

*This is a pre-copy-editing, author-produced PDF of an article accepted for publication in Schizophrenia Bulletin following peer review. The definitive publisher-authenticated version [Ross, R., McKay, R., Coltheart, M. & Langdon, R. (2015). Jumping to conclusions about the beads task? A meta-analysis of delusional ideation and data-gathering. Schizophrenia Bulletin. doi:10.1093/schbul/sbu187] is available online at: <http://schizophreniabulletin.oxfordjournals.org/content/early/2015/01/22/schbul.sbu187.full>.*

Title: Jumping to conclusions about the beads task? A meta-analysis of delusional ideation and data-gathering

Running Head: Delusional ideation and data-gathering

Authors: Robert Malcolm Ross<sup>\*a</sup>, Ryan McKay<sup>b</sup>, Max Coltheart<sup>a</sup>, Robyn Langdon<sup>a</sup>

<sup>a</sup>ARC Centre of Excellence in Cognition and its Disorders, Macquarie University, Sydney, NSW 2109, Australia

<sup>b</sup>ARC Centre of Excellence in Cognition and its Disorders, Department of Psychology, Royal Holloway, University of London, Egham, TW20 0EX Surrey, United Kingdom

\*Corresponding Author:  
Email: [robross45@yahoo.com.au](mailto:robross45@yahoo.com.au)  
Phone: +61 2 9850 2992  
Fax: +61 2 9850 6059

Abstract word count: 213

Text body word count: 3812

Total word count: 4025

## **Jumping to conclusions about the beads task? A meta-analysis of delusional ideation and data-gathering**

It has been claimed that delusional and delusion-prone individuals have a tendency to gather less data before forming beliefs. Most of the evidence for this “jumping to conclusions” (JTC) bias comes from studies using the “beads task” data-gathering paradigm. However, the evidence for the JTC bias is mixed. We conducted a random-effects meta-analysis of individual participant data from 38 clinical and non-clinical samples ( $n = 2238$ ) to investigate the relationship between data gathering in the beads task (using the “draws to decision” measure) and delusional ideation (as indexed by the “Peters *et al.* Delusions Inventory”; PDI). We found that delusional ideation is negatively associated with data gathering ( $r_s = -0.10$ , 95% CI [-0.17, -0.03]) and that there is heterogeneity in the estimated effect sizes ( $Q$ -stat  $p = 0.03$ ,  $I^2 = 33$ ). Subgroup analysis revealed that the negative association was present when considering the 23 samples ( $n = 1754$ ) from the large general population subgroup alone ( $r_s = -0.10$ , 95% CI [-0.18, -0.02]) but not when considering the eight samples ( $n = 263$ ) from the small current delusions subgroup alone ( $r_s = -0.13$ , 95% CI [-0.33, 0.06]). These results provide some provisional support for continuum theories of psychosis and for cognitive models that implicate the JTC bias in the formation and maintenance of delusions.

**Key words:** bias; beads task; delusion; jumping to conclusions; meta-analysis; schizophrenia

## **Introduction**

In a now classic study, the “beads task”<sup>1</sup> was adapted to examine the relationship between delusions and data-gathering.<sup>2</sup> Participants were shown two jars of beads, a mostly pink jar (85 pink beads; 15 green beads) and a mostly green jar (85 green beads; 15 pink beads). The jars were then hidden and participants were shown a sequence of beads apparently being drawn from one of the two jars (the sequence was actually pre-specified by the experimenter). After each draw participants were asked if they were ready to make a decision about which jar the beads were being drawn from or if they would like to see another bead. This study found that people with delusions made a decision about which jar the beads were being drawn from on the basis of significantly fewer beads than controls. This study has inspired a large empirical literature, and primarily on the basis of evidence from studies using the beads task paradigm it has been argued that people with delusions show a JTC bias: they are willing to accept hypotheses on the basis of less evidence than non-delusional people.<sup>3-5</sup>

It has long been argued that the positive symptoms of psychosis – delusions and hallucinations – lie at the extreme end of a continuum of similar subclinical phenomena in the general population.<sup>6-10</sup> The existence of a “psychosis continuum” is supported by two recent meta-analyses.<sup>11, 12</sup> Furthermore, it has

been argued that the syndrome-based diagnostic categories of psychiatry impede progress in understanding the aetiology of mental illnesses and research should be reoriented to focus on vulnerability traits and symptoms across diagnostic categories and within the general population.<sup>13-15</sup> Notably, the American National Institute of Mental Health (NIMH) has recently released a strategic plan that proposes abandoning syndrome-based classifications of the *Diagnostic and Statistical Manual of Mental Disorders (DSM)* to examine “the full range of variation, from normal to abnormal, among the fundamental components [dimensions] to improve understanding of what is typical versus pathological”.<sup>16</sup>

