Cooperation and sensitivity to social feedback during group interactions in schizophrenia

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ABSTRACT

Patients with schizophrenia show reduced cooperation and less sensitivity to social cues in pairwise interactions, however, it remains unclear whether these mechanisms are also present in interactions within social groups. We used a public goods game to investigate cooperation and sensitivity to social feedback in group interactions in 27 patients with schizophrenia and 27 healthy controls. Participants played 20 trials in two conditions: 1) no fine: participants had the choice of investing into the public good (i.e. cooperating) or not (i.e. defecting), 2) fine: participants had the same choice but defectors could be punished by the other players. On the first trial, patients invested less in the public good than healthy controls. In the no fine condition, controls decreased their investments over time, but patients did not. The possibility of being fined for defecting and actually being fined led to significantly higher cooperation in both groups. This shows that the groups were equally sensitive to social feedback. Our findings suggest that patients tend to approach social group interactions with less cooperative behaviour, which could contribute to social dysfunction in daily-life. However, an intact sensitivity to social enforcement and feedback indicates that patients can adjust their behaviour accordingly within a group.

1. Introduction

Social cognitive skills are crucial for the development of cooperation and trust in interpersonal relationships (Fett et al., 2014; Kishida et al., 2010; Sutter and Kocher, 2007). There is ample evidence that patients with schizophrenia demonstrate impairments in social cognition (Couture et al., 2006; Fett et al., 2011; Green and Leitman, 2008; Green et al., 2008; Penn et al., 2008; Pinkham et al., 2003; Savla et al., 2012); and that these impact on illness outcomes (Couture et al., 2006; Fett et al., 2011; Penn et al., 1996). Social dysfunctions are also reflected in some of the key positive and negative symptoms of the disorder, such as paranoia, social withdrawal and lack of (social) motivation (Penn et al., 2008). In daily life, social interactions pose a challenge for patients (Billeke and Aboitiz, 2013; Couture et al., 2006; Penn et al., 1996), reflected in patients' difficulties maintaining relationships with family or friends (Burns and Patrick, 2007; Pinkham and

Penn, 2006). In studies using neuro-economic exchange games to examine social interactions directly, demonstrated that patients tend to show lower levels of trust towards others (i.e. cooperate less) (Fett et al., 2016; Fett et al., 2012; Gromann et al., 2013), compared to healthy individuals, and are less likely reciprocate in interactions (Berg et al., 1995; Sigmund, 2007, 2010). Lower levels of trust were associated with more severe psychotic symptoms in chronic psychosis (Fett et al., 2012; Gromann et al., 2013). Moreover, in these pair-wise interactions, patients did not adjust their behaviour after receiving information about the other player's trustworthiness (Fett et al., 2012), suggesting lower sensitivity to social feedback, which is in line with earlier data showing that patients are less sensitive to interpersonal cues (Corrigan and Green, 1993; Johannsen, 1961). While these two-person games can help to enhance the understanding of the dynamic nature of pairwise interactions, modelling social dilemmas in groups provides additional information because social interactions often occur among more than two individuals simultaneously (Archetti and Scheuring, 2012) and the signals of more people need to be interpreted simultaneously leading to a greater complexity in the social dynamics (Brandt et al., 2003; Sigmund, 2007).

One approach to examine group dynamics during cooperation and sensitivity to feedback from others is offered by the public goods game (PGG). In this paradigm, a social dilemma is given: participants have to make a choice between maximizing the benefits across a group at a cost to their personal payoff, or maximizing their personal payoff at the expense of the group. Players are given an initial endowment and have to make the decision whether to invest the money in a group account (cooperating/public good) to mutual benefit or whether to keep the money for themselves (defecting/private good) yet still benefit from the others contributions. A key variable underlying cooperation in the PGG is trust (Balliet and Van Lange, 2013). If a player chooses the private good, his return exceeds that of the players who invested into the public good (Fehr and Fischbacher, 2004); this represents "free riding" (Fehr and Schmidt, 1999; Wischniewski et al., 2009). When players are allowed to punish those who free ride, investments in the public good increase as cooperation is socially enforced (Brandt et al., 2003; Fehr and Gächter, 1999, 2002). While fining another player is mostly done out of anger or spite, there is a cost attached to this - players have to pay to punish a defecting player, which makes this an altruistic act, a form of punishment at a personal cost (Brandt et al., 2003; Seymour et al., 2007).

