Social responsiveness buffers internalizing symptoms from social isolation

Shuhan Wang (shuhanwang@vtc.vt.edu)
Fralin Biomedical Research Institute at Virginia Tech Carilion, Roanoke, VA 24016 USA
Department of Psychology, Virginia Tech, Blacksburg, VA 24060 USA

Cong Wang (wcong@vtc.vt.edu)
Fralin Biomedical Research Institute at Virginia Tech Carilion, Roanoke, VA 24016 USA

John M. Wang (wangjm@vtc.vt.edu)
Fralin Biomedical Research Institute at Virginia Tech Carilion, Roanoke, VA 24016 USA

Jacob Lee (jacoblee@vtc.vt.edu)
Fralin Biomedical Research Institute at Virginia Tech Carilion, Roanoke, VA 24016 USA

Nanda Sankarasubramanian (nsankara@vtc.vt.edu)
Fralin Biomedical Research Institute at Virginia Tech Carilion, Roanoke, VA 24016 USA

Ethan Nichols (nethan@vtc.vt.edu)
Fralin Biomedical Research Institute at Virginia Tech Carilion, Roanoke, VA 24016 USA

Abigale Collins (agcollins@vtc.vt.edu)
Fralin Biomedical Research Institute at Virginia Tech Carilion, Roanoke, VA 24016 USA

Brooks Casas (casas@vtc.vt.edu)
Fralin Biomedical Research Institute at Virginia Tech Carilion, Roanoke, VA 24016 USA
Department of Psychology, Virginia Tech, Blacksburg, VA 24060 USA

Pearl H. Chiu (chiup@vtc.vt.edu)
Fralin Biomedical Research Institute at Virginia Tech Carilion, Roanoke, VA 24016 USA
Department of Psychology, Virginia Tech, Blacksburg, VA 24060 USA

Abstract

Social isolation is related to internalizing symptoms, but individual differences exist in the susceptibility to the negative effect of social isolation. Little is known about the factors contributing to such variable outcomes brought on by social isolation. One possibility is that social responsiveness (i.e., adaptability of social behavior) may modulate the relationship between social isolation and internalizing symptoms. In this study, participants played an iterative trust game, where they learned the trustworthiness of social others. Social responsiveness is quantified as responsive investments to others' trustworthiness by computational modeling. We found that social responsiveness attenuated the effect of social isolation on internalizing symptoms, which suggests that social responsiveness is a protective factor against negative outcomes from social isolation.

Keywords: Social responsiveness; Trust game; Social isolation; Internalizing symptoms

Introduction

Social isolation is associated with negative outcomes, including internalizing symptoms (Müller et al, 2021; Butler et al., 2016). Yet, substantial variability of these outcomes was identified in the susceptibility to social isolation, so that someone remains intact while others not (Eddie & Kelly, 2017; Rapier et al., 2019). However, it remains largely unknown what factors may contribute to the individual differences in the susceptibility to social isolation. Social responsiveness, referred to as adjustable phenotypes (e.g., behaviors) according to the social environment, is a candidate factor that might modulates internalizing symptoms (Dingemanse & Araya-Ajoy, 2015; Rappaport & Barch, 2020).

The iterative trust game is used to contextualize social responsiveness during economic exchange as tested for learning of others' strategy and adaptive modulation of behaviors based on social interaction (Chang et al., 2010). Social responsiveness parametrized in the trust game has been proven to be associated with internalizing symptoms (Jin et al., 2023). Given previous findings, we speculate that social responsiveness in the iterative trust game modulates participants' susceptibility to social isolation. More specifically, we hypothesize that: 1) Participants make adaptive response based on learned social other's trustworthiness (i.e., socially responsive) in the trust game; 2) Social responsiveness moderates the relationship between social isolation and internalizing symptoms, such that highly social responsive participants are more resilient to social isolation.

Methods

We recruited 57 participants (30 females, age = 33.88 ± 7.12). Well-established scales that assess participants' social isolation and internalizing symptoms included: UCLA Loneliness Scale (LON), Mood and Anxiety Symptom Questionnaire (MASQ), and Beck's Depression Inventory (BDI).

Participants then completed a 10-round iterative trust game (King-Casas et al., 2005; Figure 1A). In the game, participants played as the "investor" while an anonymous counterpart played as the "trustee". In each round, the investor was endowed with 20 monetary units (MUs) and decided the portion of the MUs to invest in the trustee. The trustee then received tripled investment and decided the portion of the MUs to repay the investor. The total payoff of each player in this round was displayed at the end of each round.

