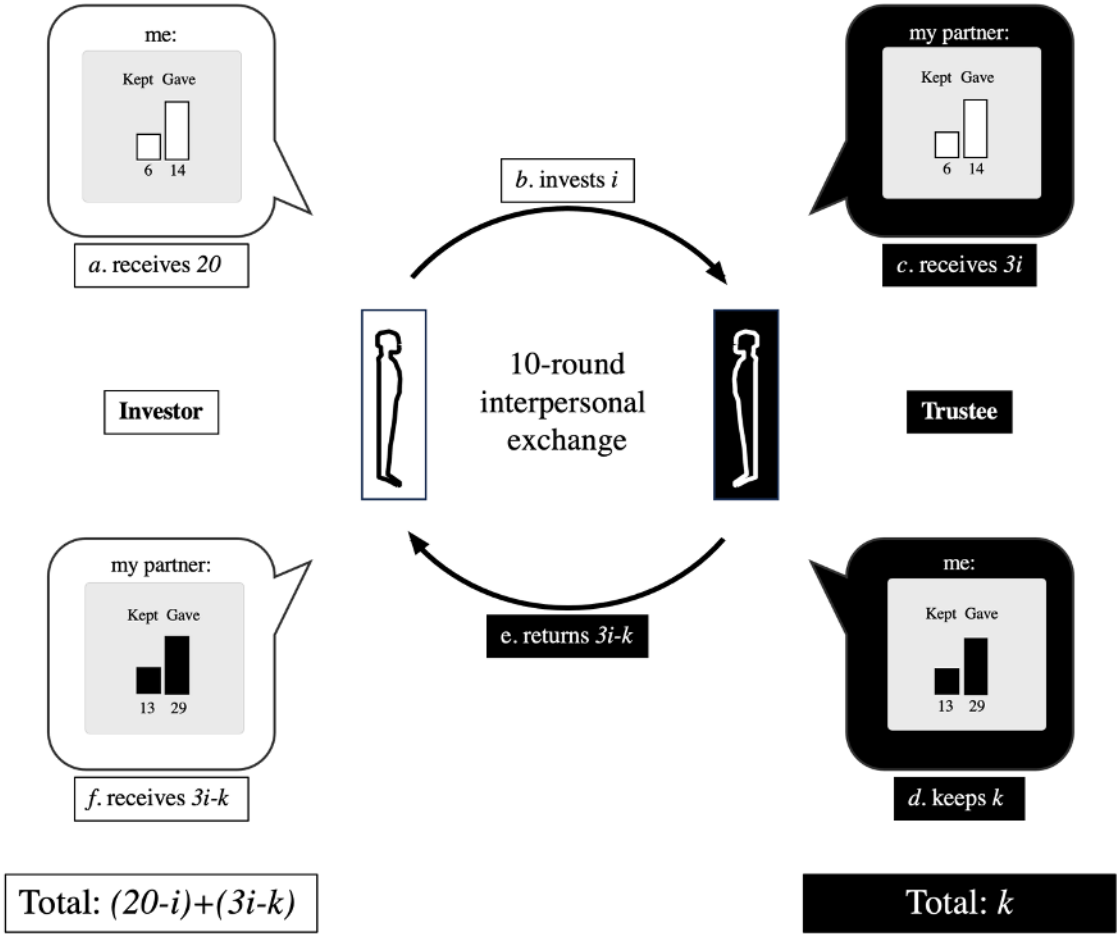

Figure 2.1: Trust Task Experimental Overview. Participants played a resource exchange game with an adaptive computer player over 10 rounds in which a given round consisted of two phases: investment and return. During investment, the player ('Investor') was a. endowed with 20 monetary units ($20) and decided to b. invest any amount, i ($0 to $20), to the computer player ('trustee'). The trustee c. received triple the investment, 3i. During the return phase, the trustee decided to d. keep any amount of the investment, k, and e. return any amount of the investment, $3i - k$. The trustee's final score for the round is k, and the investor's final score for the round is the sum of the amount they kept in the investment phase $(20 - i)$ and any return from the trustee $(3i - k)$.

2.3 Data Analysis

2.3.1 Investigating symptom-related differences trust and cooperation vs. social responsiveness

H1) Veterans with more posttraumatic stress symptoms will show decreased trust.

To investigate whether trust behavior decreases with more severe posttraumatic stress symptoms, we used the symptom severity score, *symptoms*, to predict first round investment, $invest_{t=1}$, in a linear regression of the cross-sectional dataset. The model is reported below:

$$invest_{t=1} = \hat{\beta}_0 + \hat{\beta}_1 \times severity + \epsilon \tag{2.1}$$

To determine whether cooperation is also related to severity, we performed a similar regression predicting mean investment, $\overline{invest}_{t>1}$. The model is reported below:

$$\overline{invest}_{t>1} = \hat{\beta}_0 + \hat{\beta}_1 \times severity + \epsilon \tag{2.2}$$

The $\hat{\beta}_1$ estimates for these regressions indicate the impact of a 1 unit increase in *symptoms* on the value of investment, $invest_{t=1}$ and $\overline{invest}_{t>1}$ respectively. A significant p-value for this coefficient will indicate a significant relationship between symptom severity and either trust or cooperation, respectively.

H2) Veterans with more severe posttraumatic stress symptoms will demonstrate less social responsiveness.

To investigate social responsiveness in Veterans with varying posttraumatic symptom severity, we performed a mixed effect linear regression, correlating reciprocity $recip_{t-1}$ with change in trust between rounds $\Delta invest_t$. The random effect, U, captures variation by individual, v. We determined the fixed effect of $recip_{t-1}$ on current round $\Delta invest_t$ as well as the interaction of $recip_{t-1}$ and $symptoms$. The model is reported below:

$$\Delta invest_{t,v} = \hat{\beta}_{0,v} + \hat{\beta}_{1,v} \times recip_{t-1,v} + \hat{\beta}_{2,v} \times severity_v + \hat{\beta}_{3,v} \times (recip_{t-1,v} \times severity_v) + U_v + \epsilon \tag{2.3}$$

The resultant β_1 estimate indicates how a unit of change in trustee reciprocity impacts round-level change in investment, which is an operationalization of social responsiveness. A significant p-value indicates combat-exposed Veterans in the cross-sectional dataset overall are socially responsive. The β_3 estimate indicates how a 1-point increase in posttraumatic stress symptom severity in the context of increase in trustee reciprocity impacts round-level change in investment. A significant p-value would indicate a relationship between symptom severity and social responsiveness.