To date, only one study has used the PGG to investigate group interactions in schizophrenia (Chung et al., 2013). They found higher levels of cooperation in patients compared to controls in a PGG without punishment (i.e. not examining social feedback). The authors concluded that patients played the game in a non-strategic way and demonstrate a reduced sensitivity to loss. However, the results are difficult to compare as the authors manipulated the utilized game to have 2 possible outcomes, group success or failure (success if 3 or more out of the 5 players in the game cooperated, otherwise failure), which enforced a higher rate of cooperation. More importantly, they did not include changes in cooperation over time. They also had groups exclusively of patients, which tends to amplify group differences. Therefore, their utilized PGG did not tap into the same processes as our PGG design.

We describe the first study to use a neuro-economic group interaction game to investigate behaviour in social groups in schizophrenia, using the PGG, incorporating a measure of sensitivity to social feedback. We were interested in three key elements: 1) baseline level of cooperation on the first trial, where participants do not have any information on the other players' behaviour, 2) behavioural change in response to others' behaviour, 3) behavioural change when players were able to punish other players – to investigate whether cooperation can be enforced and to examine sensitivity to social feedback. Based on expected illness reduced social cooperation, on some of the key symptoms of the disorder (e.g. paranoia and distrust) and on previous results from trust game studies we hypothesized that patients with schizophrenia would demonstrate: a) lower levels of baseline cooperation and lower mean cooperation in the PGG, b) less sensitivity to social feedback indicated by less difference in cooperation between conditions (i.e. social enforcement) and less adjustment in behaviour after being fined in the preceding trial as compared to controls (i.e. sensitivity to social feedback). We hypothesized a negative association between symptoms (positive and negative), cooperation and sensitivity to social feedback in patients. Positive symptoms are related to social abnormalities and deficits in social decision making and trust. Negative symptoms such as social withdrawal, isolation, social anhedonia, social amotivation have strong social components.

2. Methods

2.1 Subjects

Twenty-seven outpatients with schizophrenia and twenty-seven healthy controls were included in the study. Patients were recruited from the South London and Maudsley NHS Foundation Trust and healthy controls subjects were recruited through local advertising. Demographic information is displayed in Table 1. Inclusion criteria for all participants were 1) age between 18-55 years old, 2) sufficient understanding of the English language to successfully perform the task and to understand the informed consent, 3) no learning disabilities, 4) absence of a neurological condition, 5) no alcohol/drug dependence within the last six months, 6) absence of a major physical illness or motor, hearing or speech difficulties. For the schizophrenia group additional inclusion criteria were 1) a diagnosis of schizophrenia, schizoaffective disorder or psychotic disorder according to the ICD-10 criteria, 2) stable under their current treatment (> 6 weeks). The patients who were included had the following diagnoses without any comorbidity: 20 schizophrenia, 5 schizoaffective disorder, 1 psychotic disorder, 1 polymorphic psychosis with schizophrenia. All patients were medicated, with 85% treated with atypical antipsychotics.

2.2 Measures

Symptoms - To assess symptom severity in patients the Positive and Negative Syndrome Scale (PANSS) (Kay et al., 1987) was used. The PANSS is a semi-structured interview that assesses symptoms over a two-week period prior to the testing session. Thirty items are scored to evaluate the severity of psychopathology: 1 = absent, 2 = minimal, 3 = mild, 4 = moderate, 5 = moderate to severe, 6 = severe to 7 = extreme. In the current study, the PANSS subscale scores were used to get estimate of positive symptom severity (range 7-49) and negative symptom severity (range 7-49). The positive and negative scale have good concurrent validity and good internal reliability (respectively Cronbach's α = 0.62-0.73 and α = 0.83-0.92 (Kay et al., 1987; Peralta and Cuesta, 1994)).

