The communication of metacognition for social strategy in psychosis: an exploratory study

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Abstract

Sharing privately held information, for example one's confidence in the likelihood of future events, can greatly help others make better decisions as well as promoting one's reputation and social influence. Differences in metacognition on the one hand, and difficulties in social functioning and social cognition on the other, have been found in schizophrenia. However, despite clear relevance few studies have investigated the link between these abilities in psychosis. We compared individuals diagnosed with schizophrenia, bipolar disorder, and a group of unselected general population controls, in an online competitive advice-giving task. Participants gave advice to a client by making a probabilistic perceptual judgment. They could strategically adapt the advice confidence to gain influence over the client. Crucially, participants competed with a rival adviser to attract the client's endorsement. In sum, we observe that those diagnosed with bipolar and schizophrenia were less oriented to focus on influencing a social other, and more concerned with their own performance, whereas the opposite was true of controls. Symptom-based analysis provided preliminary evidence that advice confidence was associated with the presence of delusions but not hallucinations or mood symptoms. These results suggest that the social communication of uncertainty should be further investigated in psychosis.

Keywords: social cognition, metacognition, bipolar disorder, schizophrenia, psychosis

Introduction

We constantly rely on our friends and family's opinions in making everyday decisions. When facing uncertain outcomes, others' information can help us make better informed decisions (Bahrami et al., 2010; Hertz, Romand-Monnier, Kyriakopoulou, & Bahrami, 2016). Sharing information is the basis of human cultural evolution (Dunbar, 2004) and plays a major role in maintaining and enhancing social bonds and promoting one's own social influence and status (Tennie, Call, & Tomasello, 2009). Indeed, the manner in which we communicate our privately held information is shaped by our perceived social settings, such as our current level of influence on the receiver, perceived social rank, and impression management (Hertz et al., 2017; Pontari & Schlenker, 2006; Schwardmann & van der Weele, 2019). Some psychiatric disorders, particularly psychotic disorders such as schizophrenia, are characterized by altered social perception (Bell, Mills, Modinos, & Wilkinson, 2017) raising the question to what extent the cognitive mechanisms underlying social information sharing may be altered in psychosis.

Metacognition has been identified as essential to exactly such social abilities (Bahrami et al., 2010; Shea et al., 2014). Metacognition is the process of evaluation of one's own cognitive processes, for example evaluating the vividness of a memory, or the probability of making a correct perceptual judgement (Fleming & Daw, 2017). In perceptual decisions, where one indicates whether a signal was present or not, metacognition is a process that usually binds together the saliency of a signal and the uncertainty regarding this signal to form the probability of having made a correct decision. When a signal was easy to detect due to high saliency, the probability of making a correct detection increases as does confidence. When uncertainty increases, for example when the contrast is low, the probability of being correct decreases, and so do confidence levels (Zylberberg, Roelfsema, & Sigman, 2014). Confidence regarding perceptual judgments can be shared with others, informing them in a compact manner about our perceptual experience and our estimated probability of making the correct judgement, and can be used as a basis of collective decisions making (Bahrami et al., 2012). Sharing information adds a social layer to the metacognitive process, as the shared information can be used to signal socially relevant traits of the sender such as competence, group affiliation and social rank. It can also be used to manage one's relationship with others, for example to maintain or gain influence (Bayarri & DeGroot, 1989; Hertz et al., 2017; Shea et al., 2014).

Differences in metacognition and self-reflection have been found in people diagnosed with schizophrenia (Frith, 2014; Lysaker et al., 2010) along with difficulties in social functioning and social cognition (Bell et al., 2017; Couture, Penn, & Roberts, 2006; N. J. Raihani & Bell, 2017). Notably, psychosis frequently includes the experience of being influenced by outside, often illusory social agents (Bell et al., 2017), and people affected by delusional beliefs can find it hard to withhold communicating their confidence in the belief even when it may lead to social sanction (Bell, Raihani, & Wilkinson, 2020). This suggests that an alteration to the meta-cognitive processes for social influence may be involved in these experiences in psychosis. However, there is currently little experimental evidence evaluating social information sharing in psychosis.

In previous work, Hertz et al. (2017) examined the use of confidence in advice giving as a tool to gain and maintain social influence. In their advice-giving paradigm participants competed with rival advisers for influence over a client. When the participant was ignored by the client, in order to gain more influence in future interactions, participants increased their advice confidence irrespective of the uncertainty in the evidence on which they based their advice. When their influence over the client was high, they reduced their advice confidence in order to maintain their high influence, as low confidence may prevent being punished (i.e. lose influence) in case they were mistaken. In addition, participants' advice-confidence was also affected by their performance level and accuracy, as participants were more willing to increase their confidence to gain influence when their previous advice was more accurate than the rival adviser's advice (Hertz et al., 2017), and were more willing to invest in self-promotion after having given accurate advice in the immediately previous round (Hertz, Tyropoulou, Olesen, & Bahrami, 2018). These results are in line with a normative account of influence seeking and maintaining strategy (Bayarri & DeGroot, 1989), and with theories highlighting the fundamental role of social influence in human social behaviour (Anderson, Hildreth, & Howland, 2015; Berger, 1977; Ridgeway, 1991). Importantly, these results suggest that the use of advice-confidence is associated with social perception of influence and relative performance.