To characterize social learning processes in the trust game, we proposed a belief-based learning model, which assumed that participants learned the trustworthiness of trustees by updating the expectation of their repayments (R_t) following the standard reinforcement learning principle (Sutton & Barto, 1988). Participants' investments (I_t) were fit to learned trustworthiness ($E(R)_{t-1}$) linearly:

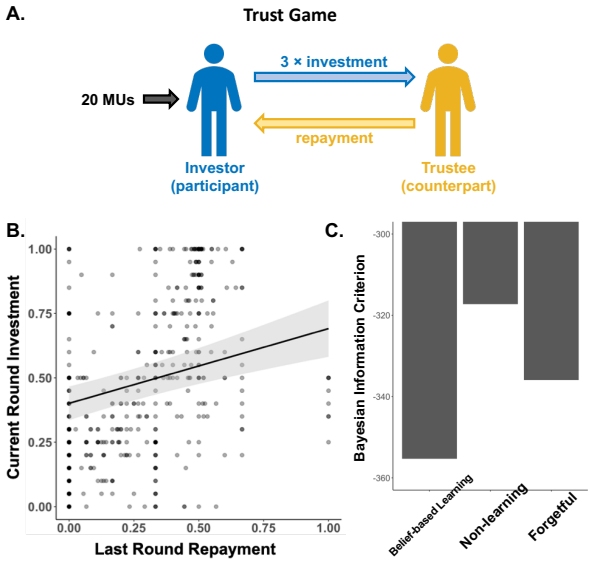

Figure 1. (A) Illustration of trust game. **(B)** Participants' current round investments were predicted by trustees' last round repayments (shown in ratio for both axis). **(C)** Model comparison revealed belief-based learning model as the optimal model.

$$E(R)_t = E(R)_{t-1} + \alpha \times (R_t - E(R)_{t-1})$$
$$I_t = \gamma_0 + \gamma_1 E(R)_{t-1} + \varepsilon$$

where γ_1 represented the adaptive investments based on updated trustworthiness, which was used to index social responsiveness. The model was estimated by hierarchical Bayesian inference using the RStan package.

Two alternative models were considered: 1) A non-learning model, assuming participants were completely non-responsive to trustworthiness, i.e., mean investors; 2) A forgetful model, assuming participants only considered last round trustworthiness, i.e., fast learners ($\alpha = 1$). Alternative models were compared using group-level Bayesian Information Criterion.

Results

To test whether participants used an adaptive social strategy in the trust game, we ran a mixed-effect regression to predict participants' current round investments. We found a significant main effect of trustee's last round repayments (β = 0.29, SE = 0.06, t = 4.97, p < .001; Figure 1B), indicating participants were responsive to trustee's repayment history and adjusted future investments accordingly.

Social belief learning in trust game

Model comparison showed that the belief-based learning model outperformed alternative models (Figure 1C), suggesting participants were responsive to social signals and kept track of more than just last round repayment. We further tested whether learned trustworthiness ($E(R)_{t-1}$) provides predictions of both players' behaviors above and beyond last round repayments (R_{t-1}). Likelihood ratio test showed trustee's current round repayments were better predicted by a full model with both $E(R)_{t-1}$ and R_{t-1} than a reduced model with only R_{t-1} ($\chi^2(1) = 42.28$, $p < .001$). This suggests that dynamically updating trustworthiness facilitated participants better monitoring future repayment of others. Participants' current round investments were also better predicted by a full model with both $E(R)_{t-1}$ and R_{t-1} as regressors than a reduced model with only R_{t-1} ($\chi^2(1) = 140.88$, $p < .001$). This suggest that learned trustworthiness facilitated participants make more responsive investments in the trust game.

Social responsiveness attenuates the effect of social isolation on internalizing symptoms

We next ran a moderation analysis to test whether model-estimated social responsiveness (γ_1) would influence the relationship between social isolation (assessed by LON) with internalizing symptoms (assessed by MASQ and BDI). We found a significant interaction between LON and γ_1 in predicting MASQ (β = -1.89, SE = 0.85, t = -2.21, p = .032; Figure 2A). Similarly, there was a significant interaction between LON and γ_1 in predicting BDI (β = -1.29, SE = 0.55, t = -2.35, p = .022; Figure 2B). These suggest that participants with higher social responsiveness were more resilient to social isolation and thus suffered fewer internalizing symptoms, compared to those with lower social responsiveness. As a comparison, there was no significant interaction between LON and learning rate (α) in predicting neither MASQ nor BDI. The moderations were robust after controlling participants' age and gender.