2.3 Estimated cognitive ability - To control for possible influence of cognitive ability on group differences in behaviour in the PGG, an estimation of cognitive ability was assessed with the vocabulary subtest of the Wechsler Abbreviated Scale of Intelligence (WASI) (Wechsler, 1999). The Vocabulary subtest has a total of 42 items, where subjects are required to define and describe the words best to their knowledge. Words are presented orally and visually. The WASI vocabulary test gives a good estimate of overall intelligence scores, the vocabulary subtest showing a 0.87 correlation with the full WAIS III (Axelrod, 2002). T-scores were converted to scaled WASI scores (range 20-80).

2.4 Experimental design

A binary public goods paradigm was used to investigate cooperation and sensitivity to others' social feedback in a group setting. Subjects participated in two three-player games involving one of two conditions; 20 trials in the no fine and 20 trials in the fine condition. Before the start of the game, participants were informed that they were playing all 40 trials with the same two opponents who were participating on computers that were connected via the Internet. In reality, they were playing computers (player 2 and player 3) that were programmed with stochastic algorithms that mimicked human choices. The study was coded in Adobe Flash (see (Reimers and Stewart, 2015), and was adapted from a version of the PGG in which participants genuinely played against other real player over the internet. As such, plausibility of playing with other real people was kept high. In the no fine condition, player 2 was programmed to play a tit-for-tat strategy (see, e.g., Axelrod, 1980); meaning player 2 would cooperate on all trials, except immediately following a trial on which the other two players did not cooperate. Player 3 was programmed to play a locally self-interested strategy, defecting on all trials. In the fine condition, players 2 and 3 used the same strategies as in the no fine condition. Both player 2 and 3 cooperated if they were punished in the preceding trial. Player 2 punished any player that defected on two consecutive trials. Player 3 never punished other players. To make the strategies used by the virtual players less transparent, players played their dominant strategy 80% of the time and a random 20% of the time the opposite strategy.

In the *no fine condition*, participants received an initial endowment of £3. They then had to make a choice whether to keep the money for themselves (invest in the private good; i.e. free riding) or to put their £3 in a public good (invest in the public good; i.e. cooperation). They made this choice before seeing the other players' decisions. At the end of the trial, the contribution of each player was revealed, and the money contributed by the three players was summed then doubled and the total amount was divided equally among all players, regardless of whether they cooperated or not. The next trial started again with £3 for each player.

The *fine condition* was identical to the no fine condition, however, after participants made their choice and had been informed about how the other players had invested, they were then given the option to punish the players who did not cooperate. To punish another player was costly, since £1 was deducted from their own total amount and £2 was deducted from the total of the fined player. So, punishing another player was only possible at a cost to themselves.

The task was presented in an animated way, presenting 3 players seated around a table, the procedure of the game is visually shown in Figure 1.

2.5 Procedure

All participants were invited to the Institute of Psychiatry, Psychology and Neuroscience, where testing took place. Trained MSc level researchers carried out the testing session and a research nurse administered the PANSS interview. Prior to participation subjects were given written information about the content of the study and what would be expected from them. It was emphasized that their participation was voluntary and they had the opportunity to withdraw at any moment without any consequences. The study was approved by the Bromley Research Ethics Committee. All participants signed informed consent before testing.

After completing a questionnaire on demographic information, participants played the PGG (the no fine condition first, followed by the fine condition) on a laptop in a web browser, which initially showed a loading message and a connecting message for the other players. After a few connection attempts, the system displayed that all players were connected and the task was launched. Plausible variable delays were used for the responses of the other players, so that they did not necessarily appear immediately after the participant made a choice. After completing the experimental task the PANSS interview was conducted. At the end of the session, subjects received an incentive of £10 for participation in the study.

2.6 Statistical analyses

Statistical analyses were performed using STATA version 14 (StataCorp, 2015). We examined group differences in demographics using t-tests and chi square tests. Logistic regression analyses were performed to investigate the differences between groups in baseline cooperation (investment on the first trial) and multilevel mixed effects logistic regression analyses to investigate the differences in mean cooperation, changes in cooperation over trials, punishment (i.e. frequency of fining other players) and social sensitivity to punishment (i.e. change in behaviour after being fined) between groups and between symptoms and cooperation within the patient group, taking into account possible effects of a-priori confounders (gender and age). The same analyses were run to investigate within group effects of condition in baseline cooperation and mean cooperation (i.e. representing social enforcement). Separate analyses were conducted to investigate group differences within each condition and the condition effect within each group, as the full model omitted essential variables due to dichotomous outcome and predictor variables.

