Paranoia, sensitisation and social inference: findings from two large-scale, multi-round behavioural experiments

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Abstract:

The sensitisation model suggests paranoia is explained by over-sensitivity to perceived threat in social environments. However, this has been difficult to test experimentally. We report two pre-registered studies that tested i) the sensitisation model as an explanation of paranoia, and; ii) the role of purported maintaining factors in supporting social sensitisation. In study one, we recruited a large general population sample (*N*=987) who serially interacted with other participants in multi-round Dictator games, matched to fair, partially fair, or unfair partners. Participants rated attributions of harmful intent and self-interest after each interaction. In study two (*N*=1011), a new sample of participants completed the same procedure and additionally completed measures of anxiety, worry and interpersonal sensitivity. As predicted, paranoid ideation predicted higher and faster overall harmful intent attributions, whereas attributions of self-interest were unaffected, supporting the sensitisation model. Contrary to predictions, neither worry nor anxiety predicted harmful intent attributions while interpersonal sensitivity predicted decreased harmful intent attributions. In a third exploratory study we combined data sets to examine the effect of paranoia on trial by trial attributional changes when playing fair and unfair dictators. Paranoia predicted a greater reduction in harmful intent attributions when playing a fair but not unfair dictator, suggesting paranoia may also exaggerate the volatility of beliefs about the harmful intent of others.

1.0 Background

Paranoia is a common feature in psychosis and involves an unfounded belief that others intend harm, now or in the future (1). Paranoid beliefs can be induced by recreational drugs (2,3), following sleep deprivation (4) during or after seizures (5), or from being subject to high stress (6). Paranoia also exists as a continuous trait in the general population and has shown to be characterised by interpersonal sensitivity, mistrust, ideas of reference, and ideas of persecution (7, 8).

Once developed, paranoid beliefs are maintained by several personal and interpersonal factors. On the personal level, worry, insomnia (9) anxiety (10, 11), probabilistic reasoning biases (12), belief inflexibility (13), and safety behaviours (avoiding the source of perceived threat) (14) all contribute to paranoia. Interpersonal cognitive biases also affect how individuals interpret social situations. The most established effect is that those with paranoid beliefs have an externalising attribution bias, whereby causes of negative events are more likely to be attributed to other people (15). Trait interpersonal sensitivity has also been associated with paranoid thinking. Those at high risk of developing psychosis report increased paranoid thinking following simulated interactions in a virtual social environment which was predicted (16) or mediated (17) by interpersonal sensitivity.

The sensitisation model of psychosis argues that environmental stresses and genetic vulnerabilities sensitise biological, cognitive, and affective processes to produce symptoms of psychosis, and importantly, paranoid beliefs (18, 19, 20). Neuroimaging studies have observed increased presynaptic dopamine leading up to (21) and during (22) the development of psychotic symptoms, suggesting aberrant dopaminergic transmission as crucial in sensitisation (23). Experimental data support the sensitisation of cognitive and affective processes that manifests as a ‘jumping to conclusions’ probabilistic reasoning bias (12, 24), high initial mistrust (25, 26) and more threatening or negatively valanced responses following heightened social arousal (27, 28).

One prediction arising from this model is that those high in paranoid ideation will show increased sensitivity to interpersonal interactions, and specifically potential or actual social threat, leading to an increased tendency to attribute harmful intent to others, putatively both more quickly and to a greater degree.

Economic games derived from game theory have been previously used to test the effect of paranoia on intention attributions. These games allow for live social interactions within a tightly controlled environment. Participants make decisions that have outcomes with genuine gains and losses and therefore real, albeit small, harms and benefits (29, 25). Existing research has shown that increases in harmful intent attributions are associated with trait paranoia, social threat (29, 30), social cohesion of task partners (31), and increased relative social rank, and outgroup status, of the interaction partner (32). However, current game theory paradigms in paranoia research that have allowed for participant-to-participant (rather than simulated; 16, 17) interactions have tended to use single round games or brief interactions that are not able to test the effect of paranoia and additional psychological variables on attributions over evolving interactions.

In this study, we implemented a multiple-round game theory interaction using serial Dictator games. The Dictator game has been used widely in paranoia research (29, 30, 32) and involves a situation where two participants are paired and one (the 'dictator') is given a sum of money that they can choose to share with the 'receiver' participant (33). The receiver has no control and must accept any amount that the dictator offers. After each interaction, receivers are required to rate to what extent the dictators were motivated by self-interest or an intent to harm. In the paradigm developed for this study, participants completed six serial Dictator trials against fair, partially fair and unfair partners, while rating harmful intent and self-interest motivating their partner's actions, allowing a test of sensitivity over evolved social interactions. This also allowed us to test the effect of several key affective processes previously identified as important in paranoia, namely anxiety, worry, and interpersonal sensitivity.

The sensitisation model of paranoia suggests several hypotheses we tested over two studies. In study one, we hypothesised that high levels of paranoid ideation would predict earlier and larger harmful intent attributions during the multi-round interaction. In study two we hypothesised that harmful intent attributions would be predicted by anxiety, interpersonal sensitivity, and worry. Studies one and two were preregistered and included hypotheses designed to replicate findings from previous studies (high attribution of harmful intent is associated with higher paranoia and unfair dictators; 29-32) as well as the key experimental hypotheses described above. In study three we combined data from study one and two to complete exploratory analysis to gain better resolution on trial by trial effects, dictator exposure effects, and dictator behaviour overall as each independent sample from study one and two gave varying results.

2.0 Study 1

This study tested the main hypothesis that paranoid ideation predicts the in-the-moment harmful intent attributions within serial interpersonal interactions, both in terms of overall value and by how quickly individuals reach a marker of high harmful intent attribution. The full list of pre-registered hypotheses is given below.

2.1 Methodology

This project was approved by the Kings College London ethics board (**Study 1**: MRS-17/18-8312). All data were collected in September 2018 using Prolific Academic (hereafter Prolific; www.prolific.ac), an online crowdsourcing platform. All data and analysis scripts are available online (https://osf.io/u92rg/).

Prior to taking part in both studies, participants were informed that their participation was voluntary, and were required to tick a box giving consent for the authors to use their anonymous data for research purposes. Using Prolific allowed rapid recruitment of a more demographically diverse sample of participants than recruitment from our social media or university networks (34). We included participants from the UK who were fluent in English and had no current or history of mental illness.

We recruited 987 participants (372 males). Participants first completed the Green Paranoid Thoughts Scale (GPTS; 35). Participants were asked to indicate the extent of feelings described in 32 statements using a Likert Scale of 1 to 5, where 1 = Not at All and 5 = Totally. Scores can range from 32–160, with higher scores indicating a greater degree of paranoia. The GPTS was chosen as a suitable measure as it includes both core aspects of the definition of paranoia (1): social concerns about others and perception of intended harm. It has also shown to be the most reliable and valid scale for measuring paranoia across the clinical and non-clinical spectrum (36). Total paranoia scores were obtained for each participant by summing the response scores to all questions, comprising both the social reference and the persecution scales. Hereafter, this variable is referred to as ‘paranoia’.

After completing the survey, and in keeping with Raihani and Bell (29, 30) we allowed a minimum interval of 7 days to elapse before inviting participants to take part in the multi-round dictator game.

We developed a within-subjects, multi-trial modification of the Dictator game design used in previous studies to assess paranoia (See Appendix A; 29, 30). Each participant played six trials against three different types of dictator. In each trial, participants were told that they had been endowed with a total of £0.10 and their partner (the dictator) had the choice to take half (£0.05) or all (£0.10) the money from the participant. Dictators were set to either always take half of the money, have a 50:50 chance to take half or all of the money, or always take all of the money. This was noted in this study as Fair, Partially Fair, and Unfair, respectively. The order that participants were matched with dictators was randomised. Each dictator had a corresponding cartoon avatar with a neutral expression to support the perception that each of the six trials was with the same partner.

After each trial, participants were asked to rate on a scale of 1-100 (initialised at 50) to what degree they believed that the dictator was motivated a) by a desire to earn more (self-Interest) and b) by a desire to reduce their bonus in the trial (harmful intent). Following each block of six trials, participants were asked to rate the character of the dictator overall by scoring intention again on both scales. Therefore, participants judged their perceived intention of the dictator on both a trial-by-trial and summary level.

After making all 42 attributions (two attributions for each of the 6 trials over 3 partners, plus three additional overall attributions for each partner), participants were put in the role of the dictator for 6 trials – whether to make a fair or unfair split of £0.10. Participants were first asked to choose an avatar from nine different cartoon faces before deciding on their 6 different splits. These dictator decisions were not used for analysis but were collected to truthfully inform participants that decisions were made by real people.

This modification to the original dictator game design allowed us to track how changes in pre-existing paranoia where associated with changes in attributions about partner behaviour and the order of initial partner exposure, and whether attributions were highly variables over trials or consistent. We recruited 812 participants (294 males) back to play the multi-round dictator game. The mean age range of participants was 36-40 in the second sample.

All participants were paid for their completion of the GPTS, regardless of follow up. Participants were paid a baseline payment for their completion of the dictator game, along with any additional bonuses won in the game.

Preregistered predictions (https://aspredicted.org/ka4ny.pdf)

1. High trait paranoia (as measured by GPTS) will be associated with increased attribution of harmful intent to partners across all trials (but trait paranoia will not be associated with variation in attributions of self-interest).
2. Attribution of harmful intent to different dictators will follow a dose-response relationship (fair < partially fair < unfair) across all ranges of paranoia. However, those will high paranoia will have a higher baseline of average harmful intent. There will be no interaction between trait paranoia and dictator fairness on attribution of harmful intent.
3. High trait paranoia will be associated with reaching a peak in harmful intent attribution (defined as a score of 60 or more) in fewer trials when analysing each participant but no difference in attribution of self-interest within each dictator.

Analysis

All analyses conform to those outlined in our preregistration unless stated otherwise.