A dimensional approach that examines variation in the general population could provide insight into clinical delusions. In particular, evidence for an association between the JTC bias and delusional ideation in the general population would provide support for influential cognitive models that implicate the JTC bias in the aetiology of clinical delusions.<sup>17-23</sup> The PDI<sup>24</sup> is by far the most widely used measure of delusional ideation in the beads task literature. The PDI is a self-report questionnaire that asks people if they have ever had particular delusion-like experiences. For example, one item asks, “Do you ever feel as if there is a conspiracy against you?” For each item endorsed people are asked to rate the degree of associated distress, preoccupation, and conviction separately on five-point Likert scales. The original PDI has 40 items,<sup>24</sup> but a 21-item version with comparable psychometric properties is also widely used.<sup>25</sup> On average, patients diagnosed with delusions report higher PDI scores than healthy controls;<sup>24, 25</sup> on average, members of new religious movements report PDI scores that fall

between those of delusional and general populations;<sup>26</sup> and PDI scores correlate moderately strongly with observer-rated delusions using a structured clinical interview.<sup>27</sup> Such findings suggest that the PDI is a valid measure of thoughts that lie on a continuum with delusional beliefs.

Studies of the association between the JTC bias and delusions do not always provide consistent results, casting doubt on cognitive models implicating the JTC bias in delusion formation and maintenance. Consequently, careful evaluation of the overall weight of evidence is needed. A 1999 systematic review by Garety and Freeman<sup>5</sup> argued that seven of eight beads task studies provided evidence that the JTC bias is associated with delusions. A 2013 follow-up by Garety and Freeman<sup>4</sup> reviewed 53 new beads task studies (and 8 studies using other probabilistic reasoning tasks) and concluded that “the clear majority of these studies... confirmed that JTC is characteristic of people with delusions” (p. 328). Although this “vote counting” approach is commonly employed in systematic reviews, it is known to have significant limitations.<sup>28, 29</sup> First, it does not take into consideration features of studies (such as sample size) that ought to result in some studies being weighed more heavily than others. Second, it does not test or control for publication bias, selective reporting bias, or other biases that can inflate the evidence for an effect. Third, it does not quantify effect sizes.

The limitations of systematic reviews make meta-analysis a crucial tool for integrating evidence across studies.<sup>29-32</sup> A 2007 meta-analysis by Fine *et al.*<sup>3</sup> examined 12 studies. They found that one measure of the JTC bias reached statistical significance (“draws to decision”), but another three measures did not.

Although useful, this meta-analysis has limitations. First, it used multiple effect sizes from the same samples (47 effect sizes from 22 samples) to estimate a single underlying construct (the JTC bias), which violates the assumption of statistical independence.<sup>29, 32</sup> Second, the Stouffer method of meta-analysis was used,<sup>33</sup> which makes the problematic assumption that all studies are sampled from a single population.<sup>29</sup> Third, the possibility of publication bias and selective reporting bias was not examined. Fourth, effect sizes were not quantified.

Taylor *et al.*<sup>34</sup> recently pre-registered a rationale and protocol for a meta-analysis that will examine whether the JTC bias is associated with clinical delusions. This protocol is methodologically sophisticated and promises to address limitations of the earlier systematic reviews and meta-analysis.

Nevertheless, because this protocol focuses on between-group differences it will not speak directly to the hypothesis that delusions lie at the extreme end of a continuum of subclinical phenomena within the general population.<sup>6-12</sup>

It has been argued that a variety of questionable research practices are prevalent in the social sciences, and an anonymous survey suggests that selective reporting of results is particularly widespread.<sup>35</sup> Selective reporting bias can result in false-positives well above the nominal rate of 5%,<sup>36</sup> even when researchers strive to report their results dispassionately and honestly.<sup>37</sup> Selective reporting bias can be curtailed by direct replication of experiments, ideally with preregistered protocols, and open access to raw data. However, due to the value placed on innovation in the social sciences, direct replication is extremely rare.<sup>38</sup> In this respect, the beads task literature fits the typical profile of social science

research. We were unable to identify any beads task study that directly replicated an earlier study, or used a pre-registered protocol, or provided open access to raw data. Consequently there is considerable scope for selective reporting bias.

In the present meta-analysis we tested the hypothesis that delusional ideation is negatively associated with data-gathering in the general population and clinical populations. We did not use the effect sizes reported in publications. Instead we acquired raw data for each study that met our inclusion criteria and calculated the precise effect size of interest for each sample: the association between draws to decision on the beads task and PDI scores. This “individual participant data” approach offers numerous advantages over conventional meta-analysis and is considered to be the “gold standard” of systematic review.<sup>39-41</sup> Two advantages are particularly salient when considering the beads task literature. First, beads task studies typically report differences *between* samples *only*. That is, variation *within* delusional samples and *within* non-delusional samples, which is crucial for testing continuum models, is rarely reported. Using individual participant data we were able to examine this crucial, but neglected, variation. Second, by consistently applying the same screening criteria and statistical tests to samples from different studies we were able to circumvent selective reporting bias and related biases.