3. Results

3.1 Demographics

Demographic information and clinical characteristics are shown in Table 1. There were no significant differences between groups in age and gender. There was a trend towards significant differences between groups in estimated cognitive ability, with patients having a lower estimated cognitive ability than healthy control subjects.

3.2 Group differences on baseline and mean cooperation by condition

Task performance per group and condition is shown in Table 2 and are displayed in Figure 2. In the no fine condition, there was a significant difference in first-trial cooperation between groups with patients showing lower cooperation, OR = 0.18, 95% CI (0.04; 0.89), $p = .04$, but no significant difference in mean levels of cooperation ($p = .23$). In the fine condition, there was a similar trend effect towards a difference in cooperation between groups, OR = 0.20, 95% CI (0.03; 1.19), $p = .077$, but mean levels of cooperation throughout the game did not differ ($p = .53$).

3.3 Changes in cooperation over trials

PGG performance changes over repeated trials are shown in Figures 3a (no fine condition) and 3b (fine condition). There was a trend towards group differences in change in cooperation over trials in the no fine condition, as indicated by the interaction between trial number and group, OR = 1.05, 95% CI (1.00; 1.10), $p = .065$. Analyses by group showed a significant change in cooperation in the healthy control group (OR = .94, 95% CI (0.91; 0.97), $p < .001$), but not in the patient group ($p = .34$).

In the fine condition the change in cooperation over time was not different between groups, as indicated by the non-significant interaction between trial number and group ($p = .86$). In the model without the interaction, the main effect of group on cooperation was also non-significant ($p = .43$), however, there was a significant main effect of change of cooperation over trials (OR = 0.96, 95% CI (0.94; 0.98), $p = .002$).

3.4 Effect of social enforcement on cooperation within groups

Within the healthy control group there was no significant difference in the percentage cooperation on the first trial between conditions, $p = 1.00$. However, controls showed a significant difference in mean levels of cooperation between conditions, with cooperation being higher in the fine than no fine condition, OR = 1.60, 95% CI (1.22; 2.10), $p = .001$.

In the patient group, there was no significant difference in percentage baseline cooperation between conditions, $p = .55$. Similar to healthy controls, patients showed a significant difference in the mean levels of cooperation throughout the game between conditions, with cooperation being higher in the fine than no fine condition, OR = 1.84, 95% CI (1.39; 2.44), $p < .001$.

3.5 Sensitivity to social feedback and punishing behaviour

The likelihood of cooperation after being punished by another player for free riding did not differ between groups, $p = .58$, see Table 2 for percentages of cooperation. Groups also did not show any differences between cooperation after defecting but not being fined by another player ($p = .67$) and no differences in cooperation after cooperating in the previous trial ($p = .52$). Healthy controls and patients did not differ in the frequency of punishments given to other players, $p = .74$.

3.6 Correlations between (baseline) cooperation and symptoms within the patient group

No significant association between positive and negative symptoms and baseline cooperation was present in either condition (no fine condition: $p = .38$ $p = .59$, fine condition: $p = .57$ and OR $p = .90$, respectively).

There was a significant interaction between positive symptoms and change in cooperative behaviour over trials in the no fine condition (OR = 1.01, 95% CI (1.00; 1.02), $p = .05$). To examine the interaction in more detail, we divided the patients into three groups based on the positive symptom severity (PANSS Group 1; N = 9, $M = 12.33$, $SD = 1.76$, PANSS Group 2: N = 7, $M = 15.57$, $SD = 0.5$ and PANSS Group 3: N = 7, $M = 21.29$, $SD = 2.97$). These results are plotted in Figure 4, demonstrating that patients with the most severe positive symptoms (PANSS Group 3) increased their level of cooperation throughout the game compared to healthy controls and patients in the PANSS Groups 1 and 2. This interaction effect was not found in the fine condition, $p = .95$, and also no main effect of positive symptoms in the model without the interaction ($p = .26$), but there was a main effect of cooperation over trials (OR = 0.96, 95% CI (0.93; 1.00), $p = .05$).