This study used an information-theoretic approach for all confirmatory analysis. We analysed the data using multi-model selection with model averaging (described in 29, 30). The Akaike information criterion, corrected for small sample sizes (AICc), was used to evaluate models, with lower AICc values indicating a better fit (37). The best models are those with the lowest AICc value. To adjust for the intrinsic uncertainty over which model is the true 'best' model, we averaged over the models in the top model set to generate model-averaged effect sizes and confidence intervals (38). In addition, parameter estimates, and confidence intervals are provided with the full global model to robustly report a variable's effect in a model (39). This used package "MuMIn" (40). All analyses were conducted in R (41). All visualisations were generated using the package 'ggplot2' (42).

In our models, all baseline continuous scale scores were centred and scaled to produce Z values. All model statistics reported are beta coefficients.

Average scores of harmful intention attributions and self-interest for each dictator were taken over each six trials for trial analysis. These were used for cumulative link mixed-models (clmm; 43). Harmful intent and self-interest attributions were set as our dependent variable. Paranoia, dictator order, dictator behaviour (fair, unfair, partially fair), age, sex, and paranoia x dictator behaviour were set as our explanatory terms with ID set as the random term.

For our third prediction, participants that scored above 60 were considered to have scored high harmful intent attributions. Both harmful intent and self-interest scores participants were set a value of 6 if they had scored 60 in their first trial, 5 if they had scored over 60 by their second trial, 4 if they had scored 60 by their third trial, and so on. We report this result, but also wanted to consider a high harm attribution as someone that scored over the mean harmful intent attribution of the population for each dictator. This is also reported in addition to our preregistered plan, which was based on previous mean group estimates. Mean thresholds for each dictator are stated for each analysis in the Results**.** All trials following the threshold being reached were coded as 0. Participants not reaching the threshold for any trial were coded 0 across all trials. Both unfair and fair dictator behaviour were analysed with two cumulative link models (clm) each, one for harm-intent and one for self-interest. This slightly deviates from our preregistration that suggests the use of Kruskal-Wallis and Dunn post-hoc tests, however we decided that using a clm is a more robust way to analyse the data.

For visualisation purposes we calculated paranoia groups based on the quantiles of GPTS scores across the population, and additionally divided those in the top quantile by those exceeding the clinical mean of paranoia defined in previous work (101.9; 35). These divisions were: Low (<36; n = 232) Medium (36-43; n = 180), High (44-59; n = 199), and Very High (59-101.9; n = 167), and Clinical (>102, n = 34). This variable is hereafter named paranoia ‘level’. Slightly different score parameters for each paranoia level were included in our pre-registration but we have adapted them in this study based on our population GPTS quartiles.

2.2 Results

812 participants were included in the analysis. 15 were removed for incomplete data, 24 removed for failing both control questions, and 136 for non-participation in the multi-round dictator game. Mean baseline paranoid ideation in the excluded participants (M = 50.43, SE = 1.62, range = 32-134) were comparable to those that were included in the analysis (t (252) = 0.322, 95%CI: -2.93, 4.08).

Explanatory variables of baseline paranoia score

Paranoia scores ranged from 32-149 with a mean of 51 (SE: 0.74; Skew: 1.7). Older participants were less paranoid (-1.89; 95% CI: -2.22, -1.57), male participants were more paranoid (0.17; 95% CI: 0.04, 0.34), and there was no effect of education on paranoia (-0.39; 95% CI: -1.16, 0.17).

Prediction 1: Paranoia and harmful intent

As predicted, paranoia positively predicted higher HI attributions across all three dictators (0.36, 95%CI: 0.19, 0.53; Table 1). There was no effect of paranoia on SI attributions (0.01, 95%CI: -0.09, 0.11).

Prediction 2: Dictator behaviour and harmful intent

As predicted, as dictators were increasingly unfair (higher proportion of unfair decisions), higher HI attributions were observed (Table 1). SI attributions also increased as a result of unfair dictator behaviour in a similar manner.

Figure 1 depicts the difference in HI and SI attributions between the population when delineated by their paranoia level (low, medium, high, very high, clinical) for both Study 1 and Study 2.

Prediction 3: Paranoia and earlier high harmful intent attributions

As predicted, high (over 60) harmful intent attributions were triggered in earlier trials as paranoia increases for both unfair (-0.12; 95% CI: -0.21, -0.03) and fair (-0.14, 95% CI: -0.33, -0.01) dictators. This was not found for SI attributions (see Appendix B).

Exploratory analysis

We also completed an analysis using a relative threshold for earlier high decisions based on the mean of the population for each dictator rather than a pre-set cut-off of 60 as in the preregistered analysis. For unfair dictators, high (mean = 53.51) HI attributions were triggered in earlier trials as paranoia increased (-0.12; 95% CI: -0.20, -0.02). However, this wasn't found for fair dictators (mean = 24.26) (-0.06; 95% CI: -0.19, 0.01). This was not found for SI attributions in either dictator condition.

See figure 2 (a) for trial-by-trial average attributions across participants for study 1 and 2.

Table 1. Variables effecting Harmful Intention and Self Interest scores in the multi-round dictator game (Study 1). Harmful Intent was coded as a five-level ordinal categorical variable and set as the response term in the clmm. ID was set as the random variable (43). Relative Importance is the probability that the term in question is a component of the true best model and a value for the amount of times the term is included in the selection of top models to be averaged. Order refers to the order in which a fair, partially fair, or unfair dictator was presented to participants.

Parameter	Estimate	Standard Error	95% CI		Relative Importance
			Lower	Upper	
Harmful Intent Attributions					
Intercept 1|2	-1.26	0.11	-1.48	-1.05	
Intercept 2|3	0.47	0.10	0.27	0.68	
Intercept 3|4	2.17	0.12	1.94	2.39	
Intercept 4|5	3.67	0.14	3.41	3.94	
Dictator (Fair < Partially Fair < Unfair)	2.22	0.09	2.06	2.39	1
Order (Fair < Partially Fair < Unfair)	-1.12	0.15	-1.42	-0.83	1
Paranoia (Z score)	0.36	0.09	0.19	0.53	1
Dictator x Paranoia	0.14	0.10	-0.06	0.34	0.79
Sex (Male)	-0.03	0.11	-0.26	0.19	0.25
Self Interest Attributions					
Intercept 1|2	-6.53	0.25	-7.01	-6.05	
Intercept 2|3	-5.25	0.21	-5.66	-4.84	
Intercept 3|4	-3.15	0.16	-3.46	-2.84	
Intercept 4|5	-0.28	0.11	-0.50	-0.07	
Dictator (Fair < Partially Fair < Unfair)	4.33	0.17	3.99	4.67	1
Order (Fair < Partially Fair < Unfair)	-0.82	0.16	-1.13	-0.50	1
Paranoia (Z score)	0.01	0.05	-0.09	0.11	0.24
Sex (Male | Female)	-0.03	0.11	-0.23	0.18	0.23

3.0 Study 2

We tested whether interpersonal sensitivity (Interpersonal Sensitivity Measure; ISM) (44), state and trait anxiety (STAI) (45) and worry (46) – key affective processes involved in paranoid ideation - would account for within-group harmful intent attributions. The full list of pre-registered hypotheses is given below.

3.1 Methodology

This project was approved by the Kings College London ethics board (Study 2: LRS-18/19-9281). Data were collected in February 2019 using Prolific. All data and analysis scripts are available online (https://osf.io/u92rg/).

We recruited 1011 participants (374 males). Participants recruited for this study were not participants in Study 1. All study procedures and analyses were identical to Study 1 aside from the inclusion of anxiety, worry and interpersonal sensitivity measures.

We assessed both trait anxiety and state anxiety using the STAI (45). It is comprised of two subscales, one for trait and one for state anxiety, each made of 20 items. Each item is rated on a scale of one to four, from “Almost Never” to “Almost Always”. The trait measure was given to participants at baseline alongside the GPTS. The state measure was given immediately after the multi-round dictator game.

We measured interpersonal sensitivity using the ISM (44). The ISM is comprised of five subscales: Fragile Inner Self (5 items), Need for Attachment (8 items), Interpersonal Awareness (7 items), Timidity (8 items), and Separation Anxiety (8 items). Each item is on a scale of one to four, from “Very Unlike You” to “Very Like You”. Subscales are summed to form summary scores. The ISM was given at baseline alongside the GPTS.

We also measured worry using the Penn-State Worry Questionnaire (PSWQ) (46) as worry has been additionally implicated as highly predictive of paranoia (1). The PSWQ is comprised of 16 items, each on a scale of one to five, from “Not at all typical of me” to “Very typical of me”. The PSWQ was given at baseline alongside the GPTS.

All analyses conform to our preregistration unless stated otherwise.

Preregistered predictions (http://aspredicted.org/yz5gr.pdf)

We pre-registered the following predictions:

1. State anxiety will be associated with increased harmful intent attributions (but not self-interest attributions) to partners when averaged across all trials within each partner.
2. There will be an interaction between state anxiety and trait paranoia leading to increased attribution of harmful intent (but not self-interest attributions) to partners across all trials.
3. High interpersonal sensitivity (as defined by Boyce & Parker) scores will be associated with increased harmful intent attributions (but not self-interest attributions) to partners when averaged across all trials within each partner.
4. High scores on interpersonal sensitivity subscales of ‘Fragile Inner Self’ and ‘Interpersonal Awareness’ will be associated with increased harmful intent attributions (but not self-interest attributions) to partners when averaged across all trials within each partner.
5. There will be an interaction between state anxiety and trait paranoia leading to a decreased number of trials before a high (> mean) attribution score of harmful intent (but not self-interest attributions) to partners is triggered separately across unfair and fair dictators.

We included the explanatory variables from the STAI, PSWQ and ISM in our cumulative link mixed models alongside the GPTS scores with ID set as the random variable. All continuous variables were z-score transformed. All model statistics reported are beta coefficients unless stated otherwise.

3.2 Results

885 participants remained in the analysis. 8 were removed for incomplete data and 118 for non-participation in the multi-round dictator game. Mean baseline paranoid ideation in the excluded participants (M = 58.54, SE = 2.35, range = 32-140) were higher than participants that were included in the analysis (t (153) = -2.41, 95%CI: -10.85, -1.09) by a small amount.