## **Methods**

### *Search strategy*

We used two strategies for identifying studies for possible inclusion in our meta-analysis. First, we assessed for eligibility studies tabulated in the 2013 systematic review by Garety and Freeman.<sup>4</sup> They reported using three search techniques. First, they searched the Web of Science and PubMed databases using the following search terms: “jump to conclusions” AND “delusions”, “jump to conclusions” AND “schizophrenia”; “jump to conclusions” AND “psychosis”; “jump to conclusions” AND “paranoia”. Second, they consulted five widely cited review articles on delusions.<sup>3, 5, 22, 42, 43</sup> Third, they manually searched “early view” articles in the journals *Schizophrenia Bulletin*, *Schizophrenia Research*, *British Journal of Clinical Psychology*, *Behaviour Research and Therapy*, *Journal of Behavioural Research and Experimental Psychiatry*, *Psychological Medicine*, and *Journal of Abnormal Psychology*. In addition, we searched for articles published from 2011 to the present and “early view” articles using the same search techniques as Garety and Freeman<sup>4</sup> to identify studies that might have been published after they completed their search.

Second, we used Google Scholar’s cited reference search functionality to identify studies that had cited the paper that introduced the 40-item PDI<sup>24</sup> or the 21-item PDI from 2011 to the present.<sup>25</sup> Of the papers identified by Google Scholar, we inspected for possible inclusion those papers that had titles that indicated that they might include the beads task. Our literature search was completed July 10, 2014, and is inclusive of studies published up to that date.

#### *Inclusion criteria*



We categorised studies as eligible for inclusion in our meta-analysis if they met two inclusion criteria. First, the study used either a 40-item or 21-item PDI. We included all studies that used a PDI, even if the PDI had been modified. This meant that we included one study that used a version of the PDI that measured preoccupation only<sup>44</sup> and three studies that did not use the three PDI subscales but used only the initial “yes/no” question.<sup>45-47</sup> Second, the study used a standard two jar draws to decision version of the beads task. We did not include studies that used “beads task-like” data-gathering paradigms (such as “emotional beads task” or “fishing task” paradigms) because we wanted studies to be as directly comparable as possible.

We are interested in delusion ideation across syndrome-based diagnostic categories, so we did not exclude clinical groups that did not have a diagnosis of schizophrenia. We emailed the authors of all eligible studies with a request for raw data from their published and unpublished studies. We succeeded in sourcing raw data for all eligible published studies (bar one<sup>48</sup>) and one currently unpublished study.<sup>49</sup> All studies we sourced that met our two inclusion criteria were included in the meta-analysis.

### *Data coding*

When possible, we calculated total PDI scores for each participant by adding the number of “yes” responses to scores from the three subscales. This was possible for 27 samples (see Table 1 for exceptions). Twenty-five samples were tested using the 21-item PDI<sup>44-46, 49-60</sup> and 13 using the 40-item PDI.<sup>47, 61-66</sup> When

calculating total PDI scores for samples that used the 40-item PDI, we included only those 21 items that appear in the 21-item PDI. Raw data obtained for six samples that used the 40-item PDI did not include scores for individual items;<sup>47, 61</sup> in these cases we used the total PDI score for all 40 items. Eight samples used a version of the PDI that did not include the subscales;<sup>45-47</sup> in these cases we used the number of “Yes” responses to the initial questions alone to calculate the PDI total score. For the sample that used a version of the PDI that measured preoccupation only,<sup>44</sup> we used the preoccupation score alone to calculate the PDI total score.

Samples varied with respect to the maximum number of beads participants were able to request before making a decision about which jar the beads were being drawn from. Participants were not told what this limit was. If they reached this limit they were asked to make a decision. Following standard practice, we retained data from participants who reached the limit. Samples also varied with respect to the number of beads task trials presented to participants. For analysis, we calculated a mean draws to decision score across trials for each participant. We coded beads task trials with a ratio of beads of 60:40 as “difficult” and beads task trials with ratios of beads of either 85:15 or 80:20 as “easy”, which we used to calculate the percentage of trials that were “easy” for each sample.

Inspection of raw data occasionally revealed instances of typographic errors. When we identified such errors we attempted to infer correct values. When this was not possible we recoded erroneous values as missing data. Participants who had missing data for PDI score, draws to decision, age, or gender were removed

prior to analysis. The single exception was the study by Broome *et al.*<sup>61</sup> that did not code for gender; we included participants from this study in all analyses that did not include gender as a variable. In total, 58 participants (2.5% of participants) were removed due to missing data.