In the current study we set out to explore the relation between psychosis and strategic use of metacognitive judgements of perceptual accuracy, i.e. confidence level, for social influence. We used the advice-giving paradigm described above, in which participants play the role of adviser, competing with another adviser for influence over a client (i.e. receiver) behaviour.

We examined three cohorts of participants, a control population recruited online, a group of participants diagnosed with schizophrenia, and a third group of participants diagnosed with bipolar disorder. We used between-group analysis to examine differences between clinical population and control population. In addition, we pooled both clinical groups to run a symptoms-based analysis in which psychosis related symptoms and mood related symptoms were used to predict the social use of advice confidence.

Methods

Sample

We recruited three cohorts of participants. The first cohort included 23 participants diagnosed with bipolar disorder (12 males, 65% bipolar I, ages 45.0±10.7, mean±std). The second cohort of participants included 26 individuals diagnosed with schizophrenia (9 males, ages 45.8±12.2). All participants had already taken part in the DNA polymorphisms in mental illness (DPIM) study at University College London (Fiorentino, Sharp, & McQuillin, 2015). Briefly, participants with an ICD-10 diagnosis of bipolar disorder or schizophrenia were recruited from UK NHS mental health services or from their primary care physicians. Participants with an ICD10 diagnosis of schizophrenia were interviewed by trained research assistants using the Schedule for Affective Disorders and Schizophrenia-Lifetime Version (SADS-L) (Mannuzza, Fyer, Klein, & Endicott, 1986; Spitzer, Sheehy, & Endicott, 1977) to confirm the diagnosis according to Research Diagnostic Criteria (RDC) (Spitzer, 1978). Research interviews were supplemented with information from clinical records. Case participants were also rated with the 90-item Operational Criteria Checklist (OPCRIT)(McGuffin, 1991). DPIM participants were re-contacted via the post to invite them to take part in the current study. Mean time between recruitment onto the register and participation in this study was 3.98 years (SD = 2.84). The invitation letter included information about the study, the technical requirements of the study and a consent form.

Participants who explicitly consented to perform the experimental task were sent a link to the online task. This process introduced additional selection criteria, such as access to a computer and internet connection, active use of an email address and technical literacy. 43 of the participants carried the task on their own computers on their own, 4 were invited to finish the experiment in the lab in UCL, and 2 were assisted at home by an experimenter. Of these participants, 17 diagnosed with bipolar disorder and 13 with schizophrenia completed the ISS mood questionnaire (Bauer, 1991) following the behavioural task. The DPIM study had ethical approval granted by the UK National Health Service Metropolitan Multi-Centre Research Ethics Committee (MREC, now called South Central – Hampshire A; MREC/03/11/090; Chief Investigator Dr. Andrew McQuillin). This study formed an extension to the DPIM study and an amendment to the ethical approval for this study was received before this study commenced.

In addition, we recruited 54 healthy participants to carry the task online via Amazon Mechanical Turk (ages 32.2±9.9 mean±std, 30 Males). These participants completed the Oxford-Liverpool Inventory of Feelings and Experiences (O-LIFE) Schizotypy questionnaire (Mason, Linney, & Claridge, 2005) (Scores mean±std: Unusual Experiences: 1.87±2, Cognitive Disorganisation: 2.83±2.66, Introvertive Anhedonia: 3.22±2.1, Impulsive Nonconformity: 1.96±1.89). All online participants provided informed consent and received monetary compensation. The study was approved by the research ethics committee at University College London. Following a previous study (Hertz et al., 2017) involving 58 participants online, we estimated our effect size to be around 0.5. As our experiment follows a within-participants design, we decided to recruit 50 participants for the control group.

Task

All participants played an advising game (Hertz et al., 2017). In this advice-giving task, over multiple trials two advisers competed for influence over a client's attention (Figure 1). All participants played the role of adviser in the game, and the behaviour of rival adviser and the client was governed by an algorithm. On each trial, the client would select an adviser to bet (on behalf of the client) on the winning colour of a ball selected from a rack of two coloured balls in differing proportions put into a raffle. The client chose between two advisers, based on their previous confidence and accuracy.

From the point of view of our participants, the trial started with the client's choice of adviser displayed to the advisers (Figure 1B, panel 1). The participant and the rival adviser then proceeded to observe the private evidence (panel 2). The advisers saw (duration: 1000ms) a rack of black and white balls about to be put in the raffle. The ratio between the black and white balls indicated the probability of the winning colour. Naturally, if there were more black balls in the rack, the probability that a black ball would be drawn from the raffle was higher. Next (panel 3), the advisers gave their advice about the more likely colour of the winning ball (black/white) and their estimate of the likelihood of it winning using a 5-stars confidence scale. Subsequently (panel 4), both declarations were shown to both advisers and the client. The client followed the chosen adviser's bet (panel 5), and finally, the colour of the winning ball was revealed to everyone (panel 6) and the next trial ensued. All participants played the advice-giving game for 70 trials. Key behavioural variables are the advisers' choice of lottery and their confidence in their suggestions in each trial.