Explanatory variables of baseline paranoia

Paranoia scores ranged from 32-159 with a mean of 53 (SE: 0.45; Skew: 1.54). Older participants were less paranoid (-0.05; 95% CI: -0.05, -0.04), there was a negligible effect of being male on paranoia (0.05; 95% CI: -0.04, 0.24), and there was a quadradic (-1.20, 95%CI: -1.80, -0.60) relationship between education and paranoia. Paranoia positively correlated with all baseline variables (see Figure 3). For a detailed distribution of the data see Appendix C.

Replication of main findings of study 1

Paranoia positively predicted higher HI attributions across all three dictators. There was no effect of paranoia on SI attributions. Additionally, unfairness of dictator was associated with higher HI and SI attributions. Order effects were also replicated**.** See Figure 1 and Table 2.

For unfair dictators, high (mean = 46.56) HI attributions were not uniformly observed in earlier trials as paranoia increased (-0.06; 95% CI: -0.17, 0.01), but were for fair dictators (mean = 21.39) (-0.12; 95% CI: -0.20, -0.03). Paranoia was not associated with high SI attributions in earlier trials in either dictator condition.

Figure 2b shows average trial by trial attributions for each level of paranoia in **Study 2**.

Table 2. Variables effecting Harmful Intent and Self Interest scores in the multi-round dictator game. Harmful Intent was coded as a five-level ordinal categorical variable and set as the response term in the clmm. ID was set as the random variable (43). Relative Importance is the probability that the term in question is a component of the true best model and a value for the amount of times the term is included in the selection of top models to be averaged. Order refers to the order in which a fair, partially fair, or unfair dictator was presented to participants.

Parameter	Estimate	Standard Error	95% CI		Relative Importance
			Lower	Upper	
Harmful Intent Attributions					
Intercept 1|2	-0.64	0.23	-1.09	-0.18	
Intercept 2|3	1.28	0.24	0.82	1.74	
Intercept 3|4	2.95	0.25	2.47	3.43	
Intercept 4|5	4.38	0.26	3.88	4.89	
Dictator (Fair < Partially Fair < Unfair)	2.00	0.09	1.82	2.18	1
Order (Fair < Partially Fair < Unfair)	-1.17	0.17	-1.52	-0.83	1
Paranoia (Z score)	0.35	0.10	0.15	0.54	1
Sex (Male | Female)	-0.16	0.21	-0.71	0.10	0.52
Age	0.00	0.01	-0.01	0.02	0.32
Self Interest Attributions					
Intercept 1|2	-6.59	0.35	-7.27	-5.91	
Intercept 2|3	-5.35	0.33	-5.99	-4.71	
Intercept 3|4	-3.16	0.30	-3.75	-2.58	
Intercept 4|5	-0.21	0.28	-0.75	0.33	
Dictator (Fair < Partially Fair < Unfair)	4.59	0.17	4.26	4.93	1
Order (Fair < Partially Fair < Unfair)	-0.71	0.16	-1.02	-0.39	1
Age	0.00	0.01	-0.02	0.00	0.43
Paranoia (Z score)	-0.03	0.07	-0.28	0.09	0.34
Sex (Male | Female)	0.01	0.07	-0.31	0.43	0.11

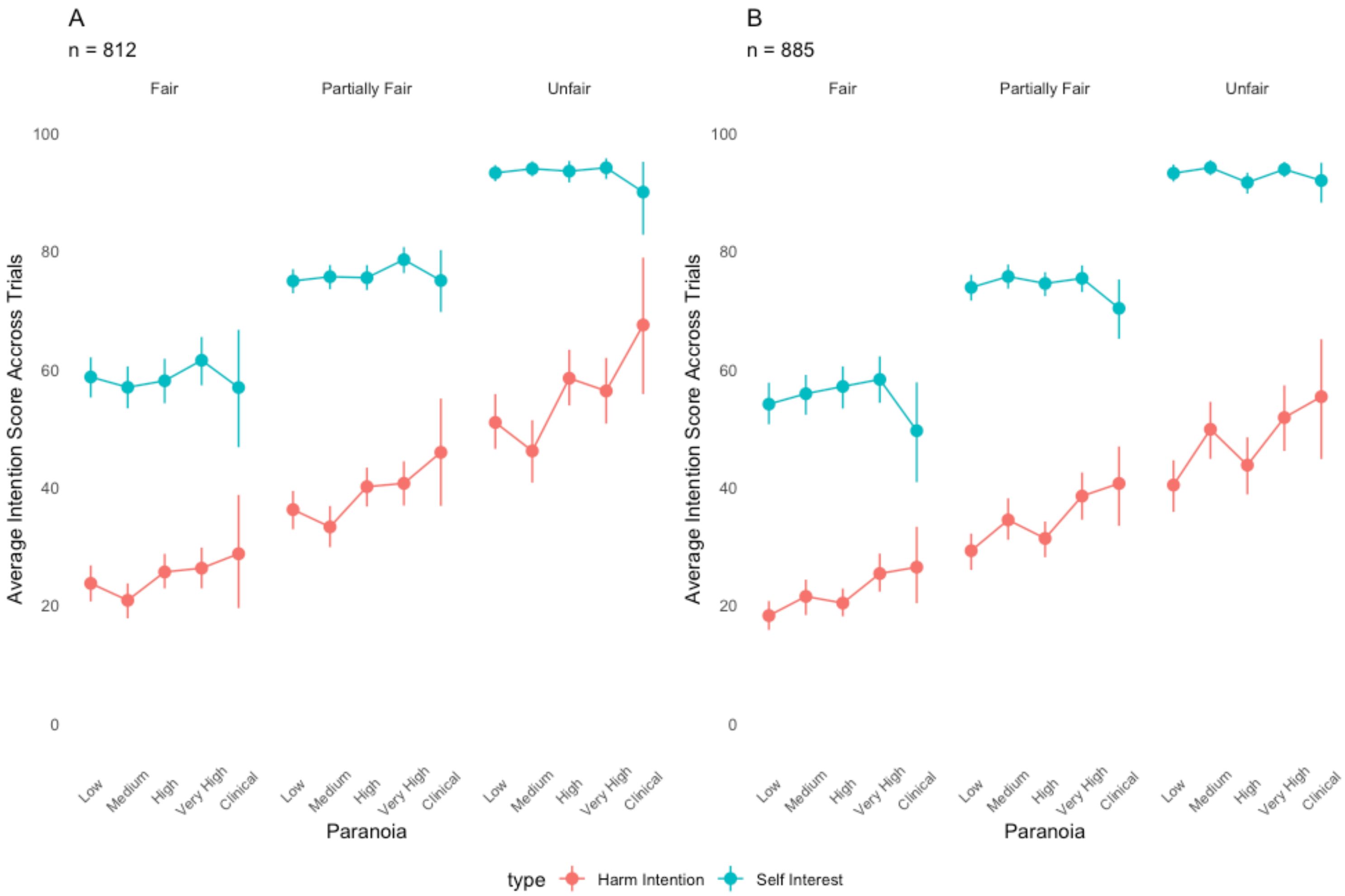

Figure 1. Average Self-Interest attributions (Blue) and Harmful Intent attributions (Red), averaged across trials for divisions of GPTS score and faceted by each type of dictator for both study 1 (A) and study 2 (B). Dots represent the mean for each level of paranoia. Lines represent the 95% confidence interval. Participants played against different partners in a pseudo-random order. ‘Clinical’ refers to participants in the general population who scored past the threshold for GPTS scores typical in clinical populations (101.9; 35). We found that the degree of fairness proportionally scaled harmful intent scores across all levels of paranoia. This was also true for self-interest scores. However, paranoia increased harmful intent scores within each condition. This was not true for self-interest scores.