--- Insert Table 1 about here ---

**Table 1.** Characteristics of samples included in the meta-analysis. N/A = Information not available; OCD = Obsessive-Compulsive Disorder; NRM = New Religious Movement; Note 1 = 40-item PDI; for total PDI score; Note 2 = Initial "Yes/No" question for total PDI score; Note 3 = preoccupation for total PDI score.

### *Statistical Analysis*

Inspection of PDI scores and mean draws to decision revealed that neither variable was normally distributed, so we used the non-parametric Spearman's rank correlation coefficient ( $r_s$ ) for analysis. As per the method advocated by Hedges and Olkin,<sup>31</sup> we converted  $r_s$  scores to their associated Fisher's z-scores for estimating uncertainty in effect sizes and back-transformed Fisher's z-scores to  $r_s$  scores for interpretation.

Meta-analysis was conducted using the software OpenMEE<sup>67, 68</sup> and the R package Metafor.<sup>69, 70</sup> We used a random effects model<sup>30, 32</sup> and examined heterogeneity in estimates of  $r_s$  for the overall group of samples and diagnostic subgroups using the  $Q$  statistic<sup>71</sup> and the  $I^2$  index.<sup>72</sup> The  $Q$  statistic can be

underpowered,<sup>73</sup> so we paid some attention to  $I^2$  indices even in cases of non-significant  $Q$  statistics. We used the Sidik–Jonkman method for estimating heterogeneity because it provides more accurate estimates than the more widely used DerSimonian–Laird method.<sup>74</sup> To examine potential moderators of effect sizes, we used random-effects meta-regression<sup>75</sup> with a separate meta-regression for each potential moderator. We assessed the evidence for publication bias using a funnel plot and Egger’s regression test for funnel plot asymmetry.<sup>76,77</sup>

## Results

### *Meta-analysis*

Figure 1 shows a forest plot for the random-effects meta-analysis. The analysis indicates that there is a negative association between draws to decision and PDI score ( $r_s = -0.10$ , 95% CI [-0.17, -0.03],  $n = 2238$ ,  $k = 38$ )(see the dark grey diamond, Figure 1). We found moderate heterogeneity ( $Q$ -stat  $p = 0.03$ ,  $I^2 = 33$ ), which suggests that the precise magnitude of the overall effect size should be interpreted with some degree of caution.

--- Insert Figure 1 about here ---

**Figure 1.** Forest plot of random effects meta-analysis showing effect sizes ( $r_s$ ) for the association between draws to decision and PDI. The black squares show effect sizes for each sample and are drawn proportional to the relative weighting

of each sample in the analysis. The error bars show the 95% CI for each sample. The dark grey diamond shows the overall 95% CI. The light grey diamonds show the 95% CI for each subgroup. The broken line shows the overall mean effect size estimate.

### *Subgroup analysis*

We found a negative association between draws to decision and PDI when considering the general population subgroup alone ( $r_s = -0.10$ , 95% CI [-0.18, -0.02],  $n = 1754$ ,  $k = 23$ ), but not in the current delusions subgroup alone ( $r_s = -0.13$ , 95% CI [-0.33, 0.06],  $n = 263$ ,  $k = 8$ ), the previous delusions subgroup alone ( $r_s = 0.02$ , 95% CI [-0.61, 0.65],  $n = 54$ ,  $k = 2$ ), or the anxiety or depression subgroup alone ( $r_s = -0.07$ , 95% CI [-0.30, 0.17],  $n = 76$ ,  $k = 2$ ) (see respective light grey diamonds, Figure 1).

We found moderate heterogeneity within the general population subgroup ( $Q$ -stat  $p = 0.04$ ,  $I^2 = 37$ ) and substantial heterogeneity within the previous delusions subgroup ( $Q$ -stat  $p = 0.02$ ,  $I^2 = 82$ ), but we did not find statistically significant heterogeneity in the current delusions subgroup ( $Q$ -stat  $p = 0.08$ ,  $I^2 = 44$ ) or the anxiety or depression subgroup ( $Q$ -stat  $p = 0.68$ ,  $I^2 = 0$ ).

### *Meta-regression*

Because there was evidence for moderate heterogeneity we performed exploratory moderator analysis. Figure 2 shows that the number of trials was a

statistically significant predictor of  $r_s$  ( $\beta = 0.07$ ,  $SE = 0.02$ ; 95% CI [0.02, 0.11];  $z = 3.00$ ,  $p < 0.01$ ;  $\alpha = -0.26$ ;  $SE = 0.06$ ; 95% CI [-0.38, -0.14];  $z = -4.10$ ,  $p < 0.01$ ).

Visual inspection of Figure 2 suggests that the three samples that had six trials (all of which came from the same study) might have had a large influence on the regression. To test the robustness of this association we re-ran the meta-regression with these three samples removed and found that the number of trials was no longer a statistically significant predictor of  $r_s$  ( $\beta = 0.06$ ,  $SE = 0.03$ ; 95% CI [0.00, 0.13];  $z = 1.89$ ,  $p = 0.06$ ;  $\alpha = -0.25$ ;  $SE = 0.08$ ; 95% CI [-0.40, -0.10];  $z = -3.26$ ,  $p < 0.01$ ), which suggests that some caution is warranted when interpreting this association.