To familiarise with the task steps, a short non-social practice version of the task was administered first. Over 10 trials, participants observed the rack of black and white balls for 1000 milliseconds and indicated which colour ball was more likely to be drawn from the raffle using the same 5-star confidence scale. This short session helped participants understand the nature of the evidence (for example that even with 95 black balls there is still a small probability that a white ball is drawn) and practice using the 5-star confidence scale appropriately.

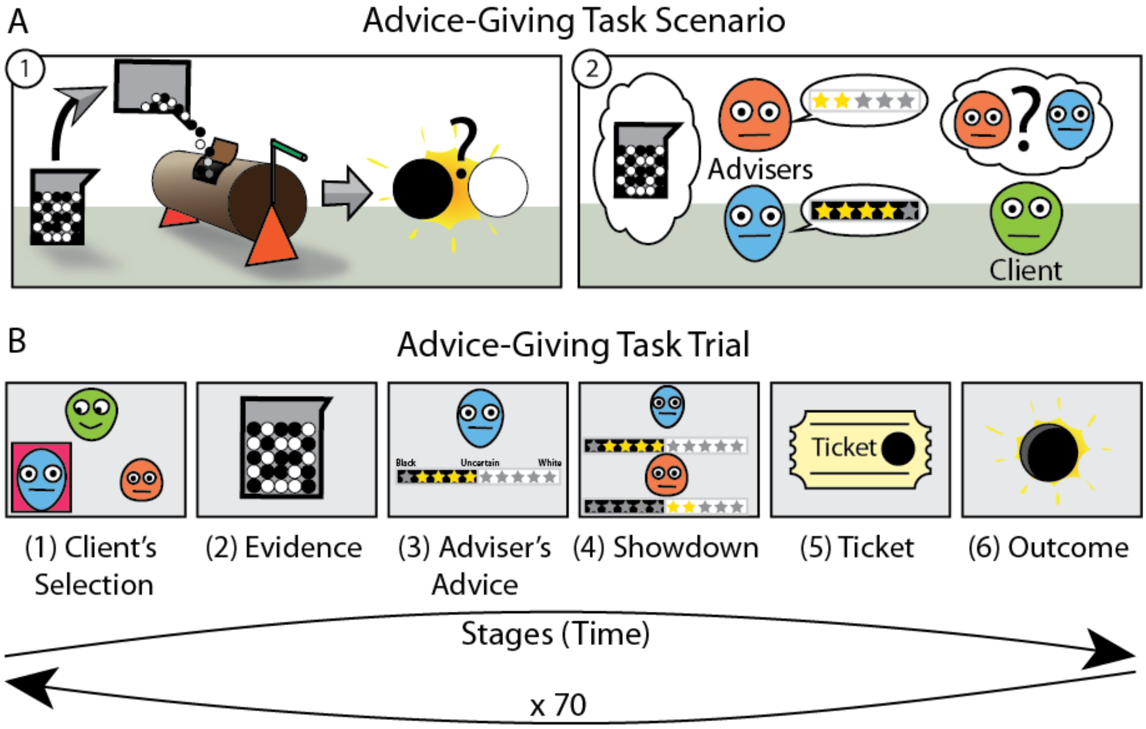

Figure 1 – Experimental Design

We used a three-person advice-giving game, in which two advisers compete for influence over a client's behaviour. (A) In the game over multiple trials a client wants to bet on a winning colour in a lottery but does not know on which colour (black or white) to bet. The client therefore has to rely on the advice of his two advisers who have private information about the chances of winning for black and white. Participants always played the role of one adviser, and the rival adviser and client were programmed virtual agents. (B) At the beginning of each trial the client publicly chooses which adviser to follow (stage 1). The advisers then get to see the rack of black and white balls about to be put in the raffle, representing the probabilistic information about the chance of winning colour (stage 2). They then advise the client using a confidence scale (stage 3). The advice of both advisers is then revealed to all participants (stage 4), after which the client's bet is made (stage 5) and the winning colour is revealed (stage 6). For the next trial, the client can decide to stick with the same adviser or to switch. For an interactive demo see: http://urihertz.net/AdviserDemo2/ .

The rival adviser's advice was calculated on each trial according to the probability of the winning ball to be black indicated by the number of black balls in the rack, plus noise: $AdviceValue = p(Black) + \epsilon$, where $\epsilon \sim N(0{,}0.08)$. When this value was greater than 0.5 the rival adviser indicated that the black ball will win, and confidence (number of stars) was determined by how much this value exceeded 0.5. When the value was lower than 0.5 the rival adviser indicated the winning ball was white, and confidence was determined on how far the value was below 0.5. The virtual client's choice of adviser was determined by assigning an influence weight to each adviser, updating the weights after each outcome and choosing the adviser with the higher weight in the next trial. If weights were equal, the client chose their adviser at random.