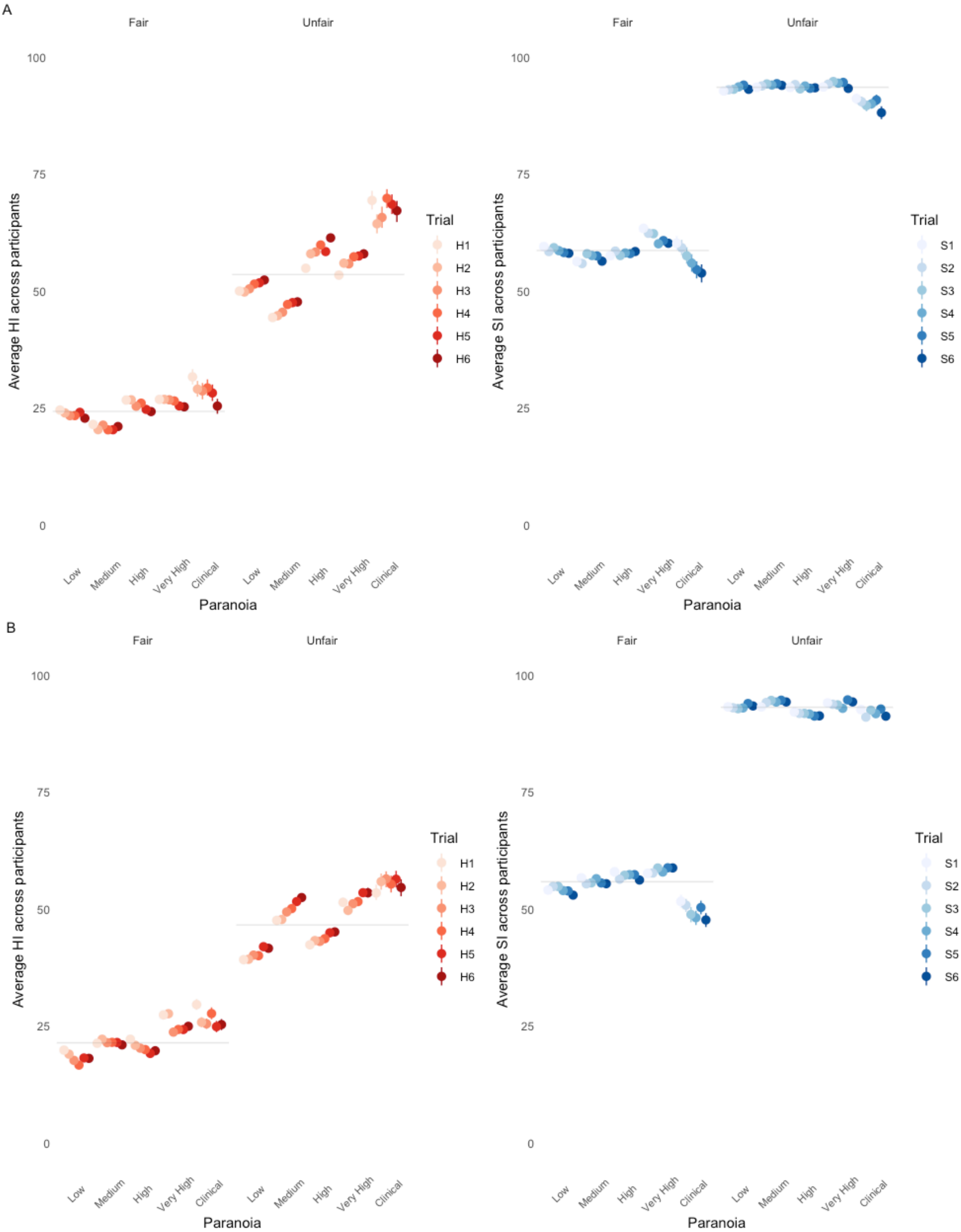

Figure 2. Average Harmful Intent (Red) and Average Self-Interest (Blue) attributions for each trial across divisions of GPTS scores, faceted by type of dictator for study 1 (A) and study 2 (B). Points = mean, bars = 95% confidence interval. Grey lines = mean score across the group. 'Clinical' refers to participants in the general population who scored past the threshold for GPTS scores typical in clinical populations (101.9; 35).

Predictions 1 and 2: State anxiety, paranoia and harmful intent

Contrary to predictions, state anxiety did not predict overall HI or SI attributions in any dictator condition and there was no interaction with paranoia.

Prediction 3 and 4: Interpersonal sensitivity, paranoia and harmful intent

Contrary to predictions, interpersonal sensitivity predicted a decrease in overall HI but not SI attributions across all dictators. There was no interaction between interpersonal sensitivity and paranoia for HI or SI attributions across all dictators.

Similarly, the “interpersonal awareness” subscale of the ISM was associated with a decrease in HI attributions overall across dictators and the ‘separation anxiety’ subscale of the ISM also was associated with an increase in HI attributions overall across dictators. The ‘need for attachment’ and ‘timidity’ subscales were not associated with an increase in HI attributions. The ‘Interpersonal awareness’ subscale score of the ISM was associated with increased SI attributions overall across dictators. ‘Need for attachment’ subscale scores of the ISM was associated with increased SI attributions and ‘timidity’ predicted decreased SI attributions overall across dictators.

Paranoia remained a strong predictor of HI attributions but not SI attributions for all models. See Table 3 for the effect sizes for all predictors.

Prediction 5: Anxiety, paranoia, and trials to peak decision

Contrary to predictions, state anxiety alone and its interaction with paranoia didn’t predict scoring above the mean in an earlier trial for HI and SI attributions during both unfair and fair dictators.

Table 3. Summary of extra explanatory variables effecting Harmful Intention and Self Interest attributions in the multi-round dictator game (Study 2). Harmful Intent was coded as a five-level ordinal categorical variable and set as the response term in the clmm. ID was set as the random variable (42). Relative Importance is the probability that the term in question is a component of the true best model. Numbers denote the model that the parameter belonged to for each outcome variable. E.g. under Harmful intent Attributions, Separation Anxiety and Timidity were run in the same model (4) but separate to Trait Anxiety (1). NA = not included in the final top model. Paranoia was included as an independent variable in each model.

Model	Parameter	Estimate	Standard Error	95% CI		Relative Importance
				Lower	Upper	
	Harmful Intent Attributions					
1	Trait Anxiety	-0.19	0.12	-0.42	0.05	1
2	State Anxiety	0.00	0.04	-0.19	0.23	0.14
3	Interpersonal Sensitivity	-0.29	0.12	-0.52	-0.06	1
4	Interpersonal Awareness	-0.54	0.13	-0.80	-0.28	1
4	Separation Anxiety	0.36	0.14	0.08	0.64	1
4	Timidity	-0.02	0.07	-0.34	0.14	0.22
4	Need for Attachment	-0.01	0.03	-0.09	0.07	0.19
4	Fragile Inner Self	0.01	0.07	-0.22	0.38	0.18
5	Worry	-0.06	0.06	-0.18	0.05	1
1-5	Paranoia (Range)	0.34 - 0.60	0.06 - 0.14	0.13 – 0.38	0.54 - 0.88	1-1
	Self Interest Attributions					
6	Trait Anxiety	0.05	0.08	-0.06	0.29	0.41
7	State Anxiety	0.14	0.12	-0.01	0.38	0.76
8	Interpersonal Sensitivity	NA	NA	NA	NA	NA
9	Interpersonal Awareness	0.31	0.14	0.04	0.58	1
9	Separation Anxiety	-0.02	0.07	-0.38	0.15	0.16
9	Timidity	-0.46	0.11	-0.68	-0.23	1
9	Need for Attachment	0.28	0.11	0.07	0.48	1
9	Fragile Inner Self	-0.05	0.10	-0.38	0.10	0.35
10	Worry	0.18	0.12	0.01	0.40	0.86
6-10	Paranoia (Range)	-0.03 - -0.10	0.05 - 0.11	-0.28 – -0.35	0.02 – 0.11	0.31 – 0.58

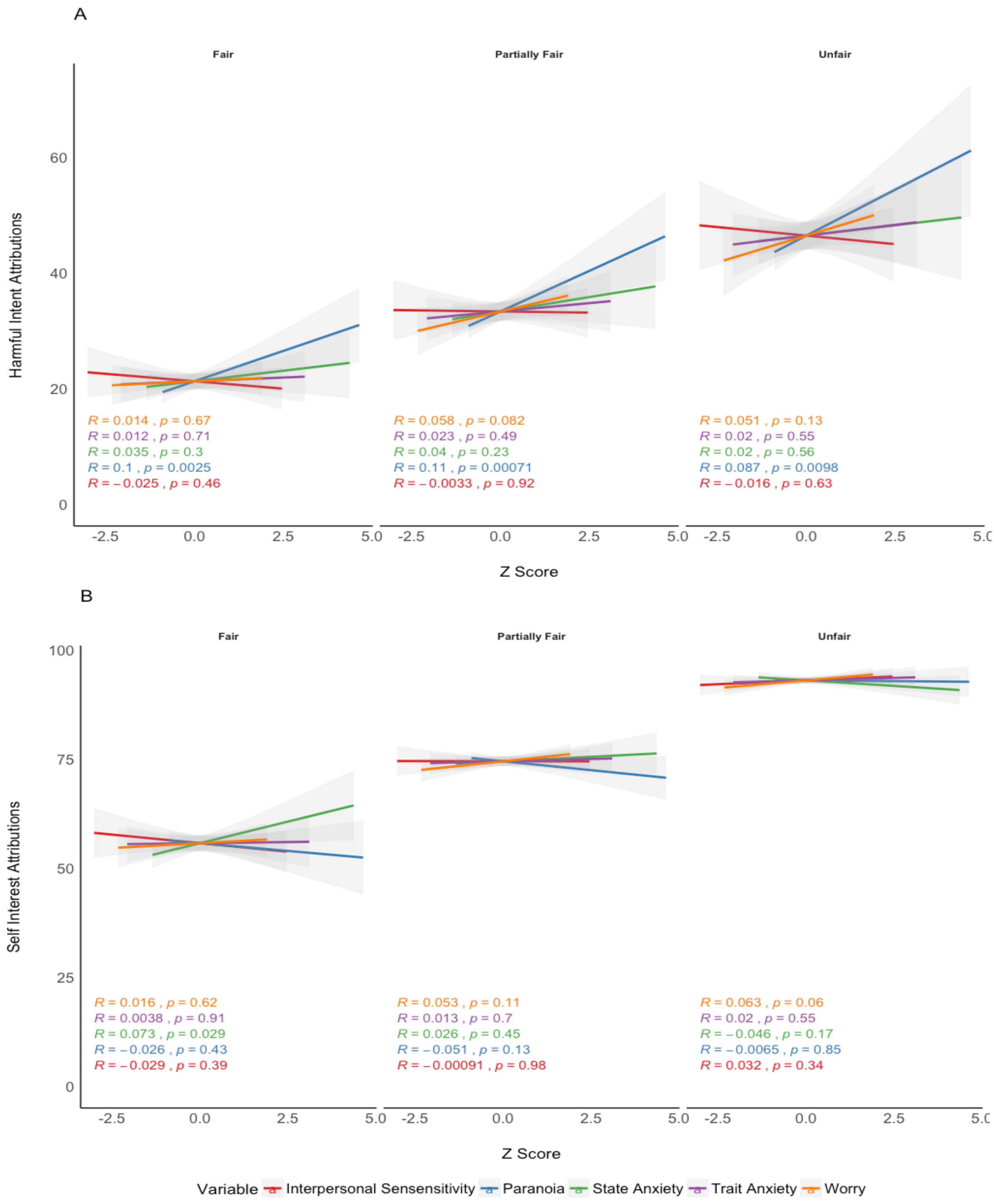

Figure 3. Pearson R correlations for centred and scaled scores on state and trait anxiety, paranoia, interpersonal sensitivity, and worry questionnaires by harmful intent (A) and self-interest (B) scores in Study 2, faceted by dictator condition. Paranoia is the only significant measure correlated with harmful intent attributions. It is not correlated with self-interest attributions. *N* = 885.

4.0 Study 3

We combined data from Study 1 and 2 to analyse the overall effect of paranoia, trial by trial attributional change for each dictator, as well as order effects, and overall dictator behaviour on attributions.

4.1 Methodology

A total of 1754 participants were included in the analysis from **Study 1** and **Study 2.**

Study 3 was not preregistered. All data and analysis scripts are available online (https://osf.io/u92rg/).

As in both previous studies, paranoia scores on the GPTS were divided into quantiles (Low, 32-36; medium, 37-44; high, 45-61; very high, 61 – 101.9) and also a group who passed GPTS scores exceeding the clinical mean (clinical, >101.9) (See Figure 4).