--- Insert Figure 2 about here ---

**Figure 2.** Regression plot showing the random-effects meta-regression examining the relationship between number of beads task trials and effect sizes. Effect sizes ( $r_s$ ) are plotted as circles with the size of the circles drawn proportional to the relative weight of the sample in the analysis.

Other potential moderators were not found to be statistically significant predictors of effect size: average age of participants in a sample ( $\beta = 0.00$ ,  $SE = 0.00$ ; 95% CI [-0.01, 0.01];  $z = -0.60$ ,  $p = 0.55$ ;  $\alpha = -0.04$ ;  $SE = 0.11$ ; 95% CI [-0.25, 0.18];  $z = -0.33$ ,  $p = 0.74$ ); percentage of females in a sample (male = 0; female = 1) ( $\beta = 0.19$ ,  $SE = 0.20$ ; 95% CI [-0.20, 0.58];  $z = 0.95$ ,  $p = 0.34$ ;  $\alpha = -0.20$ ;  $SE = 0.12$ ; 95% CI [-0.43, 0.03];  $z = -1.73$ ,  $p = 0.08$ ); and percentage of trials that used

the easy version of the beads task ( $\beta = -0.10$ ,  $SE = 0.09$ ; 95% CI [-0.28, 0.09];  $z = -1.03$ ,  $p = 0.30$ ;  $\alpha = -0.05$ ;  $SE = 0.06$ ; 95% CI [-0.17, 0.07];  $z = -0.77$ ,  $p = 0.44$ ).

### *Publication bias*

Figure 3 shows a funnel plot. A negative effect size is predicted, so publication bias would be expected to manifest as a gap in the bottom right region of the funnel plot. There is no obvious gap here or elsewhere. In addition, the plot appears to be relatively symmetric and Egger's regression test for funnel plot asymmetry was non-significant ( $z = -0.7705$ ,  $p = 0.441$ ). Overall, we found no evidence for publication bias. Nevertheless, absence of evidence should be interpreted with some caution, because even when publication bias is present it can be difficult to identify.<sup>77, 78</sup>

--- Insert Figure 3 about here ---

**Figure 3.** Funnel plot showing effect size ( $r_s$ ) plotted against standard error.

## **Discussion**

### *Summary of findings*

Overall, these results indicate that people with higher PDI scores tend to request fewer beads before making a decision about which jar beads are being drawn from than people with lower PDI scores. The overall effect size was small, and exhibited moderate heterogeneity. This negative association between PDI scores

and draws to decision was present when considering the general population subgroup alone, but not when considering the current delusions subgroup alone. We found no evidence to suggest that effect size estimates had been inflated as a result of publication bias.

### *Discussion of findings*

Overall, these results provide some provisional support for continuum theories of psychosis<sup>6-12</sup> and for cognitive models that implicate the JTC bias in the formation and maintenance of delusions.<sup>17-23</sup> That we did not find evidence for an association in the current delusions subgroup could be considered to be of concern, as cognitive theories aim to account for clinical delusions not mere delusional ideation in the general population. Nonetheless, as Figure 1 shows, the confidence intervals for the general population subgroup and the current delusions subgroup overlap substantially and have almost identical means (in fact, the mean for the current delusions subgroup is slightly more negative). We suggest that the low statistical power of subgroup analysis<sup>29</sup> is a more plausible interpretation of this counter-intuitive result than proposing that the association is present in the large general population subgroup (n = 1754) but not the much smaller current delusions subgroup (n = 263).

Although these results provide evidence for an association between delusional ideation and data gathering, it is important to consider the small effect sizes. One possible interpretation of the small effect sizes is that the JTC bias plays only a minor role in delusion formation and maintenance, despite the many published



studies reporting that the JTC bias is more common in those with current delusions than controls.<sup>4, 5</sup> It may even be the case that the JTC bias would explain *no* additional variation if other important factors were to be taken into account. This possibility is consistent with one of the largest beads task studies included in our meta-analysis, which found no evidence for an association between paranoia (in the context of paranoid delusions) and jumping to conclusions when controlling for the association between paranoia and general cognitive performance.<sup>47</sup> We anticipate that the upcoming meta-analysis by Taylor *et al.*<sup>34</sup> will help clarify as they will quantify differences in data-gathering between groups with delusions and control groups, while exploring a variety of potential moderating variables.