2.3.2 Treatment-related Changes

H3) Veterans with improvement in posttraumatic stress symptoms between pre- and posttreatment will show increased trust.

To determine the impact of treatment on trust, we investigated the change in symptom severity before and after treatment, $\Delta symptoms$, and change in investment in the first

round before and after treatment, $\Delta invest_{t=1}$. Change is calculated for each value as *posttreatment–pretreatment*. The model is reported below:

$$\overline{\Delta invest}_{t=1} = \hat{\beta}_0 + \hat{\beta}_1 \times \Delta severity + \epsilon \tag{2.4}$$

We also investigated change in cooperation before and after treatment.

$$\overline{\Delta invest}_{t>1} = \hat{\beta}_0 + \hat{\beta}_1 \times \Delta severity + \epsilon \tag{2.5}$$

The β_1 estimate for each model will indicate how a 1 point change in symptom severity impacts change in investment, and a significant p-value would indicate a relationship between change in severity and change in trust or cooperation respectively.

H4) Veterans with improvement in posttraumatic stress symptoms after treatment will demonstrate increased social responsiveness.

To determine the impact of treatment on social responsiveness in Veterans, we augmented Eq. 2.3. with treatment status (*visit*) and performed a three-way interaction of $recip_{t-1}$, $\Delta symptoms$, and *visit*. The final model is reported below.

$$\begin{aligned}\Delta invest_{t,v} = \hat{\beta}_{0,v} + \hat{\beta}_{1,v} \times recip_{t-1,v} + \hat{\beta}_{2,v} \times \Delta severity_v + \hat{\beta}_{3,v} \times visit + \\ \hat{\beta}_{4,v} \times (recip_{t-1,v} \times \Delta severity_v) + \\ \hat{\beta}_{5,v} \times (recip_{t-1,v} \times visit) + \\ \hat{\beta}_{6,v} \times (\Delta severity \times visit) + \\ \hat{\beta}_{7,v} \times (recip_{t-1,v} \times \Delta severity \times visit) + U_v + \epsilon\end{aligned} \tag{2.6}$$

The β_1 estimate for this model will indicate how a 1-point change in trustee reciprocity impacts round-level change in investment, which is our operationalization of social responsiveness. A significant p-value would indicate social responsiveness overall in this population. The β_4 estimate indicates how a 1-point increase in posttraumatic stress symptom severity in the context of increase in trustee reciprocity impacts round-level change in investment. A significant p-value would indicate different social responsiveness by change in symptom severity, regardless of visit. The β_5 estimate indicates how increase in trustee reciprocity impacts round-level change in investment differently at posttreatment than pretreatment. A significant p-value would indicate different social responsiveness by visit. Finally, the β_7 estimate indicates how 1 point less change in posttraumatic stress symptom severity in the context of increase in trustee reciprocity impacts round-level change in investment differentially at posttreatment, compared to pretreatment. A significant p-value would indicate different social responsiveness by change in symptom severity at posttreatment.

Chapter 3

Results

3.1 Mechanisms of social dysfunction

3.1.1 Symptom-related disruption in trust

H1) Veterans with more posttraumatic stress symptoms will show decreased trust.

To determine whether trust was decreased in Veterans with more severe posttraumatic stress symptoms, two linear regressions were performed as described above using the cross-sectional dataset. More severe posttraumatic stress symptoms, as measured by PCL score, correlated with lower first round investment (Figure 3.1, $\beta_1 = -0.002, p = 0.003^{**}, n = 153$), indicating Veterans with more severe posttraumatic stress symptoms exhibit less trust. Mean investment across later rounds also decreased with increased PCL score ($\beta_1 = -0.003, p = 0.003^{**}, n = 153$), indicating Veterans with more severe posttraumatic stress symptoms also exhibit less cooperation across rounds.

3.1.2 Social responsiveness

H2) Veterans with more severe posttraumatic stress symptoms will demonstrate less social responsiveness.

To investigate social responsiveness in Veterans with varying symptom severity, we performed a mixed effect linear regression as described above , using the cross-sectional dataset. Increase in trustee reciprocity correlated with increase in change in investment (Figure 3.2, $\beta_1 = -0.25, p < 0.001^{***}, n = 153$), indicating Veterans were responsive to changes in partner social signal. There was no variation in relationship between trustee reciprocity and change in investment by symptom severity (Figure 3.2, $0 < \beta_3 < 0.001, p = 0.5, n = 153$).

3.2 Treatment-related changes

3.2.1 Changes in trust

H3) Veterans with improvement in posttraumatic stress symptoms between pre- and post-treatment will show increased trust.

To determine whether trust changed with treatment in Veterans with posttraumatic stress symptoms, two linear regressions were performed as described above, Eq. 2.4 and Eq. 2.5 using the dataset that underwent 7 weeks of residential treatment for PTSD. Less improvement in symptoms correlated with decrease in first-round investment , an operationalization of trust (Figure **??**, $\beta_1 = -0.006, p = 0.015^{*}, n = 36$). Less improvement in symptom severity also correlated with decreased mean investment , an operationalization of cooperation ($\beta_1 = -0.006, p = 0.006^{*}, n = 36$).

3.2.2 Treatment-related changes in social responsiveness

H4) Veterans with improvement in posttraumatic stress symptoms after treatment will demonstrate increased social responsiveness.

To determine whether there was treatment-related change in social responsiveness, we performed a mixed effect linear regression Eq. 2.6 using the dataset that underwent 7 weeks of residential treatment for PTSD. The results of the mixed-effect model are reported in Figure 3.4. Significant effects included a positive correlation between trustee reciprocity and round-level change in investment ($\beta_1 = 0.39, p < 0.001^{***}, n = 36$), with a significant decrease in this correlation at posttreatment ($\beta_5 = -0.29, p = 0.001^{*} n = 36$), and a greater decrease in this correlation at posttreatment in those with less change in posttraumatic stress symptoms ($\beta_7 = -0.01, p = 0.02^{*}, n = 36$). As described in Methods, a positive β_1 and significant p-value suggests Veterans in the treatment dataset show social responsiveness. The negative β_5 and significant p-value suggests Veterans experience a decrease in social responsiveness at posttreatment, and the negative β_7 and significant p-value suggest a greater decrease in social responsiveness at posttreatment for those whose symptoms do not improve as much.