The weights summed to 10 and were set to 5 for each adviser in the beginning of the experiment. Following Bayarri and DeGroot (Bayarri & DeGroot, 1989), to update the weights, we calculated the prognostic value of advice (PA) for each adviser as follows. We first multiplied the advice absolute confidence (range 1-5) by its accuracy (1 correct, -1 wrong), then added 5 to it increasing the range to 0-10. We used the notation PA_p for to refer to prognostic value of the participant's advice and PA_O for prognostic value of the rival adviser's advice. Thus, if a given advice was highly confident (e.g., 5) and turned out to be correct (+1), it would have a high prognostic value (1x5+5=10). Alternatively, if the same advice turned out to be wrong, it would have low prognostic value ((-1)x5+5=0). For a given adviser i, the weight (w_i) for trial (t+1) was updated according to:

$$w_i(t+1) = 10 \cdot \frac{w_i(t) \cdot PA_i(t)^2}{w_P(t) \cdot PA_P(t)^2 + w_O(t) \cdot PA_O(t)^2}$$

Note that $w_P + w_O = 10$. If advisers give the same advice, the influence weights remain the same.

An important aspect of our experimental paradigm was that client's choice of adviser was linked to the advisers' previous performance and confidence, in order for the participants' advice to play a role in the strategic management of their influence. However, such updating rule had the potential of the client not switching between advisers, for example if one of them is not making any big mistakes and keep getting chosen. In accordance with our earlier implementation of the advice-giving task (Hertz et al., 2017), we selectively manipulated the participant's and the rival adviser's advice quality on two 10-trials intervals. In these restricted periods of trials, we introduced some noise to one of the two advisers' evidence such that the ratio of black and white balls in the rack became a poor predictor of the winning colour. The procedure was as follows: if in a specific trial the probability of the winning ball being black was 0.75, the rack of balls would normally include 75 black and 25 white balls. On a noisy trial with similar probability of 0.75, this composition would change to 55 black and 45 white balls, a reduction in contrast by 20 balls. In all noisy trials, contrasts were reduced by 20 balls in a similar fashion. The procedure ensured that one adviser's advice accuracy was systematically inferior to the other's for a number of consecutive trials, thus increasing the probability that the virtual client would shift to selecting the other adviser. This procedure was implemented for 10 trials every 30 trials (10 noisy trials followed by 20 non-noisy trials, 10 trials into the game, and favoured the participant and the rival adviser alternately. Importantly, this noise manipulation was shown to have no effect on the effect of interest in the advice giving task beyond its local effect on client switches (Hertz et al., 2017).

Non-Social Performance Measures

We wanted to measure the differences between individuals diagnosed with bipolar disorder, individuals diagnosed with schizophrenia, and control participants in how well they could interpret evidence uncertainty and report their decision and confidence accordingly. We were interested in this measurement regardless of the social aspects of the task. We calculated the participants' advice accuracy, their average confidence ratings, and the time it took them to give the advice (reaction time). We also used signal detection theory measures of perceptual (i.e., d') and metacognitive sensitivity (i.e., meta-d') (Maniscalco & Lau, 2012). The latter measure estimates the likelihood of being correct when using high confidence ratings and making mistakes when using low confidence reports. Finally, M-ratio was calculated as the ratio between meta-d' and d'. M-ratio controls for potential perceptual differences as well as response biases, and has therefore been argued to be more accurate than model-free approaches (Fleming & Lau, 2014). All analyses were carried using Matlab R2018b Statistics Toolbox (MathWorks Inc.) and the type 2 signal detection theory analysis toolbox by Maniscalco and Lau (Maniscalco & Lau, 2012).

Social Influence Strategy Measures

To assess the participants strategic social behaviour in advising, we followed Hertz et al. (2017). We started by examining the trial-by-trial deviance of advice confidence from the probabilistic evidence. If an adviser is strictly committed to communicating the evidence they are given, then confidence should exactly match the ratio of black to white balls in the rack (Figure 1b). For such adviser, confidence level of five stars for black to win is reported when close to 100% of the balls in the rack are black. Conversely, a low-confidence advice of one star for black would be reserved to weak evidence, in which the ratio between black and white balls is very close to 50-50. Advice confidence would deviate if the confidence is higher (positive deviance) or lower (negative deviance) than the probability indicated by the evidence and is calculated as the residual in confidence after correlation with evidence was regressed out.

Hertz et al. (2017) showed that advice deviance is affected by whether the client has selected or ignored the adviser, and by the history of the advisers' performance in previous trials. We therefore evaluated the trial-by-trial effect of (1) influence (ignored/chosen by the client) and (2) the accuracy of previous advice (wrong/correct) on advice deviance as our key dependent variable. We therefore used mixed effect linear models, with advice deviance as the dependent variable, participant identity as a random effect and influence (ignored/chosen) and accuracy in previous trial (wrong/correct) as within-subjects fixed effects and group (control, schizophrenia and bipolar) as between-subject independent variable.