Another possible interpretation of these small effect sizes is that the beads task might not be a very good task for examining the JTC bias. This possibility is supported by claims that studies that have used the beads task may have had significant methodological limitations. First, if a participant asks to see only a small number of beads it is not always clear that they are *jumping* to conclusions on the basis of *insufficient* evidence.<sup>79</sup> In many instances, very few beads need to be drawn for the posterior probability of one of the jars to be very high (e.g., when the ratio of colours is 85:15 and the first two beads are the same colour, the posterior probability of the corresponding jar is 0.97). Second, evidence from a “graded estimates” variant of the beads task suggests that people with delusions misunderstand task instructions more often than controls.<sup>80</sup> Third, the beads task is rarely incentivised and motivation might partially explain differences in performance.<sup>81, 82</sup> We suggest that investigating between-group

differences in beads task performance using meta-analysis,<sup>34</sup> exploring new data-gathering paradigms that might overcome methodological limitations of the beads task,<sup>81-87</sup> examining exactly when participants stop drawing beads,<sup>88</sup> controlling for important aspects of individual variation,<sup>47</sup> and revisiting the original – and methodologically sophisticated – beads task paradigm<sup>1</sup> could help clarify whether the JTC bias plays a role in delusions.

### **Funding**

This work was supported by an Australian Research Council (ARC) Centre of Excellence in Cognition and its Disorders grant (grant number CE110001021 with MC, RL and RM being Chief or Partner Investigators), salary support to RL from an ARC Future Fellowship (FT110100631), and a MQRES PhD scholarship awarded to RMR by Macquarie University.

### **Acknowledgements**

We thank the authors of the studies included in the meta-analysis for kindly supplying us with raw data and three anonymous reviewers for insightful comments that improved the manuscript.

### **References (\* indicates used in analysis)**

1. Phillips LD, Edwards W. Conservatism in a simple probability inference task. *J Exp Psychol* 1966;72(3):346-354.

2. Huq SF, Garety PA, Hemsley DR. Probabilistic judgements in deluded and non-deluded subjects. *Q J Exp Psychol A* 1988;40(4):801-812.
3. Fine C, Gardner M, Craigie J, Gold I. Hopping, skipping or jumping to conclusions? Clarifying the role of the JTC bias in delusions. *Cogn Neuropsychiatry* 2007;12(1):46-77.
4. Garety PA, Freeman D. The past and future of delusions research: from the inexplicable to the treatable. *Br J Psychiat* 2013;203(5):327-333.
5. Garety PA, Freeman D. Cognitive approaches to delusions: a critical review of theories and evidence. *Br J Psychiat* 1999;38 (Pt2):113-154.
6. Meehl PE. Schizotaxia, schizotypy, schizophrenia. *Am Psychol* 1962;17(12):827-838.
7. Claridge G. *Origins of mental illness: temperament, deviance and disorder*. Oxford, UK: Blackwell; 1985.
8. Chapman LJ, Chapman JP. Scales for rating psychotic and psychotic-like experiences as continua. *Schizophr Bull* 1980;6(3):476-489.
9. Bentall RP. *Madness explained: psychosis and human nature*. London, UK: Penguin; 2003.
10. van Os J, Hanssen M, Bijl RV, Ravelli A. Strauss (1969) revisited: a psychosis continuum in the general population? *Schizophr Res* 2000;45(1-2):11-20.
11. van Os J, Linscott RJ, Myin-Germeys I, Delespaul P, Krabbendam L. A systematic review and meta-analysis of the psychosis continuum: evidence for a psychosis proneness–persistence–impairment model of psychotic disorder. *Psychol Med* 2009;39(2):179-195.
12. Linscott RJ, van Os J. An updated and conservative systematic review and meta-analysis of epidemiological evidence on psychotic experiences in children and adults: on the pathway from proneness to persistence to dimensional expression across mental disorders. *Psychol Med* 2013;43(6):1133-1149.
13. Hyman SE. The diagnosis of mental disorders: the problem of reification. *Annu Rev Clin Psychol* 2010;6:155-179.
14. Cuthbert BN. The RDoC framework: facilitating transition from ICD/DSM to dimensional approaches that integrate neuroscience and psychopathology. *World Psychiatry* 2014;13(1):28-35.
15. Insel TR, Cuthbert BN, Garvey M, Heinssen, Pine DS, Quinn K, Sanislow C, Wang P. Research domain criteria (RDoC): toward a new classification framework for research on mental disorders. *Am J Psychiatry* 2010;167(7):748-751.
16. NIMH. The National Institute of Mental Health Strategic Plan. Available at: <http://www.nimh.nih.gov/about/strategic-planning-reports/index.shtml> - strategic-objective1/ .
17. Bentall RP, Corcoran R, Howard R, Blackwood N, Kinderman P. Persecutory delusions: a review and theoretical integration. *Clin Psychol Rev* 2001;21(8):1143-1192.
18. Morrison AP. The interpretation of intrusions in psychosis: an integrative cognitive approach to hallucinations and delusions. *Behav Cogn Psychoth* 2001;29(3):257-276.