To visualize this complex effect, Veterans were split by median change in PCL into a group that experienced "More Improvement" and "Less Improvement". We ran a new mixed model that interacted improvement status instead of the continuous change in symptom severity. There was no difference in the relationship between trustee reciprocity and change in investment at pretreatment for the two groups ($\beta_4 = -0.28, p = 0.53, n = 36$) nor a difference in relationship between trustee reciprocity and change in investment at pretreatment for the two groups ($\beta_5 = 0.008, p = 0.335, n = 36$). There was a difference in the relationship between trustee reciprocity and change in investment at posttreatment for the group that showed less improvement ($\beta_7 = 0.38, p = 0.002^{**}, n = 36$). This effect was confirmed by an ANOVA

of the mixed effect models with and without the interaction of change in PCL, and reported less variance using the model that included the interaction ($F = 2.9, p = 0.04^{*}, n = 36$).

Mixed effect model Eq. 2.3 was also run separately for the two groups to further confirm this effect was due solely to differences at posttreatment in the group that showed Less Improvement. The More Improvement group showed no difference in the relationship between trustee reciprocity and change in investment between pre- and posttreatment (Figure 3.4, $\beta_3 = 0.04, p = 0.6, n = 36$). The Less Improvement group had a significant decrease in the relationship between trustee reciprocity and change in investment posttreatment. (Figure 3.4, $\beta_3 = -0.32, p < 0.001^{***}, n = 36$).

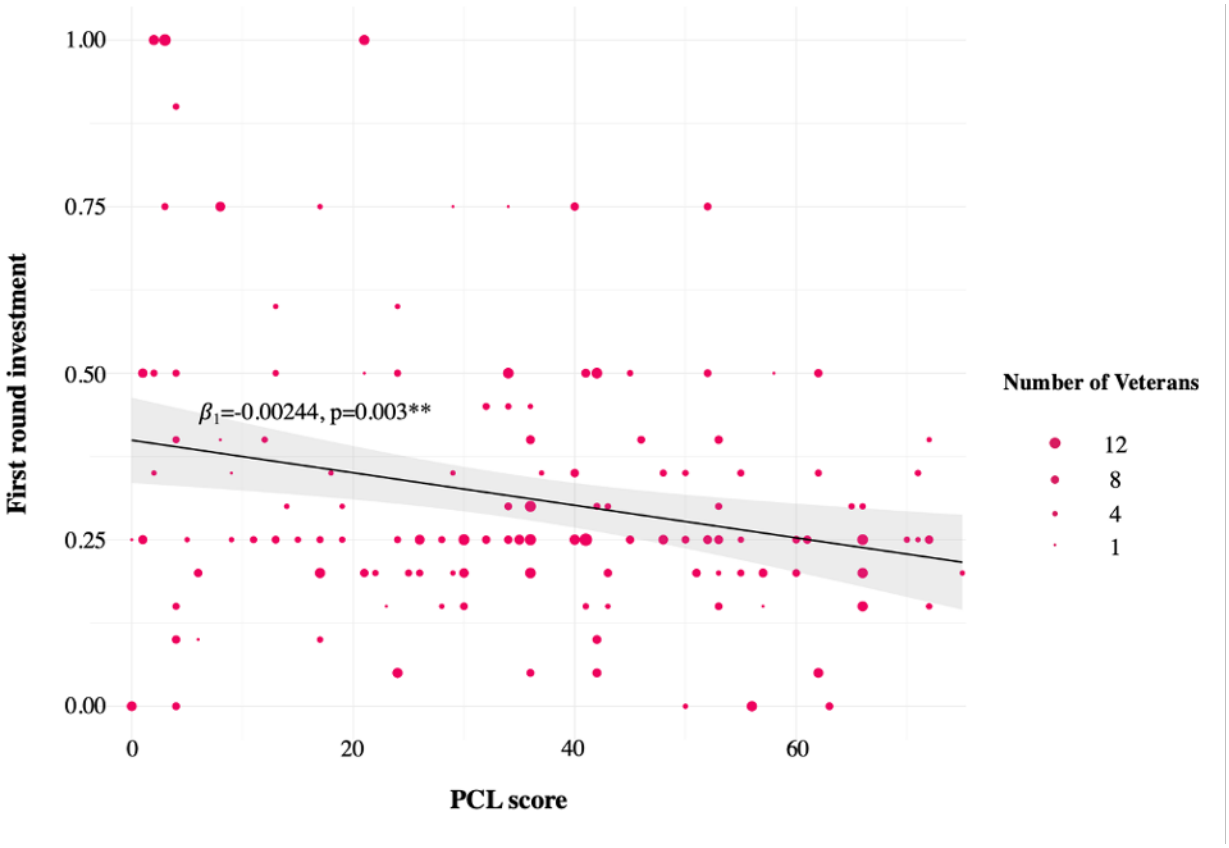

Figure 3.1: The results of regression Eq. 2.1 , relating posttraumatic stress symptoms and trust behavior in a cross-sectional dataset of combat-exposed Veterans, are visualized above. Higher posttraumatic stress symptom severity as measured by the PTSD CheckList (PCL) correlated with decrease in an operationalization of trust, investment during the first round of the iterated trust task ($\beta = -0.002, p = 0.003^{**}$). Higher PCL also correlated with lower cooperation, operationalized as mean investment during the later rounds ($\beta = -0.003, p = 0.003^{**}$).