Results

Non-Social measures of task performance

We first compared the overall accuracy of advice, i.e., the percentage of times the participants picked the winning colour (Figure 2). While overall performance was different across groups, it is clear that all groups were able to perform the task as their accuracy levels were comparable, and far higher than chance. We found that individuals diagnosed with bipolar disorder gave the most accurate advice (Figure 2A, mean±std [percent correct], control: 0.71±0.052, schizophrenia: 0.71±0.043, bipolar: 0.75±0.05, two tailed t-test: control vs bipolar: $t(75)= 2.62$, $p = 0.01$, control vs schizophrenia: $t(78)= 0.51$, $p = 0.6$, bipolar vs schizophrenia: $t(47)= 2.98$, $p = 0.0045$).

Control participants spent less time on each advice (Figure 2B, mean±std [seconds], control: 1.3±0.43, schizophrenia: 3±1.8, bipolar: 1.7±0.55, two tailed t-test: control vs bipolar: $t(75)= 3.3$, $p = 0.0015$, control vs schizophrenia: $t(78)= 6.55$, $p < 0.00001$, bipolar vs schizophrenia: $t(47)= 3.32$, $p = 0.0017$). Decision efficiency, defined as the accuracy divided by the time spent on each advice, was highest in the control group (Figure 2C, mean±std [decision efficiency], control: 0.58±0.15, schizophrenia: 0.31±0.14, bipolar: 0.47±0.13, two tailed t-test: control vs bipolar: $t(75)= 2.93$, $p = 0.0045$, control vs schizophrenia: $t(78)= 7.75$, $p < 0.00001$, bipolar vs schizophrenia: $t(47)= 4.22$, $p = 0.0001$). Individuals diagnosed with either bipolar disorder or schizophrenia spent more time contemplating each advice, which made their decisions less efficient.

Next, we examined the use of confidence scale by our participants. We found that individuals diagnosed with schizophrenia tended to use the higher confidence ratings more often than individuals diagnosed with bipolar disorder and the control participants (histograms in Figure

2D), resulting in higher average confidence ratings (mean±std [confidence], control: 3.1±0.46, schizophrenia: 3.4±0.7, bipolar: 3±0.39, two tailed t-test: control vs bipolar: t(75)= 0.68, p = 0.49, control vs schizophrenia: t(78)= 2.76, p = 0.007, bipolar vs schizophrenia: t(47)= 2.65, p = 0.01).

To formally examine the differences in metacognitive abilities we employed signal detection theory groups (Maniscalco & Lau, 2012) and compared measures for perceptual sensitivity (d'), metacognitive sensitivity (meta-d') and metacognitive efficiency (the ratio between meta-d' and d') across. Perceptual sensitivity assessed the ability of an agent to notice small difference in the evidence (black-white marble ratio). Metacognitive sensitivity indicated how well confidence reports matched the evidence strength. Finally, while metacognitive efficiency offered a finer measure of metacognitive sensitivity by controlling for individual differences in perceptual sensitivity (see Methods for details).

Confirming the accuracy effects, we found that the individuals diagnosed with bipolar disorder displayed the highest perceptual sensitivity, but were not significantly different from control participants (Figure 2E, mean±std [perceptual sensitivity], control: 2.7±0.55, schizophrenia: 2.5±0.55, bipolar: 2.9±0.55, two tailed t-test: control vs bipolar: t(75)= 1.77, p = 0.08, control vs schizophrenia: t(78)= 1.52, p = 0.13, bipolar vs schizophrenia: t(47)= 2.82, p = 0.007). The metacognitive sensitivity of individuals diagnosed with bipolar disorder was lowest, but not significantly lower than the sensitivity of individuals diagnosed with schizophrenia (Figure 2F, mean±std [metacognitive sensitivity], control: 2.2±0.53, schizophrenia: 2.1±0.86, bipolar: 1.9±0.7, two tailed t-test: control vs bipolar: t(75)= 2.15, p = 0.03, control vs schizophrenia: t(78)= 0.53, p = 0.59, bipolar vs schizophrenia: t(47)= 1.01, p = 0.31). Finally, controlling for perceptual performance, we found that the individuals diagnosed with bipolar disorder had the lowest metacognitive efficiency (Figure 2G, mean±std [adjusted metacognitive efficiency], control: 0.86±0.25, schizophrenia: 0.89±0.35, bipolar: 0.69±0.31, two tailed t-test: control vs bipolar: t(75)= 2.52, p = 0.013, control vs schizophrenia: t(78)= 0.43, p = 0.66, bipolar vs schizophrenia: t(47)= 2.06, p = 0.04).

To conclude, individuals diagnosed with schizophrenia tended to use higher confidence ratings compared to individuals diagnosed with bipolar and control participants. However, their metacognitive sensitivity matched those of control participants, i.e. their confidence reports were informative regarding their accuracy. Individuals diagnosed with bipolar disorder matched control participants in their average confidence but displayed reduced metacognitive sensitivity and efficiency – their confidence reports were less informative (vs control) about the accuracy of perceptual decisions.