There was no significant interaction between negative symptoms and trial number on the likelihood of cooperation in the no fine condition and the fine condition, respectively $p = .63$ and $p = .31$. There was no main effect of negative symptoms in the no fine condition ($p = .99$), nor in the fine condition ($p = .51$). There was no main effect of cooperation over trials in the no fine condition (OR = 0.99, 95% CI (0.95; 1.02), $p = .42$), but this was significant in the fine condition (OR = 0.96, 95% CI (0.93; 1.00), $p = .05$).

All analyses were repeated with IQ as a covariate in the model. Due to many missing values in IQ, we used a multiple imputation-based procedure to re-create the individual missing scores. This yielded slightly different parameter results, however, significance did not change and the direction of the effect remained the same.

4. Discussion

This study examined cooperation and sensitivity to social feedback in schizophrenia in a PGG, to measure the dynamics of social group interactions. Our findings on baseline cooperation show that patients are less cooperative at task onset. However, patients did not differ from controls in their reaction to social enforcement or sensitivity to social feedback (i.e. punishment).

Patients have lower initial inclination to cooperate in social groups, as indicated by a lower level of baseline investments into the public good compared to healthy controls. This finding is in line with evidence from pairwise interactions, where patients show less basic trust (Fett et al., 2012; Gromann et al., 2013). To engage in social interactions, one has to trust the other person's willingness to cooperate, which seems to be a key precursor in the development of cooperation in a public goods dilemma (De Cremer, 1999). Patients may choose more selfishly in a PGG compared to healthy controls, because they are less trusting due to negative beliefs about other individuals. Another possible explanation is that patients with schizophrenia are more self-oriented, due to a reduced ability to take the perspective of others (Sprong et al., 2007).

Change in behaviour over trials was different between groups in the condition without fining, but not in the condition where cooperation was socially enforced. Healthy controls started out with high levels of cooperation and then decreased their cooperation over trials, which is in line with previous findings on cooperation in a public goods paradigm, cooperation in multi-shot public goods games tends to be high initially and then declines throughout the game (Andreoni, 1988; Fehr and Fischbacher, 2003; Fischbacher et al., 2001; Ledyard, 1995). This can be explained by a game-theoretic view: the allocation of the public good is equal no matter what amount each individual invests, thus, to maximize one's own profit, the dominant long-term strategy is to defect (Andreoni, 1988). A possible explanation for decreasing cooperation could be that participants are reluctant to invest into the public good because of fear that others are not going to contribute as well. This is called inequity aversion. In the beginning of the game, healthy participants may be more willing to take a risk, or are more trusting in others' good will compared to patients. However, when their contributions are not routinely reciprocated, this feeling of inequity overrides the willingness to cooperate (De Cremer, 1999; Kurzban et al., 2001). The decline may also be related to a self-serving bias (Fischbacher et al., 2001). Patients' motivation to defect may be based on a lack of trust due to fear of uncooperative behaviour of others. Another possible explanation could be that patients value monetary reward in a different way than controls do, which could be related to impulsive choices (Heerey et al., 2007) and amotivation (Fervaha et al., 2013).

Adding the option of punishing another player for free riding increased the likelihood of cooperation within both groups compared to the condition where fining was not allowed. Although this is in line with previous findings in healthy subjects, who tend to increase cooperation when the punishing of free riders is allowed (Brandt et al., 2003; Fehr and Gächter, 2002), this was in contrast to our expectations in the patient group. We anticipated that patients would be less sensitive to social enforcement by introducing the possibility of fining others, due to patients' deficits in processing social information. The findings suggest that patients are sensitive to social enforcement. Moreover, there was an increase in cooperation after defecting and being fined for it: in healthy controls from 12.80% to 45.10% and in patients from 13.72% to 44.83%. This change in behaviour was similar in both groups, indicating that patients did not show the expected reduced sensitivity to social feedback. There is some evidence from other studies for unimpaired sensitivity to punishment in schizophrenia (Cheng et al., 2012). In pairwise encounters a reduced sensitivity, i.e. no changes in trust, was shown after providing information about the trustworthiness of the other player (i.e. top-down processing) (Fett et al., 2012). In our study patients had to use bottom-up processing to deduct the social information (i.e. learning trial-to-trial in the game). It might be that problems arise when patients have to use top-down processing of social information specifically (integration of *a priori* information) and not when patients use bottom-up processing of social feedback that is data-driven.