19. Bentall RP, Fernyhough C, Morrison AP, Lewis S, Corcoran R. Prospects for a cognitive-developmental account of psychotic experiences. *BJ Psychiat* 2007;46(Pt2):155-173.
20. Garety PA, Bebbington P, Fowler D, Freeman D, Kuipers E. Implications for neurobiological research of cognitive models of psychosis: a theoretical paper. *Psychol Med* 2007;37(10):1377-1391.
21. Garety PA, Kuipers E, Fowler D, Freeman D, Bebbington PE. A cognitive model of the positive symptoms of psychosis. *Psychol Med* 2001;31(2):189-195.
22. Freeman D. Suspicious minds: the psychology of persecutory delusions. *Clin Psychol Rev* 2007;27(4):425-457.
23. Freeman D, Garety PA. Advances in understanding and treating persecutory delusions: a review. *Soc Psych Psych Epid* 2014;49(8):1179-1189.
24. Peters ER, Joseph SA, Garety PA. Measurement of delusional ideation in the normal population: introducing the PDI (Peters et al. Delusions Inventory). *Schizophr Bull* 1999;25(3):553-576.
25. Peters ER, Joseph SA, Day S, Garety PA. Measuring delusional ideation: the 21-item Peters et al. Delusions Inventory (PDI). *Schizophr Bull* 2004;30(4):1005-1022.
26. Peters ER, Day S, McKenna J, Orbach G. Delusional ideation in religious and psychotic populations. *Br J Clin Psychol* 1999;38(Pt1):83-96.
27. Lincoln TM, Ziegler M, Lullmann E, Muller MJ, Rief W. Can delusions be self-assessed? Concordance between self- and observer-rated delusions in schizophrenia. *Psychiatry Res* 2010;178(2):249-254.
28. Bushman BJ, Wang MD. Vote counting procedures in meta-analysis. In: Cooper H, Hedges LV, Valentine JC, eds. *Handbook of Research Synthesis and Meta-Analysis*. New York, NY: Russell Sage; 2009:207-220.
29. Schmidt FL, Hunter JE. *Methods of meta-analysis: correction error and bias in research findings*. 3rd ed. Thousand Oaks, CA: Sage; 2014.
30. Cumming G. *Understanding the new statistics: effect sizes, confidence intervals, and meta-analysis*. New York, NY: Routledge; 2012.
31. Hedges LV, Olkin I. *Statistical methods for meta-analysis*. San Diego, CA: Academic Press; 1985.
32. Borenstein M, Hedges LV, Higgins JPT, Rothstein HR. *Introduction to meta-analysis*. Chichester, UK: John Wiley & Sons, Ltd; 2009.
33. Mosteller FM, Bush RR. Selected quantitative techniques. In: Lindzey G, ed. *Handbook of Social Psychology: Vol I. Theory and Method*. Cambridge, MA: Addison-Wesley; 1954.
34. Taylor P, Hutton P, Dudley R. Rationale and protocol for a systematic review and meta-analysis on reduced data gathering in people with delusions. *Systematic Reviews* 2014;3:44.
35. John LK, Loewenstein G, Prelec D. Measuring the prevalence of questionable research practices with incentives for truth telling. *Psychol Sci* 2012;23(5):524-532.
36. Simmons JP, Nelson LD, Simonsohn U. False-positive psychology: undisclosed flexibility in data collection and analysis allows presenting anything as significant. *Psychol Sci* 2011;22(11):1359-1366.