Linear mixed effects models (function “lmer”; package “lme4”; 47, ID as the random variable) were run to determine the effect of initial dictator exposure on overall HI and SI attributions for fair and unfair dictators. They were also used to calculate changes in HI and SI attributions for each trial relative to the first, and the overall effect of paranoia and sex on attributions. Probability distributions and uncertainty estimates of the direction of beta coefficients produced by mixed effect models were computed for HI and SI attributions for each trial and each dictator (using “rstanarm”, ID set at the random variable; 48; probability of direction fitted with “bayestestR”; 49) to give a visual description of changes in HI and SI scores as trials continued (figure 5).

Finally, we calculated the trial where a high (> mean) attribution was made and trial by trial changes to attributions when considering pre-existing paranoia (GPTS score). Cumulative link models with multimodal averaging (as with Study 1 and 2) were used for each dictator. Trial by trial analyses between levels of paranoia were visualised separately for harmful intent and self-interest attributions for each dictator (Figure 6).

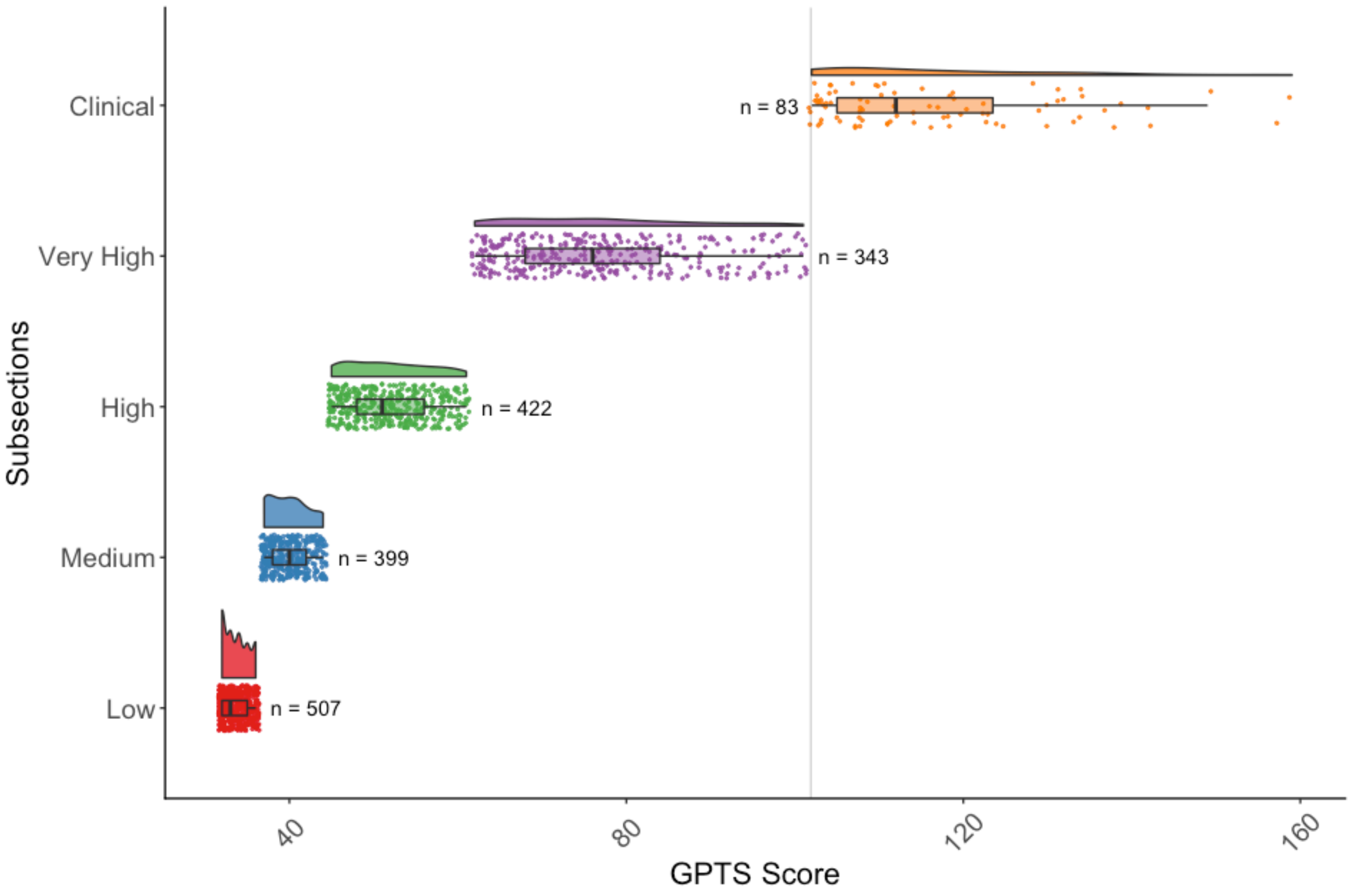

Figure 4. Rainbow cloud plot for each quartile of the Green Paranoid Thoughts Scale (GPTS). The highest quantile was subdivided into those who had and hadn't passed the clinical threshold (101.9) (35). The clinical division is denoted by a grey line.

4.2 Results

See Appendix D for the density distributions of scores for each dictator and trial.

Order effects

Being initially exposed to a more unfair dictator predicted a decrease in HI attributions for fair (-3.61, 95%CI: -4.38, -2.85) and unfair dictator conditions (-16.70, 95%CI: -19.50, -13.84) in the context of the whole population. Being initially exposed to a more unfair dictator predicted a decrease in self-interest attributions when playing fair (-5.89, 95%CI: -8.05, -3.74) and unfair dictator conditions (-1.66, 95%CI: -2.61, -0.71). Paranoia predicted an increase in HI attributions for both dictators in these models (fair dictator: 1.92, 95%CI: 0.91, 2.94; unfair dictator: 3.47, 95%CI: 1.84, 5.11), but not SI attributions.

Trial by trial analysis

See Figure 5 (Appendix E for confidence intervals) for overall changes in HI and SI scores for each dictator from trials 1-6 across the population.

Paranoia predicted earlier trials in which a high HI score (> mean) was triggered for both unfair (-0.08, 95%CI: -0.14, -0.01) and fair (-0.08, 95%CI: -0.14, -0.02) dictators. This was not true for SI scores.

Paranoia predicted an overall decrease in scores between the first and the sixth trial for fair (-0.70, 95%CI: -1.54, -0.03) but not unfair dictators. This was not true for SI scores for either dictator (Figure 6 for visual summary).

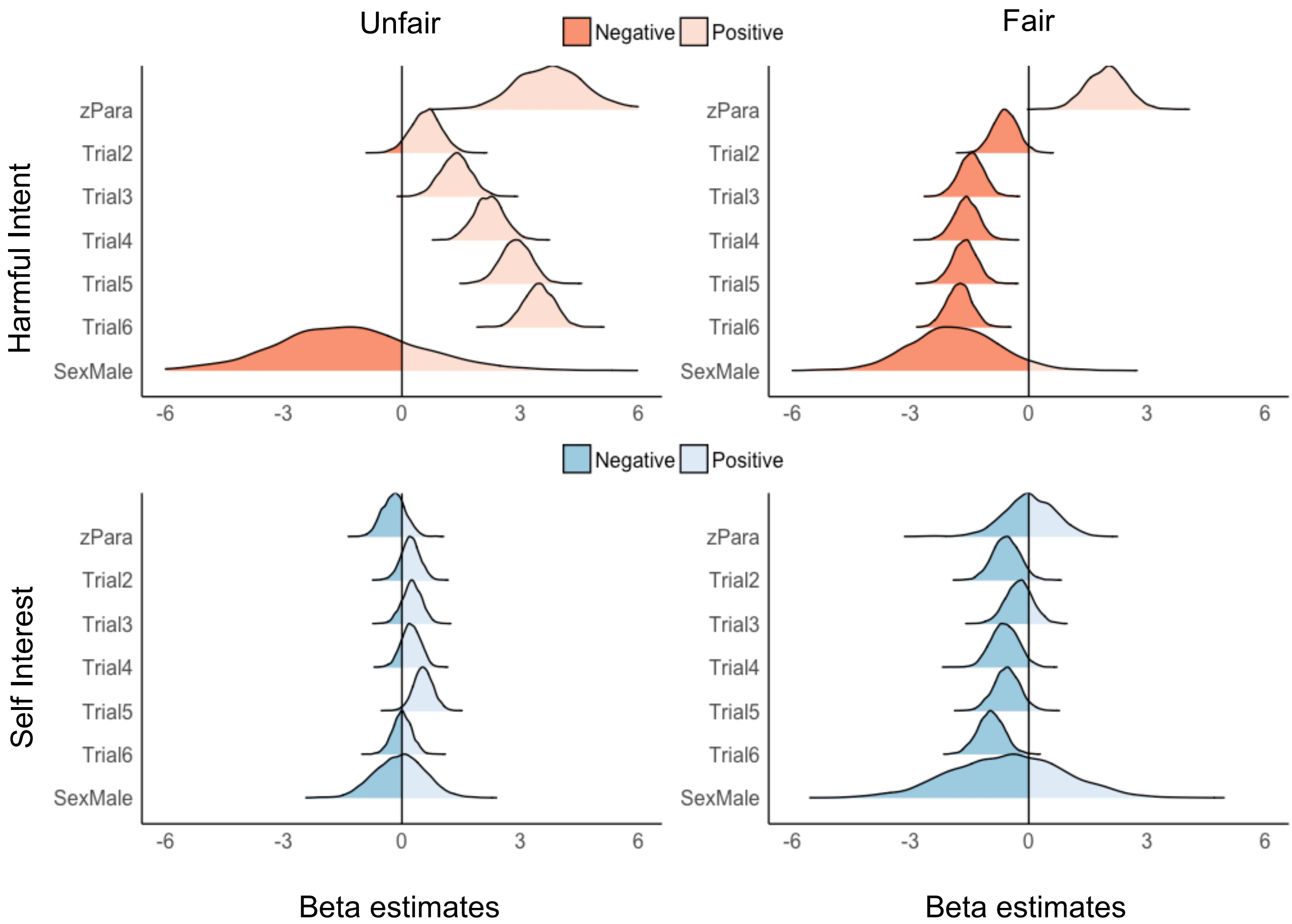

Figure 5: Probability distributions of beta coefficient from linear mixed effects models representing HI and SI attributions by unfair and fair dictators between trials two to six when compared with trial one. Probability distributions of beta coefficients modulated by paranoia (zPara; scaled and centred GPTS scores) and being a male (SexMale) when compared with being a female are also included. From trials three to six, unfair and fair dictators led to increases and decreases in harmful intent attributions, respectively. Social context had no impact on changes in self-interest attributions over trials.