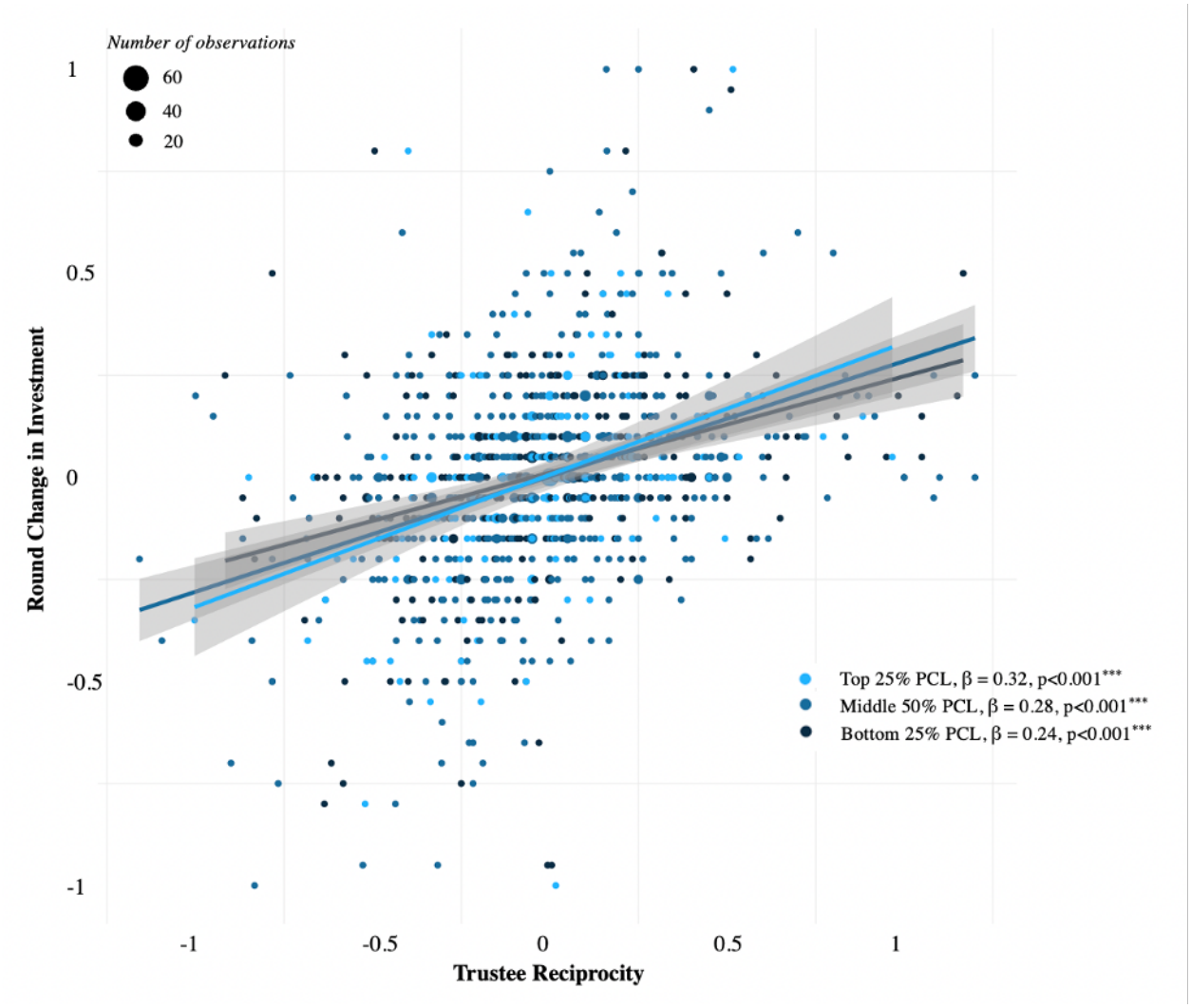

Figure 3.2: Results of regression Eq. 2.3 , relating trustee reciprocity to changes in investment in a cross-sectional dataset of combat-exposed Veterans are reported above, with observations and line of best fit colored by PCL5 quartile (top quartile, middle quartiles, bottom quartile.) Trustee reciprocity correlates with round change in investment ($\beta_1 = 0.32, p < 0.001^{***}, n = 153$), suggesting social responsiveness in this dataset. There is no impact of PCL5 on the relationship between trustee reciprocity and round change in investment ($0 < \beta_3 < 0.001, p = 0.5, n = 153$).