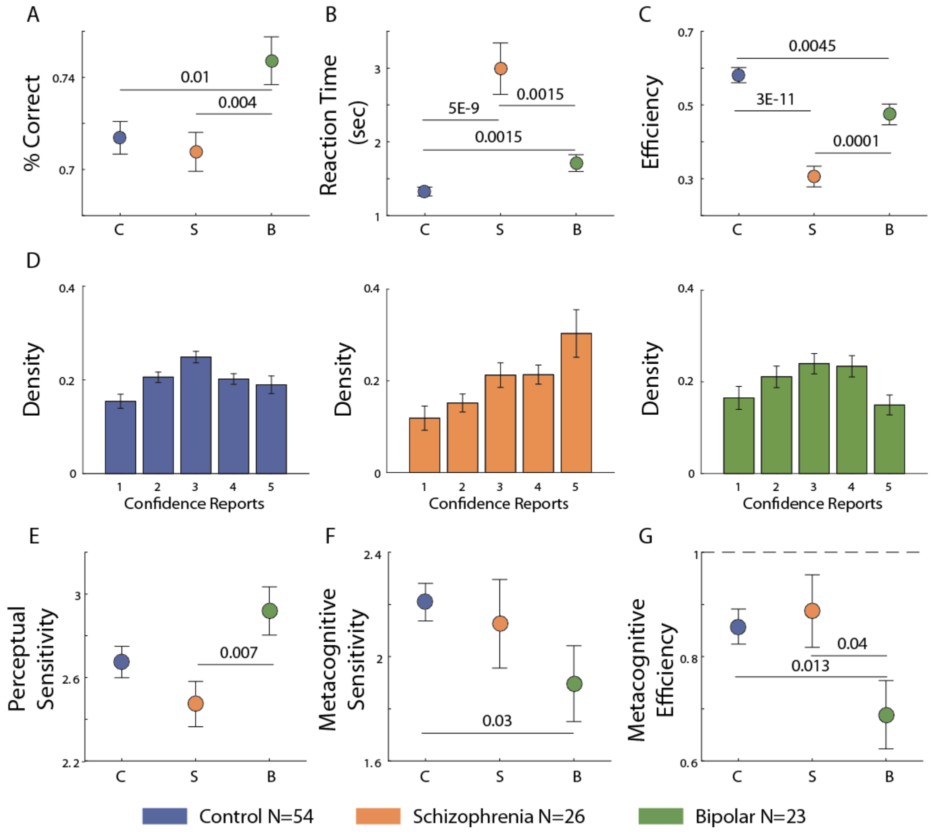

Figure 2. Non-Social Measures of task performance.

(A) Overall perceptual accuracy (i.e., frequency of choosing the winning colour) comparing Control participants (blue - C) to individuals diagnosed with schizophrenia (orange - S) and individuals diagnosed with bipolar (green - B) disorder. (B) Reaction times. (C) Decision efficiency (i.e., accuracy divided by reaction time) (D) Frequency histogram of confidence in the 3 groups. Individuals diagnosed with schizophrenia (middle panel) were more likely to use the highest confidence level in their advice. (E) Perceptual sensitivity (d'). (F) Metacognitive sensitivity (Meta-d'). (G) Metacognitive efficiency (meta-d'/d'). Error bars indicate SEM.

Social measures of task performance: Advice confidence as a persuasive signal

We were primarily interested in understanding the way participants were using advice confidence as a social persuasive signal to manage their influence over the client. Previous results using the advice-giving task (Hertz et al., 2017) showed that trial-by-trial advice deviance was affected by the participants' level of influence over the client, i.e. was the participant chosen or ignored by the client by their performance level and their advice accuracy. With this hypothesis in mind, we used a mixed effect linear regression, with advice deviance as a dependant variable and influence (chosen/ignored) and previous advice accuracy (wrong/correct) as within-subjects independent variables. We also included group (control, schizophrenia and bipolar) as between-subject dependent variable, and subject identity as a random variable (results in Table 1).

Variable Name	*Estimate ± SE*	*t(DF)*	*p*	*95% CI*
Intercept	0.15 ± 0.08	1.9(7201)	0.056	-0.004, 0.3
Influence (Ignored)	0.14 ± 0.03	3.9(7201)	0.0001*	0.07, 0.2
Accuracy (Correct)	-0.006 ± 0.03	-0.17(7201)	0.86	-0.07, 0.06
Group (SCZ)	0.27 ± 0.14	1.96(7201)	0.049*	0.0006, 0.54
Group (BP)	-0.17 ± 0.14	-1.22(7201)	0.22	-0.45, 0.11
Influence (Ignored) x Group (SCZ)	-0.05 ± 0.066	-0.81(7201)	0.41	-0.18, 0.07
Influence (Ignored) x Group (BIPOLAR)	-0.046 ± 0.066	-0.69(7201)	0.48	-0.17, 0.08
Accuracy (Correct) x Group (SCZ)	0.17 ± 0.062	2.71(7201)	0.007*	0.046, 0.29
Accuracy (Correct) x Group (BP)	0.16 ± 0.066	2.36(7201)	0.02*	0.027, 0.28

Table 1. The effect of diagnosis, advice accuracy and influence on advice confidence
SCZ individuals diagnosed with schizophrenia; BP individuals diagnosed with bipolar disorder; * $p < 0.05$