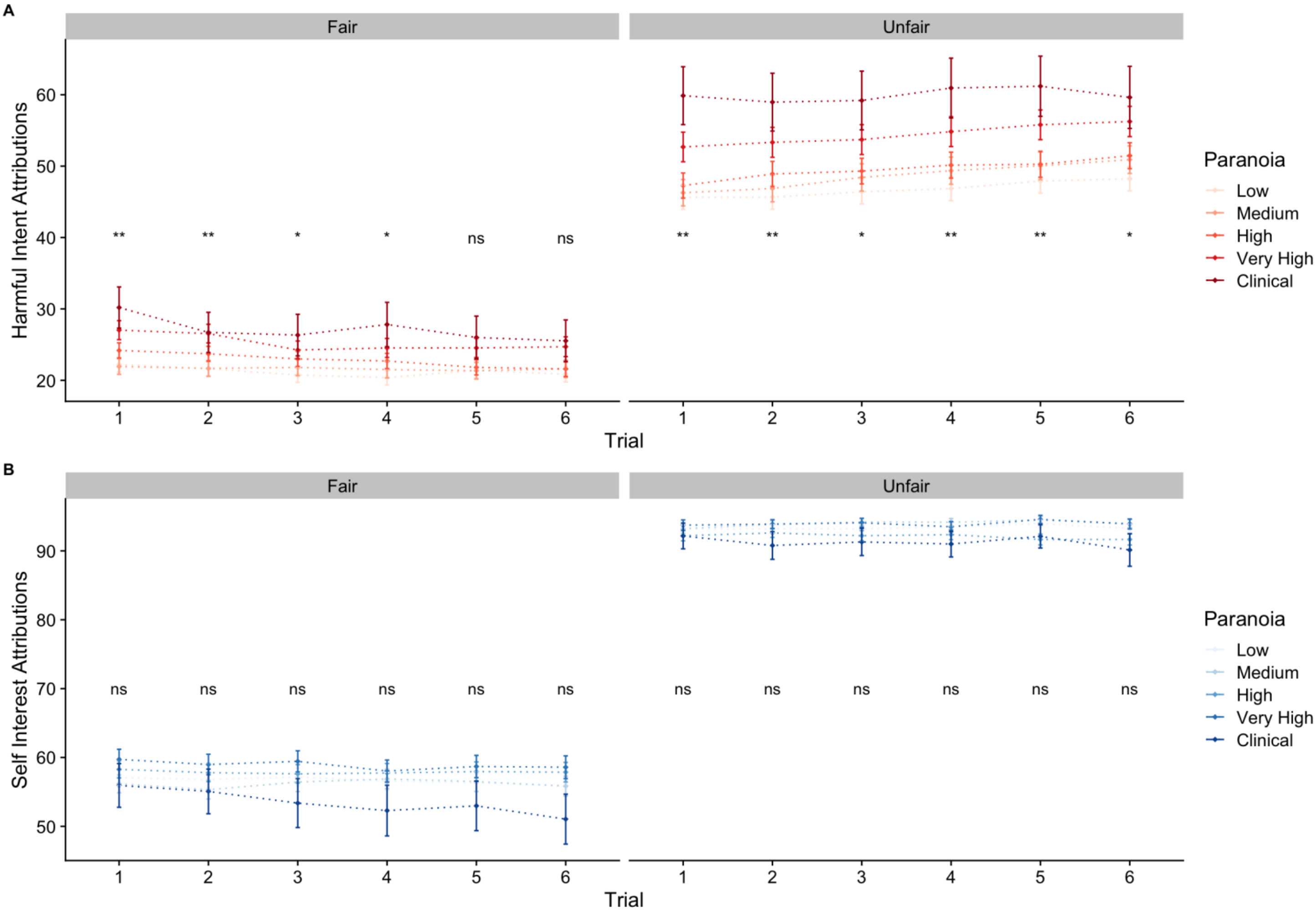

Figure 6: Each plot displays mean and SD for harmful intent (red) and self-interest (blue) attributions, faceted by dictator. (A) Harmful Intent Attributions for each trial (1-6), coloured by paranoia division. Group comparisons represent HI score ~ Paranoia for each trial. (B) Self Interest Attributions for each trial (1-6), coloured by paranoia division. Group comparisons represent SI score ~ Paranoia for each trial. * = p<0.05, ** = p<0.01, ns = not significant. Paranoia exaggerates the magnitude of harmful intent attributions relative to social context. Higher paranoia leads to greater reductions in HI attributions as trials continue for fair, but not unfair dictators where initial harm HI attributions are sustained. This visualisation using frequentist statistics on the combined sample is confirmed by more robust information theoretic analyses from in study 3.

4.0 Discussion

We undertook two studies to test the sensitisation model of paranoia using a multi-round Dictator game. This controlled experimental design models social inferences about the intentions of a ‘dictator’ (playing partner) over successive interactions and varying conditions of fair behaviours. In study one we tested the effect of self-reported paranoid beliefs on the attribution of harmful intent. In study two we tested the effect of anxiety, worry and interpersonal sensitivity in moderating these effects.

In line with our predictions, paranoia was associated with earlier and higher levels of harmful intent attribution across all conditions, and higher levels of harmful intent attribution as partners were increasingly unfair in their division of resources. Contrary to predictions, we found no meaningful effects of anxiety or worry on the attribution of harmful intent. Moreover, trait interpersonal sensitivity was associated with a *reduction* in attributed harmful intent. Post-hoc analyses (study three) highlighted that paranoia was associated with greater reductions of harmful intent attributions in fair dictator conditions over six trials, but not unfair dictators. Additionally, harmful intent attributions increased over trials with unfair dictators and decreased over trials in fair dictators when analysing our population as a whole.

Our data provides additional evidence for the sensitisation model in paranoia. This is convergent with previous game theory studies on paranoia that measured attribution of harmful intent using between-subject single shot designs. In previous studies that used Dictator games, paranoia predicted greater harmful intent attributions relative to to partner fairness (29, 30). This new study replicated these findings and additionally showed through the use of a within-group design and serial interactions that paranoia was associated with faster and larger attributions of harmful intent relative to partner fairness, suggesting increased sensitivity to perceived threat in interpersonal interactions. This is in line with previous findings from studies using a range of alternative paradigms. Simulated social exclusion with the ‘cyberball’ game increased state paranoia in non-clinical individuals with high trait paranoia (50), in individuals at high risk of psychosis (51), and patients with paranoid delusions (52). Experience sampling studies have found that moments of subjective stress (53, 54, 56) and physiological arousal (55) predict an increase in paranoia. Similarly, immersion in a stressful social environment, either in virtual reality (56) or a genuine city street (57), increased state paranoia.

Our data also converge with theories of social learning. Models of social impression formation in healthy populations suggest that impressions of ‘bad’ others are more volatile (changeable), and hence updated more quickly when a putatively bad agent becomes fairer (58). Our findings that paranoia was associated with greater reductions in harmful intent attributions in fair partner conditions provides initial convergent evidence that pre-existing paranoia may amplify belief volatility.

Counter to our predictions, however, we did not find any effect of anxiety or worry on the attribution of harmful intent. Cognitive models of paranoia (59-61) cite worry and anxiety as maintaining paranoid ideation based on a range of prior evidence. Worry has been found to be present at high levels in in highly paranoid people (62) and psychological treatment for worry has been shown to reduce paranoia in a targeted randomised controlled trial (63). Similarly, induction of stress has been shown to increase state paranoia, mediated by anxiety (6, 57), in addition to anxiety predicting higher state paranoia in ambiguous virtual environments (64). Given the strength of prior evidence we think it unlikely that anxiety and worry play no part in paranoia and suggest three possibilities for why no effect was found in this study. The first may be that we measured harmful intent attributions for specific events and general worry and anxiety may be more involved in maintaining paranoid ideation (i.e. promoting paranoid rumination) than amplifying in-the-moment paranoid attributions. Secondly, other predisposing factors (e.g. trauma; 17) not measured may be more relevant to the relationship between general anxiety and harmful intent attributions. Finally, possibility may be that the online paradigm was simply unable to capture relationships between these variables. However, we find this unlikely given that we detected expected relationships between variables, interactions between paranoid ideation and the speed of harmful intent attributions, and found typical population distributions of anxiety, worry and paranoia. Similarly, ‘screen-based’ studies have previously reported reliable effects when testing paranoid ideation (29-33, 50-52).

Contrary to our prediction that trait interpersonal sensitivity would be associated with increased harmful intent attributions, we found it was associated with reduced harmful intent attributions. A recent systematic review reported a strong relationship between interpersonal sensitivity and trait paranoia, but a variable and unclear relationship with state paranoia (65). For example, using a general population sample, virtual reality studies have found an association between state paranoia and overall interpersonal sensitivity (66), even when adjusting for confounders (67, 68). However, when using ‘real world’ stooges, an association with state anxiety was only found with the separation anxiety subscale (69). However, we did find a positive relationship between harmful intent attributions and one subscale of the interpersonal sensitivity measure, namely separation anxiety. Insecure attachment has been found to be a robust predictor of paranoia in psychosis across multiple studies (70) potentially indicating that this finding reflected a genuine relationship, giving additional validity to our null findings from the same scale. This may suggest that the interpersonal sensitivity scale used in these studies (the Interpersonal Sensitivity Measure) may be measuring various distinct processes that are not always helpfully summarised with a single score.