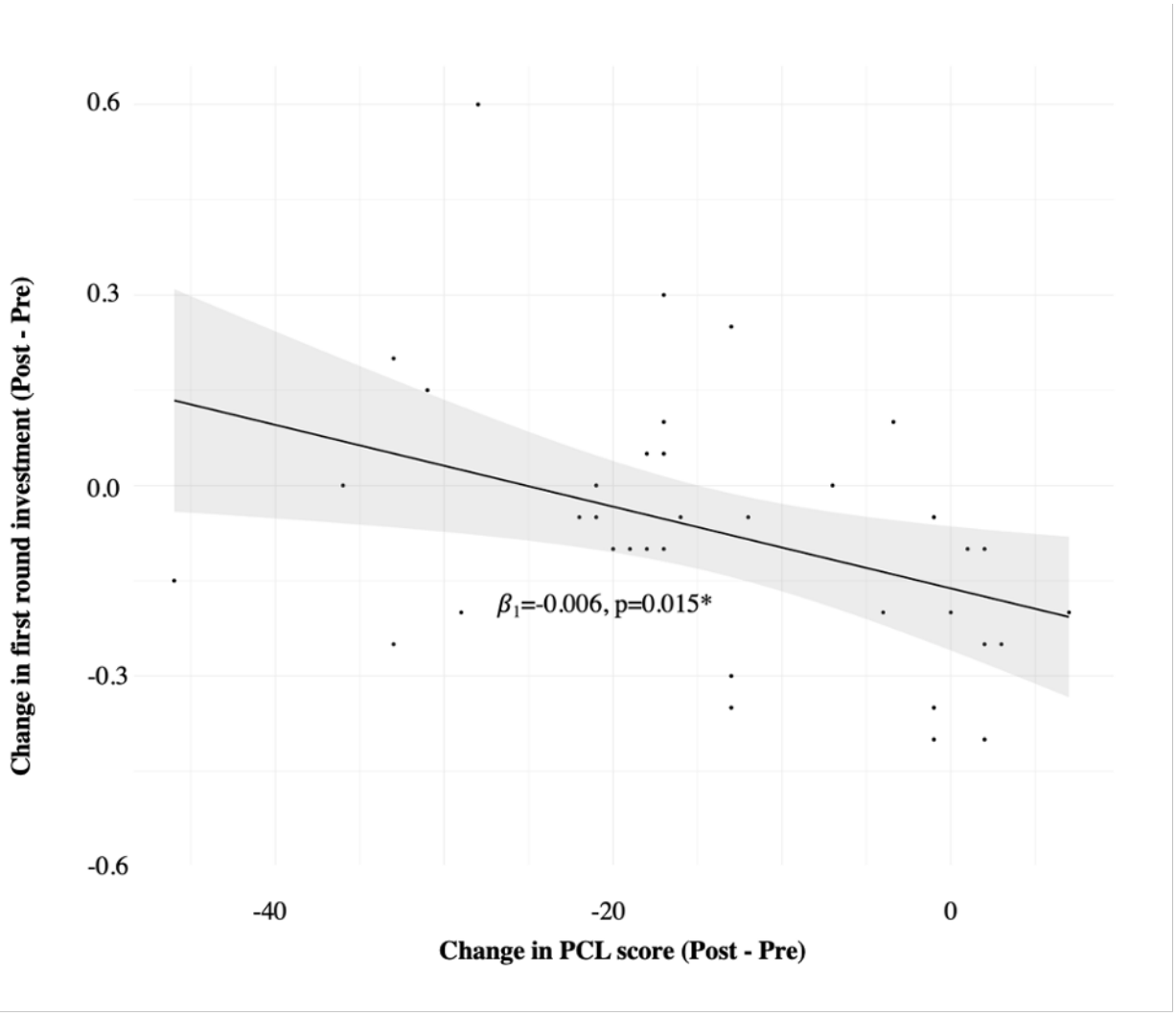

Figure 3.3: The results of regression described in Eq. 2.4, relating posttraumatic stress symptoms and trust before and after 7 weeks of residential PTSD treatment, are reported. Reduction in symptom severity after treatment, measured by PTSD CheckList (PCL) score, correlates with positive change in first round investment between pre and posttreatment; less reduction in severity correlates with decrease in first round investment. ($\beta = -0.006, p = 0.015^{*}$). Reduction in PCL at posttreatment also correlates with increase in mean investment posttreatment (Eq. 2.5, $\beta = -0.006, p = 0.006^{**}$).

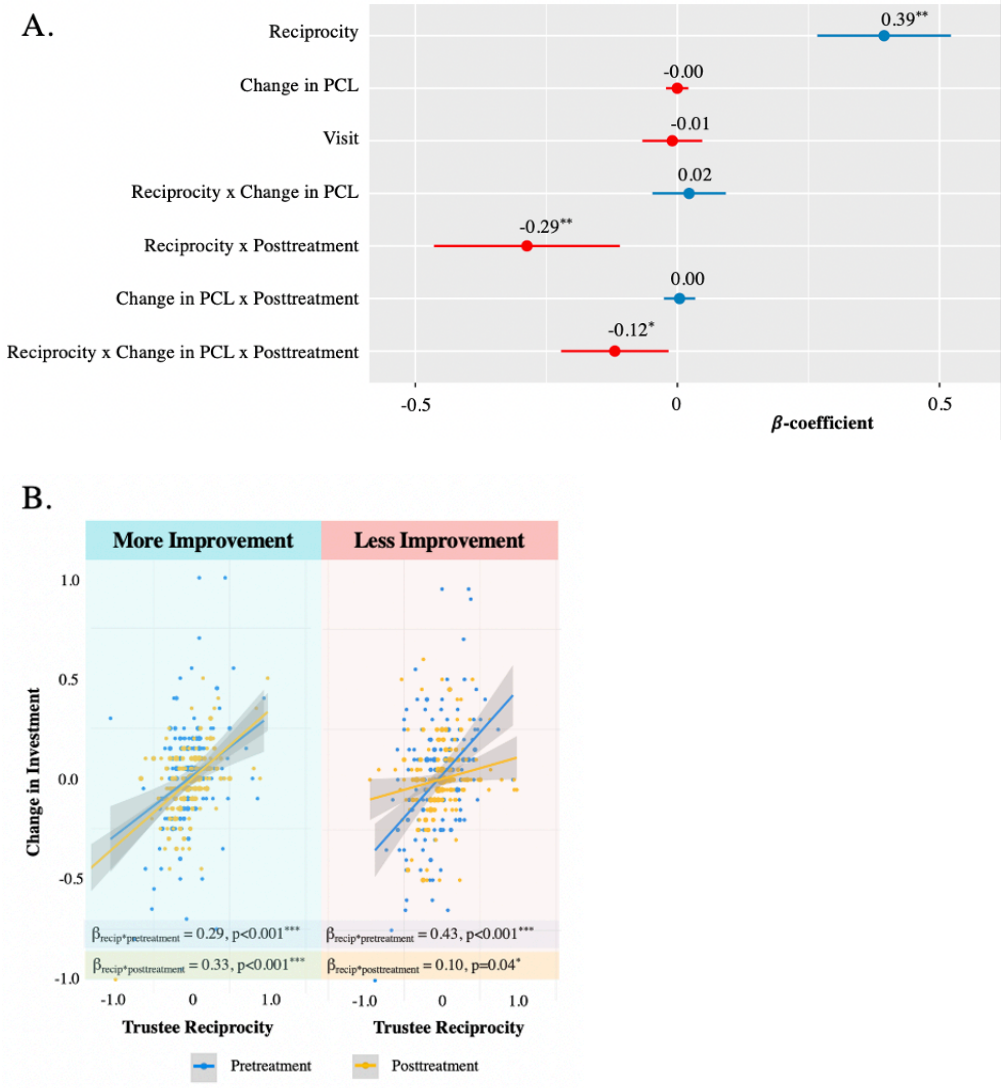

Figure 3.4: Responsiveness differences between those whose symptoms improve with treatment and whose symptoms improve less. A. Mixed effect model of comparing pretreatment and posttreatment interaction of trustee reciprocity and change in symptom severity, measured by PCL *posttreatment–pretreatment*, regressed onto change in investment, Eq. 2.6 . Significant effects included positive correlation between trustee reciprocity and change in investment ($\beta = 0.39, p < 0.001^{***}$), with a significant decrease in correlation between trustee reciprocity and change in investment at posttreatment ($\beta = -0.29, p = 0.001^{*}$), and a greater decrease in reciprocity with higher PCL score at posttreatment ($\beta = -0.01, p = 0.02^{*}$). B. Veterans whose symptoms improved more with residential treatment showed no significant difference in the relationship between trustee reciprocity and change in investment between pre- and posttreatment ($\beta_5 = 0.04, p = 0.6$), whereas those who experienced less improvement exhibited a significantly reduced relationship between trustee reciprocity and change in investment at posttreatment ($\beta_7 = -0.32, p < 0.001^{***}$).

Chapter 4

Discussion

4.1 Mechanisms of Social Dysfunction: Comparing H1 and H2

Our study first sought to use the iterated Trust Game to determine whether lower levels of trust and cooperation or reduced social responsiveness were likely mechanisms of the social dysfunction observed in Veterans with more severe posttraumatic stress symptoms.