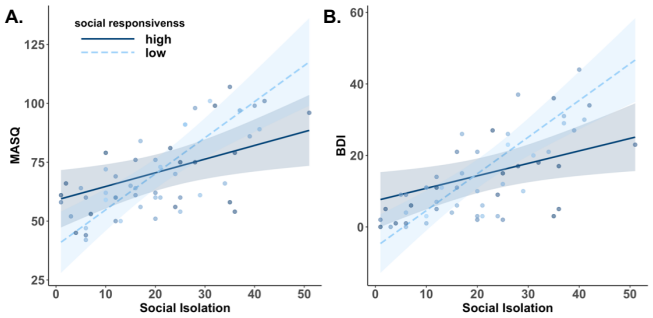

Figure 2. Social responsiveness moderated relationship between social isolation and internalizing symptoms (MASQ and BDI). Moderations are visualized by showing fitted regression curves at high (mean+1.5SD) or low (mean−1.5 SD) level of social responsiveness.

Conclusions

Participants made adaptive investments based on updated expectation of other's trustworthiness in the trust game. Importantly, model-estimated social responsiveness attenuated the relationship between social isolation and internalizing symptoms. One explanation is that with higher social responsiveness, people could benefit more from social support even with limited social connection, preventing the development of depression and anxiety. Overall, the study highlighted a buffering role of social responsiveness against the negative effects from social isolation, which contributes to the resilience especially for those less socially-connected population.

Acknowledgment

This work was funded by the National Institutes of Health (R01AA029222 to PC). We gratefully acknowledge all members of the Chiu and Casas labs at Fralin Biomedical Research Institute at Virginia Tech Carilion.

Reference

Butler, T. R., Karkhanis, A. N., Jones, S. R., & Weiner, J. L. (2016). Adolescent social isolation as a model of heightened vulnerability to comorbid alcoholism and anxiety disorders. *Alcoholism: Clinical and Experimental Research, 40*(6), 1202-1214.

Chang, L. J., Doll, B. B., van't Wout, M., Frank, M. J., & Sanfey, A. G. (2010). Seeing is believing: Trustworthiness as a dynamic belief. *Cognitive psychology, 61*(2), 87-105.

Dingemanse, N. J., & Araya-Ajoy, Y. G. (2015). Interacting personalities: behavioural ecology meets quantitative genetics. *Trends in ecology & evolution, 30*(2), 88-97.

Eddie, D., & Kelly, J. F. (2017). How many or how much? Testing the relative influence of the number of social network risks versus the amount of time exposed to social network risks on post-treatment substance use. *Drug and alcohol dependence, 175*, 246-253.

Jin, Y., Gao, Q., Wang, Y., Dietz, M., Xiao, L., Cai, Y., ... & Zhou, Y. (2023). Impaired social learning in patients with major depressive disorder revealed by a reinforcement learning model. *International journal of clinical and health psychology, 23*(4), 100389.

King-Casas, B., Tomlin, D., Anen, C., Camerer, C. F., Quartz, S. R., & Montague, P. R. (2005). Getting to know you: reputation and trust in a two-person economic exchange. *Science, 308*(5718), 78-83.

Müller, F., Röhr, S., Reininghaus, U., & Riedel-Heller, S. G. (2021). Social isolation and loneliness during COVID-19 lockdown: Associations with depressive symptoms in the German old-age population. *International journal of environmental research and public health, 18*(7), 3615.

Rapier, R., McKernan, S., & Stauffer, C. S. (2019). An inverse relationship between perceived social support and substance use frequency in socially stigmatized populations. *Addictive behaviors reports, 10*, 100188.

Rappaport, B. I., & Barch, D. M. (2020). Brain responses to social feedback in internalizing disorders: A comprehensive review. *Neuroscience & Biobehavioral Reviews, 118*, 784-808.

Sutton, R. S., & Barto, A. G. (1998). *Reinforcement learning: An introduction* (Vol. 1, No. 1). Cambridge: MIT press.