Patients and controls demonstrated the same amount of punishing behaviour, which is in line with results in pairwise interactions in dictator game with punishments (Wischniewski and

Brüne, 2011). These findings suggest that patients are sensitive to social rules and willing to altruistically punish other players to reinforce social norms at the same level as healthy control subjects.

Interestingly, positive symptoms were only associated with the level of cooperation over trials in the no fine condition. Patients with more severe positive symptoms showed an increase in cooperation over time, compared to reduced cooperation in the lower symptom groups and the healthy control group. An inability to estimate the risk of loss (Pedersen et al., 2016; Shurman et al., 2005) and reduced sensitivity to unfairness (Agay et al., 2008; Csukly et al., 2011) might explain why patients in the highest symptom group in our study increase their level of cooperation instead of decreasing this behaviour. It is possible that the higher level of cooperation in our study is related to making choices without fully contemplating the best strategy. In accordance with previous studies these abnormalities in behaviour in the PGG may reflect aberrant reward processing (Juckel et al., 2006a; Juckel et al., 2006b; Nielsen et al., 2012; Schlagenhauf et al., 2008) and reward learning (Gold et al., 2008; Murray et al., 2008; Strauss et al., 2014; Waltz et al., 2013). This should be interpreted with caution due to the small sample sizes in the three symptom groups. However, the possibility of being punished resulted in an appropriate behavioural adjustment in patients with more severe positive symptoms. It is not possible to be definitive about the reason for this aberrant behaviour without social enforcement, which may be contributed by a lower sensitivity to other people's choices or lack of cognitive flexibility. It would therefore be interesting to investigate this association with specific clusters of symptoms and cooperation in group interactions in future studies.

There are limitations in this study. First, the PGG in this study was a binary 3-player game, this choice was made for task simplicity, either an investment in the private or the public good; incorporating continuous investment opportunities may have made the game more sensitive to changes in social enforcement and feedback. Second, the punishment in our study was potentially low; a free riding player punished by a cooperating player would still receive £3 (i.e. the initial endowment) if the other 2 players cooperated; a flexible level of punishment could have greater influence on behaviour. Last, we did not differentiate between medication type, although the majority of patients were on atypical antipsychotics. Future studies have to systematically investigate the possible roles of medication and stage of the illness are.

This study is the first to investigate cooperation, social enforcement and sensitivity to social feedback in group interactions in schizophrenia. Although all effect sizes were small, our findings suggest that patients demonstrate a tendency to initiate social group interactions with less cooperative behaviour, which may set a negative tone in social settings, potentially contributing to social difficulties in initiating interactions in real life functioning. However, the results clearly suggest that social enforcement and sensitivity to social feedback are intact, which indicates that it may be possible for patients adjust their social behaviour accordingly during repeated social interactions. This may be particularly important for interventions that target social skills and suggests that group-based interventions may be particularly helpful. The study would benefit from replication, since this is the first study to investigate cooperation and sensitivity to social feedback in this manner. It would be interesting to extend this work into social group interactions in real time and to use neuroimaging, to test the underlying neural mechanisms.

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Figure legends

Figure 1. Schematic representation of the binary public goods game: a) no fine condition and a+b) fine condition; a) participants could cooperate (black arrows) or free ride (light grey arrow), a choice made without knowing the other players' decisions. The amount in the public good was doubled and split equally among all players (grey arrows), b) The players who cooperated could fine (punish; grey arrows) the players who free rode after receiving information on the other players' decisions. Costing the fining player £1, but deducting £2 from the free riding player.

Figure 2. Group and condition comparisons for baseline cooperation and overall mean cooperation in the multi-round binary public goods game. The error bars depict the dispersion of cooperation over all trials within groups and conditions. † $p < 0.08$, * $p < .05$, ** $p <= .001$

Figure 3: Cooperation per trial in the multi-round binary public goods game in the a) no fine condition, and the b) fine condition.

Figure 4. To visualize the interaction effect found between positive symptoms and change in cooperation over trials within the patient group, 3 groups for symptom severity were made. Change of cooperation over trials by positive symptom severity are plotted in the no fine condition.