H1) Veterans with more posttraumatic stress symptoms will show decreased trust.

Those with greater posttraumatic stress symptoms invested less in their partner in our cross-sectional dataset, both in the first round of the game (Figure 3.1, $\beta = -0.002, p = 0.003^{**}, n = 153$) and over the course of the game ($\beta = -0.003, p = 0.003^{**}, n = 153$). This suggests deficits in both trust and cooperation in those with more severe posttraumatic stress symptoms. This aligns with prior literature that has also found that reduced subjective trust has been associated with higher posttraumatic stress symptoms (PTSS) in literature on Veterans and active servicemembers [38, 56] as well as trauma-exposed female civilians [41, 42, 50].

H2) Veterans with more severe posttraumatic stress symptoms will demonstrate less social responsiveness.

There were no PTSD symptom-related differences in social responsiveness in our cross-sectional dataset. Veterans changed their investment in response to changes in trustee reciprocity (Figure 3.2, $\beta_1 = -0.25, p < 0.001^{***}, n = 153$), regardless of posttraumatic stress symptom severity ($0 < \beta_3 < 0.001, p > 0.05, n = 153$). This finding is supported by previous literature on the Trust Game in trauma-exposed civilians, where there were no reported differences in the relationship between investment and trustee reciprocity [41, 42, 50]. This rejects hypothesis H2, and suggests that social dysfunction in Veterans with more severe posttraumatic stress symptoms are not due to reduced social responsiveness in Veterans with PTSD.

These findings suggest social dysfunction occurs in those with PTSD due to deficit in trust and cooperation, as opposed to deficit in social responsiveness. This suggests that despite less willingness to trust, Veterans with increasing posttraumatic stress symptoms are just as responsive to their partner as peers that express greater trust. These results are especially interesting in the context of literature suggesting social learning rate is slower for interpersonal violence-exposed women and civilians diagnosed with PTSD [41, 42]. Further studies of the Trust Game in trauma-exposed Veterans should include an investigation into their social learning rate, to determine whether these deficits in learning rate are present in males, in Veterans, and in the context of learning over the course of the Trust Game (as opposed to using a paradigm that includes a "cooperative" or "uncooperative" trustee, or time-based manipulations in return.) Further investigations are also necessary to determine whether the deficit in trust is a vulnerability factor for PTSD, due to comorbidities, or caused by PTSD.

4.2 Treatment-related Change

An additional aim of our study was to quantify treatment-related changes to two potential deficits in constructs related to social dysfunction—trust and social responsiveness. We measured operationalizations of these constructs using the Trust Game in a cohort of Veterans undergoing 7 weeks of residential treatment for PTSD at a VA Medical Center, both before and after treatment.

H3) Veterans with improvement in posttraumatic stress symptoms between pre- and post-treatment will show increased trust.

Change in symptom severity after treatment was correlated with trust (Figure **??**, $\beta_1 = -0.006, p = 0.015^{*}, n = 36$) and cooperation ($\beta_1 = -0.006, p = 0.006^{*}, n = 36$), such that less improvement in symptoms correlated with greater decrease in trust and cooperation after treatment. This trend was in the direction expected but the intercept of the correlation ($\beta_0 = -0.18, p =< 0.001^{***}, n = 36$) made it best described as a mitigation of decreased investment in those who improved more, as opposed to an increase in trust after treatment. This rejects hypothesis H3, that Veterans with improvement in symptoms will increase trust after treatment, but does suggest that improvement in symptoms after PTSD treatment correlates with less decrease in trust. A prior study of Vietnam Veterans undergoing treatment found that those who improved with treatment both started and ended with higher trust as measured by the Trust Game than those who did not improve as much; these findings support prior literature that suggests trust is an important construct related to treatment outcomes, and future studies should investigate whether higher trust at pretreatment predicts better treatment outcomes; whether capacity to change trust mediates treatment outcomes; or whether effective treatment changes trust, as well as the relationship between trust, PTSD,

and comorbidities before and after treatment.

H4) Veterans with improvement in posttraumatic stress symptoms after treatment will demonstrate increased social responsiveness.

There was no significant difference in social responsiveness by change in symptom severity in the treatment dataset at pretreatment ($\beta_3 = 0.0023, p = 0.6, n = 36$). However, at posttreatment, there is a decrease in change in investment per unit increase in trustee reciprocity, per unit of increased PCL ($\beta_7 = -0.01, p = 0.02^{*}, n = 36$). In other words, we observed a decrease in responsiveness in those with less improvement posttreatment. (Figure 3.4, $\beta_3 = -0.32, p < 0.001^{***}, n = 36$). Those whose symptoms improve with treatment show no such effect (Figure 3.4 $\beta_3 = 0.04, p = 0.6, n = 36$). This suggests Veterans whose symptoms improve with treatment show no change in social responsiveness after treatment, rejecting hypothesis H4. Furthermore, Veterans whose symptoms improve less with treatment are less socially responsive posttreatment, despite no differences pretreatment.

This iatrogenic effect identified in our study was confirmed by separately running a regression in Veterans with improvement of less than 14.5 points on the PCL (Figure 3.4, $\beta_3 = -0.32, p < 0.001^{***}, n = 36$). Veterans that undergo residential treatment experience a mean decrease of between 6.5 and 17 points on the PCL-5 after treatment [57], suggesting a significant portion of Veterans could experience decreased social responsiveness after treatment.

Decreases in both trust and social responsiveness after treatment provide unexpected but important findings to further investigate to inform residential PTSD treatment. Social dysfunction mediates treatment-seeking behavior [25], adherence [26, 27], and outcomes [5, 28, 30, 31, 32] in Veterans with PTSD; it is important to determine how these iatro-

genic deficits affect daily social functioning and future treatment-seeking behavior. It is also important to determine whether this effect is specific to residential treatment, if a particular population is impacted, and if it can be lessened with additional treatment. Trauma Management Therapy [33, 34, 35, 36, 37], for example, is an evidence-based intervention specifically developed to reduce social dysfunction in Veterans and could be employed outpatient after discharge to reduce iatrogenic social dysfunction in those who responded poorly to treatment.