We also note some limitations to this study. As with previous designs, our study used crowd-sourcing platforms. This affords us a much larger, more representative sample than university or community samples (34), with higher response rates (71), greater experimental naivety and larger chances of replication (72), although our data drew solely on a UK population. However, given our exclusion criterion (participants had to fail both questions to be removed), it is possible that some participants did not respond accurately due to poor attention, potentially leading to inflated effect sizes (34). We note however that previous studies have found online participants to produce equal or better-quality data than lab participants for the same task (73). Additionally, it is not clear to what extent those who score above the clinical mean on the paranoia scale resemble patients with paranoid delusions. Given such a large sample, it would be surprising if at least some of the high scorers didn’t have delusions, although it is also the case that those most disabled by psychosis may be least able to participate in computer-based studies.

Our game theory paradigm measured harmful attributions in ambiguously motivated, loss-inducing, online interaction. One potential limitation is the extent to which participants were sceptical and believed they were being deceived by the experimenters. We found no relationship between scepticism and harmful intent attributions, and likewise our findings have replicated previous evidence using a similar manipulation (29, 30). One additional question is the extent to which our findings generalise to diverse social situations. As noted above, the results reported here reflect those reported in experience sampling studies of everyday interactions and immersive experimental studies, suggesting they also reflect the operation of common cognitive mechanisms. However, the specific differences in how paranoia manifests in online and offline contexts has yet to be tested and we feel this is something that needs further research.

5.0 Conclusion

We have demonstrated that paranoid ideation leads to quicker and exaggerated attributions of harmful intent, but not attributions of self-interest, in a motivationally ambiguous, live online social task. Our findings support the theory of sensitisation in paranoia. We provide experimental evidence that pre-existing paranoid beliefs reflect a heightened sensitivity to social stress, making one more likely to attribute harmful intent. We also show in a within group design that the cognitive mechanism to detect social threat from unfair decisions are at least partially distinct. The finding that anxiety and worry did not predict attributions of harmful intent suggests that anxiety and worry may mediate paranoid rumination rather than in-the-moment attributions. Additionally, while interpersonal sensitivity as a single summed score predicted reduced harmful intent attributions, we did find that separation anxiety predicted paranoid attributions, supporting previous work indicating a relationship between insecure attachment and paranoia. We aim to test specifically clinical populations to address the divide between non-clinical and clinical paranoia. At a neural level, evidence of the involvement of the mesolimbic dopamine system in psychosis suggest that future studies should investigate how dopamine modulates threat attribution in the general as well as patient populations.

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Conflict of Interest Statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Author Contributions

JMB initially devised the studies. JMB constructed the multi-round dictator game. JMB and NR revised the multi-round dictator game. JMB collected the data, analysed the data and wrote initial the draft of the manuscript. JMB, QD, OR, NR, VB and MAM critically revised the manuscript.

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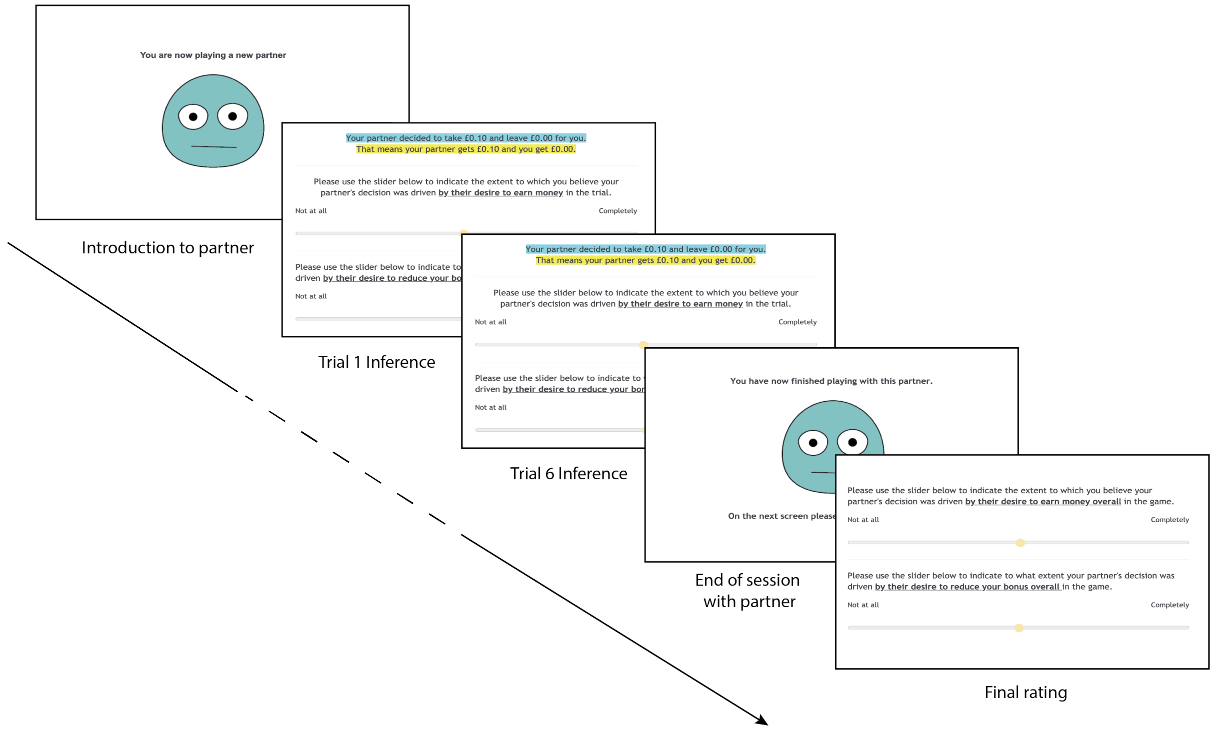
7.0 Supplementary Material

7.1 Appendix A – The multi-round dictator game task schematic for one partner.



7.2 Appendix B **–** Trials-to-peak-decision for Harmful intent and Self-Interest scores

Variables affecting earlier trial-to-peak-decision for Harmful Intent attributions within unfair and fair dictator decisions in the multi-round dictator game (Study 1). Trials where 53.51 (unfair) or 24.26 (fair) was first triggered were coded like so: 6 < 5 < 4 < 3 < 2 < 1 < 0, where 0 means over the mean was never scored or an earlier trial scored over the mean. Relative Importance is the probability that the term in question is a component of the true best model.

Parameter	Estimate	Standard Error	95% CI		Relative Importance
			Lower	Upper	
Unfair Dictator					
Intercept 6|5	-2.49	0.09	-2.66	-2.32	
Intercept 5|4	-2.40	0.08	-2.57	-2.24	
Intercept 4|3	-2.37	0.08	-2.54	-2.21	
Intercept 3|2	-2.33	0.08	-2.50	-2.17	
Intercept 2|1	-2.30	0.08	-2.47	-2.14	
Intercept 1|0	-2.28	0.08	-2.44	-2.11	
Paranoia (Z score)	-0.12	0.05	-0.21	-0.02	1
Age	-0.01	0.02	-0.06	0.02	0.32
Sex (Male | Female)	0.01	0.05	-0.14	0.26	0.21
Fair Dictator					
Intercept 6|5	-2.61	0.10	-2.81	-2.40	
Intercept 5|4	-2.51	0.10	-2.71	-2.31	
Intercept 4|3	-2.47	0.10	-2.66	-2.27	
Intercept 3|2	-2.43	0.10	-2.63	-2.23	
Intercept 2|1	-2.39	0.10	-2.59	-2.20	
Intercept 1|0	-2.38	0.10	-2.58	-2.18	
Age	-0.02	0.02	-0.07	0.01	0.69
Paranoia (Z score)	-0.06	0.06	-0.19	0.01	0.55
Sex (Male | Female)	0.01	0.04	-0.15	0.26	0.13

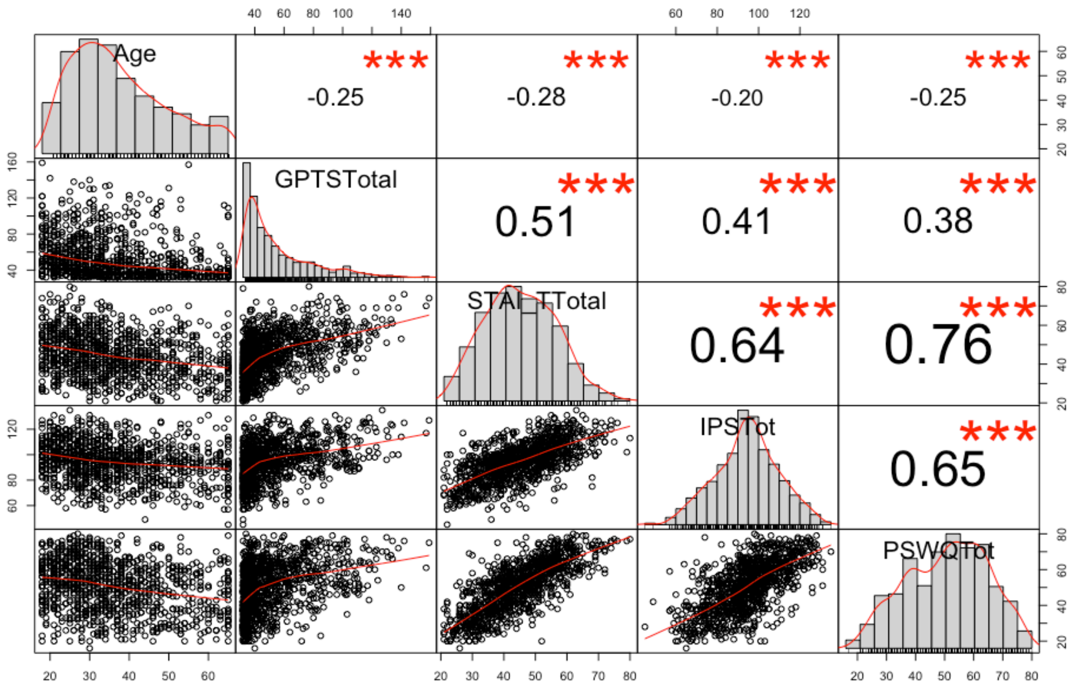
Variables effecting earlier trial-to-peak-decision for Self-Interest within unfair dictator decisions in a multi-round dictator game (Study 1). Trials where 60 was triggered were coded like so: 6 < 5 < 4 < 3 < 2 < 1 < 0, where 0 means 60 was never scored or an earlier trial scored 60. Relative Importance is the probability that the term in question is a component of the true best model.