We found that overall individuals diagnosed with schizophrenia tended to give overconfident advice (t(DF) = 1.96 (7201), p = 0.049), in line with our results indicating the use of higher confidence ratings overall (Figure 2). Confirming our principle hypothesis, we found a significant main effect of influence (t(DF) = 3.9(7201), p = 0.0001): across all groups, participants gave more confident advice when they were ignored by the client compared to when they were the chosen advisers. This finding is in line with our previous results (Hertz et al., 2017, 2018). There was no significant interaction between influence and group, either in the schizophrenia or the bipolar disorder groups, indicating that the effect did not differ by diagnosis. We did not find any significant main effect for advice accuracy: however, accuracy significantly affected the advice confidence for individuals diagnosed with schizophrenia and individuals diagnosed with bipolar disorder (schizophrenia: t(DF) = 2.71(7201), p = 0.007, bipolar: t(DF) = 2.36(7201), p = 0.02). Compared to control, schizophrenia and bipolar diagnosis groups gave more confident advice after having given accurate advice in the previous trial.

To illustrate the direction and magnitude of these effects we separated the trials according to group, influence (ignored/chosen) and advice accuracy (wrong/correct) and calculated each participant's average advice deviance in each condition (Figure 3). Control participants were mostly driven by influence level - they gave more confident advice when they were ignored by the client. Participants in the schizophrenia and bipolar groups were much more affected by their own previous advice accuracy, increasing their advice confidence after having been correct. These findings indicate that control participants were more strategic in their use of advice confidence: unencumbered by their previous failure or success, control participants increased their confidence when ignored in order to gain influence and attenuated it when selected consistent with normative prescriptions for maintaining social influence (Bayarri & DeGroot, 1989; Hertz et al., 2017). Individuals diagnosed with schizophrenia and those with bipolar disorder were less affected by the social aspect of their advice and its consequence for their influence and seemed to be more concerned by monitoring their own performance.

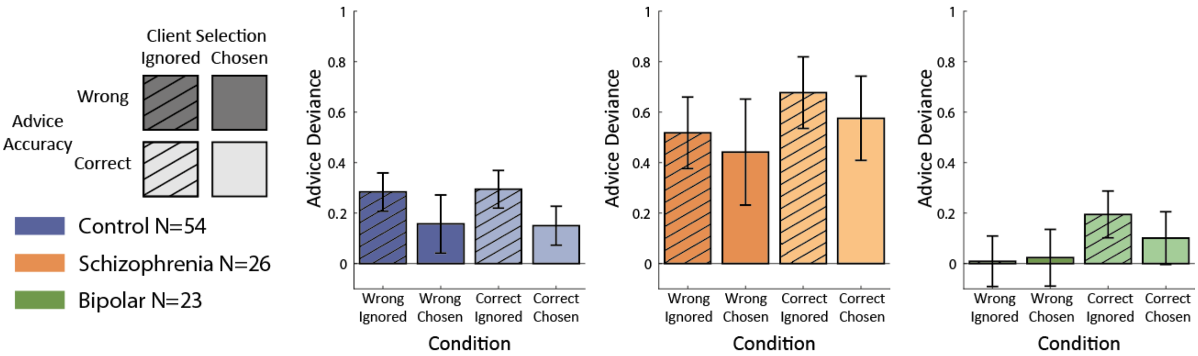

Figure 3. The Strategic effects of influence level and competence on advice confidence when participants are treated as social agents. a graphical demonstration of the effect revealed by our mixed effect linear regression in Table 1. Advice deviance from perceptual evidence (i.e. how over- or under-confident the advice was) is depicted here in a 2x2 design consisting of accuracy in the previous trial (dark shade for incorrect previous advice and light shade for accurate previous advice), and social influence level in the current trial (lined bars for ignored by the client and empty bars for chosen by the client). Both individuals diagnosed with bipolar disorder and schizophrenia were more affected by their own advice accuracy compared with control

participants. Only healthy controls demonstrated a strategic use of confidence for increasing their social influence. The bars indicate the groups' mean scores, and the error bars indicate SEM.

We used a mixed effect linear regression to evaluate how task variables affected advice confidence. We used advice deviance as a dependant variable – was the advice over- or under-confident given the evidence. We examined how advice deviance was affected by the client's selection of the adviser, i.e. was the participant just ignored or chosen by the client, and advice accuracy, i.e. was the participant's last advice wrong or correct, as dependant variables. To demonstrate the effects found in the regression we separated the trials according to these conditions, in a 2x2 design, and plotted the average and SEM for each condition in each group of participants. We found that participants in the control group were mostly influenced by their influence level and tended to increase their advice confidence when they were ignored by the client (Table 1). Participants in both schizophrenia and bipolar group were mostly affected by their own accuracy, giving more confident advice when their recent advice was accurate. Schizophrenia participants showed overall higher advice-deviance, while bipolar participants tended to give calibrated advice.