One important limitation to consider in the context of these results is the lack of waitlist control group. It is possible that Veterans with high symptom severity that does not decrease over time and who play the Trust Game multiple times will demonstrate decreases in trust and social responsiveness. Further studies could investigate the impact of treatment

4.3 Conclusion

In our investigation of two potential mechanisms of social dysfunction in combat-exposed Veterans with varied posttraumatic stress symptoms, we found Veterans with more severe posttraumatic stress symptoms exhibit less trust and cooperation behavior (Figure 3.1) but intact social responsiveness (Figure 3.2). In a dataset of Veterans that underwent 7 weeks of residential treatment, we found that those who show less improvement in posttraumatic stress symptoms decrease trust and social responsiveness at posttreatment (Figure 3.4). This is in contrast to those who show more improvement maintain or increase trust, and maintain social responsiveness at posttreatment (Figure 3.4). Overall, our study contributes to a body of literature characterizing the impact of posttraumatic stress symptoms on social interaction, and suggests future attention be paid to the impact of treatment on social dysfunction.

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Appendices

Appendix A

Supplemental Methods

A.1 Supplemental Participant and Procedure Information

The local Institutional Review Board and VA Research & Development Committees approved all study procedures described below. Prior to participation, procedures were reviewed with potential participants, and study staff answered questions regarding participation. All participants provided written informed consent before commencing study procedures. Throughout the study, procedures were re-reviewed with participants, and participants were reminded they could discontinue participation at any time without penalty and would be compensated for the participation up to that point.

A.1.1 Recruitment and Exclusion Criteria

Subjects were Veterans that served in Operation Iraqi Freedom (OIF), Operation Enduring Freedom (OIF), and/or Operation New Dawn (OND). For the cross-sectional data set, Veterans were recruited from the community, and in the treatment dataset, from the residential PTSD treatment unit at the Salem Veterans Affairs Medical Center (VAMC) in Salem, VA. Individuals who had comorbid psychotic disorders, antisocial personality disorder, or met criteria for substance dependence will be excluded from participation. In the case of sub-

stance dependence, subjects could be included if their substance use was under control for two weeks prior to the study. Participants with neurological disorders, co-morbid mood, anxiety, or other personality disorders, or receiving psychotropic medication, were not excluded unless taking benzodiazepines, which needed to be discontinued under the supervision of psychiatrist two to four weeks prior to beginning the study. Subjects were on a stable medication plan before the study and maintained it throughout the study.

A.2 Supplemental Assessment Information

A.2.1 Comorbidities

In both datasets, Veterans were assessed for comorbidities using the Structured Clinical Interview for the Diagnostic and Statistical Manual (SCID). In the cross-sectional group, the SCID for Axis I Disorders in the DSM-IV was used (First & Gibbon, 2004); in the treatment group, the SCID-5, which is for DSM-5, was used (First et al., 2016). Both groups were also administered the Beck Depression Inventory (BDI, Beck et al., 1961, 1996), which was used to quantify depression symptoms for the demographics in Table 1. Due to staffing difficulties, the SCID was not administered to 12 Veterans in the Treatment dataset; for these Veterans, a putative diagnosis of depression was made given a BDI score suggesting moderate or severe depression symptoms. In the cross-sectional dataset, PTSD symptoms were measured by the Posttraumatic Stress Disorder Check List, Military Version for DSM-IV (Weathers et al., 1991) The PCL-M measure is a self-report consisting of 17 items of criterion B, C, and D PTSD symptoms in the DSM-IV, rated in severity of problem from 1 (not at all) to 5 (extremely), and includes language specifically related to military experiences in questions 1-8, which ask about intrusion (B) and avoidance/numbing (C)

symptoms. In the treatment dataset, PTSD symptoms were measured by the Posttraumatic Stress Disorder Check List for DSM-5 (PCL-5) self-report (Blevins et al., 2015) This measure consist of 20 items inquiring about symptoms of criterion B (intrusion), C (avoidance), D (negative cognitions), and E (changes in reactivity to stimuli) from the DSM-5 criteria for PTSD, rated in severity of problem from 0 (not at all) to 4 (extremely) (American Psychiatric Association, 2013; Blevins et al., 2015).

A.2.2 Diagnosing PTSD

To diagnose PTSD in the cross-sectional and treatment datasets, the Clinician Administered PTSD Schedule was administered (CAPS). The original CAPS was administered to the cross-sectional group 19, and the CAPS for DSM5 (CAPS-5) was administered to the treatment group. Due to staffing difficulties, CAPS-5 data was not collected for 12 Veterans in the treatment dataset. A PCL-5 score of 50 or more, which is used by the US miliary to suggest a putative diagnosis of PTSD, was used as a cutoff to suggest a likely current diagnosis of PTSD for demographic purposes in Table 2.1.

A.2.3 Comparing PTSD Symptoms Across Datasets and Imputing Missing Data

For the treatment dataset, PCL-5 data was missing for 7 individual questions across five individuals, with two individuals as part of pretreatment and three individuals in post-treatment. An additional individual refused to answer the PCL-5 questionnaire, and data was missing for one individual, both at pretreatment. For 24 individuals, CAPS-5 data was collected, and for five of the seven individual questions, as well as the data for the refusal and missing questionnaire, was imputed by dividing the sum frequency/intensity score for

each measure by two, to approximate the score for each missing PCL-5 question. For two individuals that missed an individual question apiece at posttreatment, CAPS-5 was not collected. In this case, the average score for the other questions in the relevant cluster on the PCL-5 was computed and substituted in for the missing question. For the cross-sectional dataset, the Clinician Administered PTSD Scale for DSM-IV was collected in addition to the PCL-M. The CAPS is a clinician-administered semi-structured interview that asks for frequency and intensity of 30 items related to the DSM-IV criteria for PTSD and concludes with the clinician's binary assessment of whether the participant meets all diagnostic criteria for PTSD. All of the questions collected on the PCL-M as a 1-5 Likert scale are also asked and rated in frequency and intensity as a 1-5 Likert scale on the CAPS; in one case where the PCL-M data was missing but the CAPS was present, it was possible to impute the PCL-M score by taking the selected CAPS items and dividing the sum of the frequency and intensity score for each question by 2, to obtain an equivalent PCL-M answer. In addition, the DSM criteria for PTSD significantly changed when the DSM-5 was released in 2013, including splitting cluster B into two clusters and integrating one into a new cluster, D. The PCL-M was updated from a 17-question, 1-5 Likert scale to the PCL-5, 20-question 0-4 Likert scale. To compare the cross-sectional and treatment data PTSD characteristics, a crosswalk study was used to estimate the approximate PCL-5 score based on a given PCL-M score for the cross-sectional data 18.