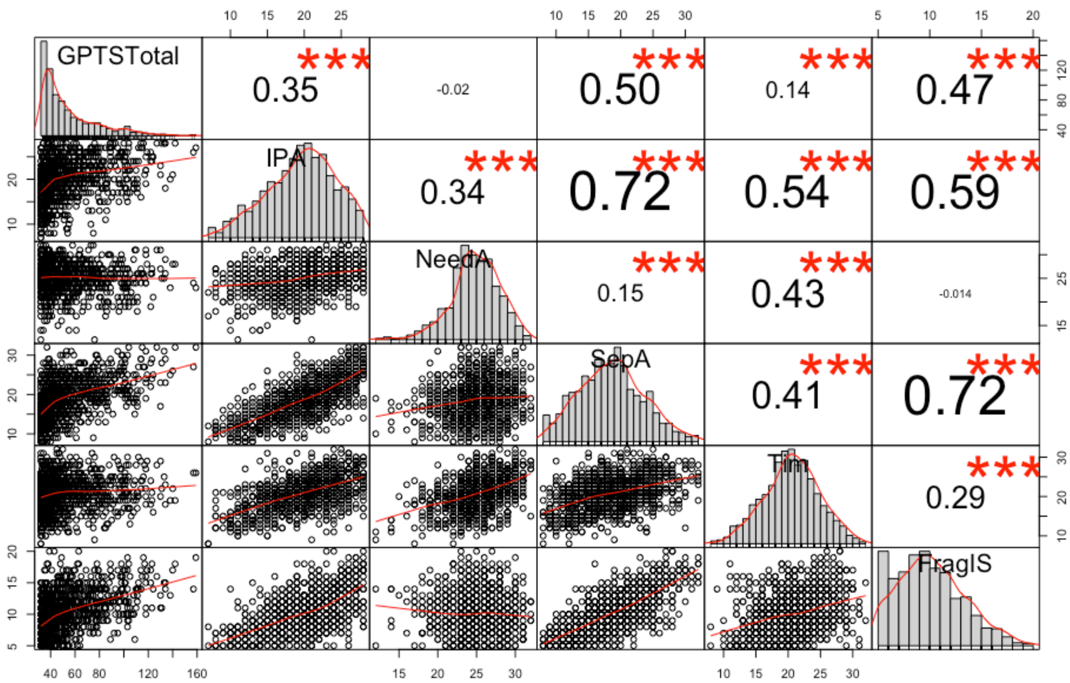
Parameter	Estimate	Standard Error	95% CI		Relative Importance
			Lower	Upper	
Intercept 6|5	-1.64	0.04	-1.72	-1.57	
Intercept 5|4	-1.63	0.04	-1.70	-1.55	
Intercept 4|3	-1.63	0.04	-1.70	-1.55	
Intercept 3|0	-1.63	0.04	-1.70	-1.55	
Paranoia (Z score)	0.01	0.08	-0.14	0.17	0.21
Age	0.01	0.08	-0.15	0.16	0.21

Variables effecting earlier trial-to-peak-decision for Self-Interest within fair dictator decisions in a multi-round dictator game (Study 1). Trials where 60 was triggered were coded like so: 6 < 5 < 4 < 3 < 2 < 1 < 0, where 0 means 60 was never scored or an earlier trial scored 60. Relative Importance is the probability that the term in question is a component of the true best model.

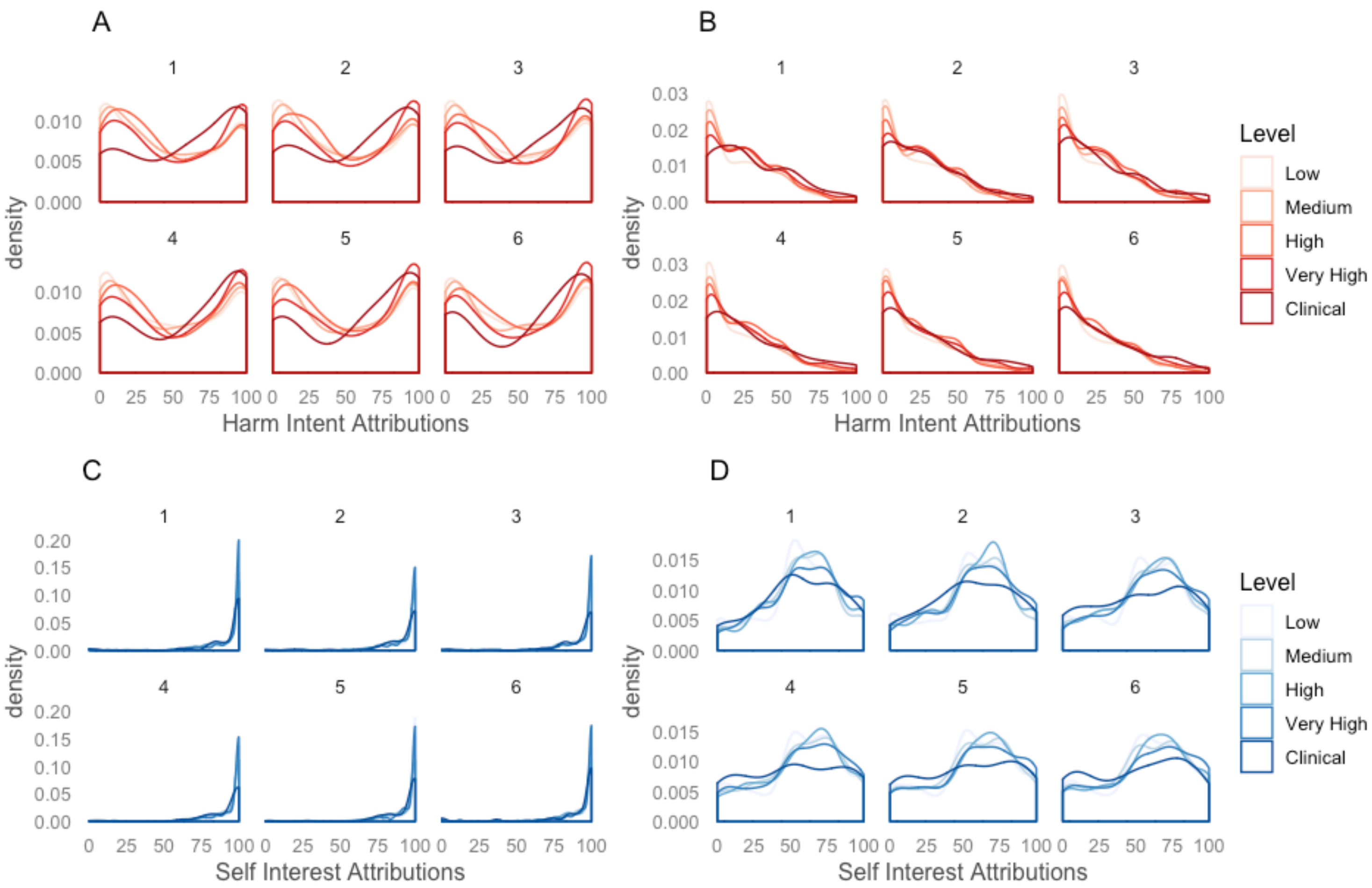
Parameter	Estimate	Standard Error	95% CI		Relative Importance
			Lower	Upper	
Intercept 6|5	-2.37	0.05	-2.47	-2.26	
Intercept 5|4	-2.27	0.05	-2.38	-2.17	
Intercept 4|3	-2.23	0.05	-2.33	-2.13	
Intercept 3|2	-2.20	0.05	-2.30	-2.10	
Intercept 2|1	-2.18	0.05	-2.28	-2.08	
Intercept 1|0	-2.17	0.05	-2.26	-2.07	
Age	0.04	0.10	-0.15	0.23	0.22
Sex (Male | Female)	0.03	0.09	-0.16	0.22	0.22

7.2 Appendix C – Correlation coefficients of all baseline variables. Top panel: Age, GPTS, STAI-T, IPS (total measure), and PSWQ. Bottom panel: GPTS, Interpersonal awareness, Need for Attachment, Separation Anxiety, Timidity, and Fragile Inner Self Subscale of the IPS.





7.3 Appendix D - **A & B:** Density distributions for Harmful Intent scores within each trial (1-6) for unfair (A) and fair (B) dictators for each level of paranoia. **C & D:** Density distributions for Self Interest scores within each trial (1-6) for unfair (C) and fair (D) dictators for each level of paranoia.



7.4 Appendix E – Beta coefficient 95% confidence intervals from linear mixed effects models for harmful intent and self-interest attributions for paranoia, dictator, and sex.

	Harmful Intent Attributions				**Self Interest Attributions**			
	Unfair Dictator		**Fair Dictator**		**Unfair Dictator**		**Fair Dictator**	
95% CI	*2.50%*	*97.50%*	*2.50%*	*97.50%*	*2.50%*	*97.50%*	*2.50%*	*97.50%*
.sig01	34.85	37.27	20.73	22.19	11.03	11.83	25.76	27.57
.sigma	11.09	11.42	9.04	9.31	6.93	7.14	9.52	9.81
(Intercept)	46.66	51.04	23.31	25.99	92.29	93.80	56.23	59.51
zPara	1.93	5.34	0.91	2.96	-0.74	0.36	-1.29	1.24
Trial2	-0.13	1.36	-1.21	0.00	-0.25	0.68	-1.21	0.06
Trial3	0.62	2.11	-2.07	-0.86	-0.21	0.72	-0.89	0.39
Trial4	1.46	2.95	-2.19	-0.98	-0.23	0.70	-1.25	0.03
Trial5	2.16	3.65	-2.23	-1.02	0.08	1.01	-1.20	0.08
Trial6	2.75	4.24	-2.38	-1.16	-0.46	0.47	-1.60	-0.33
SexMale	-5.22	1.85	-4.03	0.20	-1.23	1.06	-3.29	1.95