Variable Name	*Estimate ± SE*	*t(DF)*	*p*	*95% CI*
Intercept	0.12 ± 0.34	0.34(1742)	0.58	-0.46,0.83
Influence (Ignored)	-0.036 ± 0.09	-0.4(1742)	0.68	-0.21,0.14
Accuracy (Correct)	0.16 ± 0.05	2.79(1742)	0.0052*	0.047,0.27
Delusion	-0.61 ± 0.57	-1.08(1742)	0.28	-1.73,0.5
Mood	-0.1 ± 0.18	-0.58(1742)	0.56	-0.25,0.47
Hallucination	1.07 ± 0.64	1.65(1742)	0.098	-0.19,2.33
Influence (Ignored) x Delusion	0.51 ± 0.24	2.09(1742)	0.036*	0.03,0.99
Influence (Ignored) x Hallucination	-0.26 ± 0.24	-1.08(1742)	0.28	-0.74,0.21

Table 2 – The effect of symptoms (Hallucination, Delusions, Mood), advice accuracy and influence on advice confidence

* p < 0.05

Exploratory analysis: association with Psychotic Symptoms

We used the scores associated with hallucination, delusions and mood items of the 90-item Operational Criteria Checklist (OPCRIT)(McGuffin, 1991) across participants, and fitted a mixed effect linear regression to advice confidence, with task related effects (Accuracy and

Influence), and symptom related effects (hallucination, delusion and mood scores) as fixed effects. We found that delusion scores interacted with influence, i.e. participants with high delusion scores increased their confidence more when they were ignored by the client (Table 2). However, we wish to emphasise the exploratory nature of this analysis and caution the reader - with a p value of 0.036 and the number of comparisons perhaps this finding is best interpreted as preliminary evidence.

Discussion

In this study we examined the association of psychosis-spectrum disorders and symptoms with differences in sharing metacognitive judgements of confidence for social influence. We compared the performance of three groups of participants in a competitive advice-giving task: individuals diagnosed with psychiatric disorders with high levels of psychotic symptoms, individuals diagnosed with bipolar disorder, and healthy controls. In this task participants observed probabilistic perceptual evidence about the likelihood of two different outcomes in a lottery and (i) gave advice about which outcome was more likely, and (ii) communicated their confidence in (i). Crucially, participants competed with rival advisers over a client's attention which was awarded based on a function of advice accuracy, confidence and outcome. We found that the highest overall confidence in advice was found in participants diagnosed with schizophrenia. Moreover, only participants in the control group used their confidence strategically to increase their influence over their client. Participants diagnosed with schizophrenia and those diagnosed with bipolar disorder were, instead, mostly driven by their recent accuracy in advice giving. Symptom-based analysis revealed that variation in advice confidence was associated with the presence of delusions but not hallucinations or mood symptoms.

It is important to note that we are reporting an exploratory study and further research will be needed to confirm the results reported here. However, the association of differences in confidence, and differences in communication of confidence for social influence, with psychotic disorder and delusions has prima facie validity. Delusions are the defining feature of psychosis and, by definition, beliefs that are held with high degrees of confidence which do not conform to social norms and are not swayed by those in the social milieu in which the affected person resides. Previous research has shown that individuals diagnosed with schizophrenia show increased metacognitive confidence for inaccurate beliefs about others during strategic interactions (Joyce, 2013) and for inaccurate perception of self-referential communication (White, Borgan, Ralley, & Shergill, 2016). This suggests that alterations to metacognition for social judgements may play a role in the generation or maintenance of psychotic symptoms (Raihani and Bell 2019) (Bell et al., 2020) echoing recent work on the role of beliefs as having primarily a social function (Williams, 2020). Nevertheless, the extent to which this is characteristic of all people with schizophrenia and / or psychosis has been debated in light of results that suggest that extreme overconfidence for social cognitive judgements was characteristic of only a subset of patients (Jones et al., 2020) which may be one factor in the low strength of evidence for clear effects reported in this study.

It is worth noting some limitations to this study. Patient diagnoses were established and symptoms were measured using gold standard structured interviews at the time of recruitment onto the research register but participation happened later and so may have changed since participation. Symptoms measured at the time of participation were solely through validated self-report scales. Longitudinal studies looking at symptom stability over multi-year periods have found that baseline severity is more likely to change than relative severity between symptoms which remains relatively stable (Marengo, Harrow, Herbener, & Sands, 2000; Reichenberg, Rieckmann, & Harvey, 2005). However, further studies that measure psychotic symptoms using gold standard assessments at the time of cognitive task participation would likely provide a better estimate of the associations reported here. Furthermore, this study did not measure cognitive function which may account for the differences between participant groups reported here. We found that individuals diagnosed with schizophrenia used higher confidence ratings compared to individuals diagnosed with bipolar and control participants but that their metacognitive abilities matched those of control participants, potentially suggesting that differences in general cognitive function did not play a role in overall task performance. However, dedicated measures of general cognitive function are needed to confirm this. Although not a limitation per se, this was an exploratory study and further pre-registered research will be needed to test specific hypotheses regarding the association between clinical features and the sharing confidence judgements for social influence.

In conclusion, we report an exploratory study suggesting that psychosis, particularly delusions, is associated with differences in sharing metacognitive judgements of confidence for social influence. Although exploratory in nature, given the face validity of this association in light of the presentation of psychosis, we suggest further research in this domain may be a useful line of enquiry.

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