A.3 Supplemental Task Infromation

A.3.1 Task Instruction

In the cross-sectional dataset, Veterans were informed they would perform the investor role across the repeated exchange and play with either another Veteran or a computer. In the Salem treatment dataset, Veterans were taught the task and informed they may play either the investor or trustee role, but always played the investor role.

A.3.2 Generating the computer player

To ensure that variability was from differences in investors rather than trustees, repayment decisions for each investment were generated using an adaptive computer player based on data from a cohort of prior healthy controls (n=36) as described in the supplementary information of [58]. Choices of the adaptive computer player were generated using a k-nearest neighbors sampling algorithm. For every next decision, a data vector including investment from the current round and the previous round (if present). All returns with all rounds with the same round number as well as the two previous rounds were extracted. Euclidean distance between the indices from the current data vector and those from the selected historical rounds was calculated. The computer player's choices were generated by randomly sampling from the decisions of the five nearest neighbors. If the fifth-closest round shared the same distance as the round(s) above or below it, we shuffled all rounds with the same distance so that they had an equal chance of being sampled from. For decisions within the first round, choices were randomly sampled from all first rounds in the dataset.

Appendix B

Supplemental Regression Outputs

B.1 Cross-sectional

B.2 Treatment

In addition to measuring treatment outcomes, an analysis was performed interacting reciprocity, PCL, and treatment status (instead of change in PCL, as outlined in the methods and discussion.

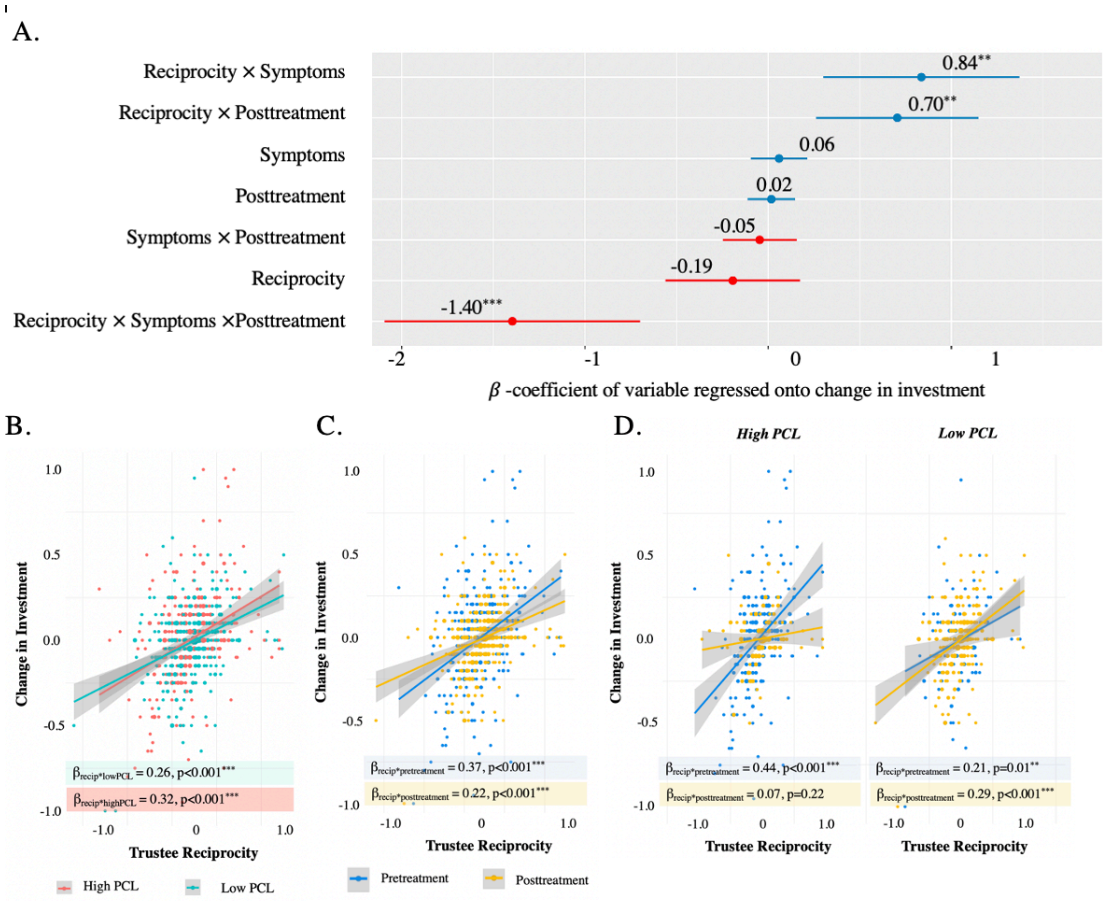

Figure B.1: The results of supplemental investigation into reciprocity and PCL at pretreatment vs. posttreatment, where reciprocity x PCL x t2 (posttreatment) is regressed onto change in investment in a dataset of Veterans that underwent 7 weeks of residential treatment for PTSD. A. Significant fixed effects include positive correlation between reciprocity x PCL and reciprocity at t2, as well as negative correlation between reciprocity x PCL at t2. B. Correlation between trustee reciprocity and change in investment for those with high and low PCL is reported; PCL is median split at a score of 46.5. The interaction of PCL and trustee reciprocity is correlated with change in investment in the normalized (reported above) and unnormalized beta coefficient in the mixed-effect model ($\beta_{recip \times PCL} = 0.01 p = 0.002^{**}$); the visualization is split between those with "high" vs. "low" PCL, where a split is performed at the median (46.5). C. Correlation between reciprocity and change in investment at t1 vs. t2 is reported. The interaction of visit and trustee reciprocity is significant in the normalized (reported above) and unnormalized beta coefficient in the mixed-effect model ($\beta_{recip \times t2} = 0.7 p = 0.002^{**}$). D. Correlation between trustee reciprocity and change in investment at t1 and t2 for those with high and low PCL scores is reported; there is a significant three-way interaction such that, at t2, with higher PCL there is less correlation between trustee reciprocity and change in investment, both in the normalized (above) and unnormalized regressions ($\beta_{recip \times PCL \times t2} = -0.02 p > 0.001^{***}$). There is a significant difference in the correlation between trustee reciprocity and change in investment between t1 and t2 for those with high PCL scores ($Z = 2.36, p = 0.02^{**}$) but not for those with low PCL scores ($Z = -1.63, p = 0.1$).