37. Gelman A, Loken E. The garden of forking paths: Why multiple comparisons can be a problem, even when there is no “fishing expedition” or “p-hacking” and the research hypothesis was posited ahead of time. *Am Sci* in press.
38. Makel MC, Plucker JA, Hegarty B. Replications in psychology research: how often do they really occur? *Perspect Psychol Sci* 2012;7(6):537-542.
39. Cooper H, Patall EA. The relative benefits of meta-analysis conducted with individual participant data versus aggregated data. *Psychol Methods* 2009;14(2):165-176.
40. Stewart LA, Tierney JF, Clarke M. Reviews of individual patient data. In: Higgins PT, Green S, eds. *Cochrane Handbook for Systematic Reviews of Interventions*. Chichester, UK: Wiley-Blackwell; 2008:547-558.
41. Stewart LA, Tierney JF. To IPD or not to IPD?: Advantages and disadvantages of systematic reviews using individual patient data. *Eval Health Prof* 2002;25(1):76-97.
42. Dudley REJ, Over DE. People with delusions jump to conclusions: a theoretical account of research findings on the reasoning of people with delusions. *Clin Psychol Psychot* 2003;10(5):263-274.
43. Bentall RP, Taylor JL. Psychological processes and paranoia: implications for forensic behavioural science. *Behav Sci Law* 2006;24(3):277-294.
- \*44. Ochoa S, Haro JM, Huerta-Ramos E, Cuevas-Esteban J, Stephan-Otto C, Usall J, Nieto L, Brebion G. Relation between jumping to conclusions and cognitive functioning in people with schizophrenia in contrast with healthy participants. *Schizophr Res* 2014;159(1):211-217.
- \*45. Langdon R, Ward PB, Coltheart M. Reasoning anomalies associated with delusions in schizophrenia. *Schizophr Bull* 2010;36(2):321-330.
- \*46. Langdon R, Still M, Connors MH, Ward PB, Catts SV. Jumping to delusions in early psychosis. *Cogn Neuropsychiatry* 2013;19(3):241-256.
- \*47. Bentall RP, Rowse G, Shryane N, Kinderman P, Howard R, Blackwood N, Moore R, Corcoran R. The cognitive and affective structure of paranoid delusions: a transdiagnostic investigation of patients with schizophrenia spectrum disorders and depression. *Arch Gen Psychiatry* 2009;66(3):236-247.
48. Warman DM. Reasoning and delusion proneness: confidence in decisions. *J Nerv Ment Dis* 2008;196(1):9-15.
- \*49. Ephraums R, Balzan RP. [Beads task data examining the association between draws to decision and Peters et al. Delusions Inventory (PDI)]. Unpublished raw data. 2014.
- \*50. Bensi L, Giusberti F, Nori R, Gambetti E. Individual differences and reasoning: a study on personality traits. *Br J Psychol* 2010;101(Pt3):545-562.
- \*51. Cafferkey K, Murphy J, Shevlin M. Jumping to conclusions: The association between delusional ideation and reasoning biases in a healthy student population. *Psychosis* 2014;6(4):206-214.
- \*52. Colbert SM, Peters ER. Need for closure and jumping-to-conclusions in delusion-prone individuals. *J Nerv Ment Dis* 2002;190(1):27-31.
- \*53. Jacobsen P, Freeman D, Salkovskis P. Reasoning bias and belief conviction in obsessive-compulsive disorder and delusions: jumping to conclusions

- across disorders?: Reasoning bias and belief conviction in OCD and delusions. *BJ Clin Psychol* 2012;51(1):84-99.
- \*54. Lim MH, Gleeson JF, Jackson HJ. The jumping-to-conclusions bias in new religious movements. *J Nerv Ment Dis* 2012;200(10):868-875.
- \*55. McKay R, Langdon R, Coltheart M. Need for closure, jumping to conclusions, and decisiveness in delusion-prone individuals. *J Nerv Ment Dis* 2006;194(6):422-426.
- \*56. Menon M, Quilty LC, Zawadzki JA, Woodward TS, Sokolowski HM, Boon HS, Wong AHC. The role of cognitive biases and personality variables in subclinical delusional ideation. *Cogn Neuropsychiatry* 2013;18(3):208-218.
- \*57. Peters ER, Garety PA. Cognitive functioning in delusions: a longitudinal analysis. *Behav Res Ther* 2006;44(4):481-514.
- \*58. Rodier M, Prevost M, Renoult L, Lionnet C, Kwann Y, Dionne-Dostie E, Chapleau I, Debrulle JB. Healthy people with delusional ideation change their mind with conviction. *Psychiatry Res* 2011;189(3):433-439.
- \*59. So SH, Freeman D, Garety PA. Impact of state anxiety on the jumping to conclusions delusion bias. *Aust NZ J Psychiat* 2008;42(10):879-886.
- \*60. White LO, Mansell W. Failing to ponder? Delusion-prone individuals rush to conclusions. *Clin Psychol Psychot* 2009;16(2):111-124.
- \*61. Broome MR, Johns LC, Valli I, et al. Delusion formation and reasoning biases in those at clinical high risk for psychosis. *Br J Psychiat* 2007;51:s38-42.
- \*62. Keefe KM, Warman DM. Reasoning, delusion proneness and stress: an experimental investigation. *Clin Psychol Psychot* 2011;18(2):138-147.
- \*63. Lincoln TM, Ziegler M, Mehl S, Rief W. The jumping to conclusions bias in delusions: specificity and changeability. *J Abnorm Psychol* 2010;119(1):40-49.
- \*64. Warman DM, Martin JM. Jumping to conclusions and delusion proneness: the impact of emotionally salient stimuli. *J Nerv Ment Dis* 2006;194(10):760-765.
- \*65. Warman DM, Lysaker PH, Martin JM, Davis L, Haudenschild SL. Jumping to conclusions and the continuum of delusional beliefs. *Behav Res Ther* 2007;45(6):1255-1269.
- \*66. Ziegler M, Rief W, Werner S-M, Mehl S, Lincoln TM. Hasty decision-making in a variety of tasks: does it contribute to the development of delusions? *Psychol Psychother-T* 2008;81(3):237-245.
67. *OpenMEE: software for ecological and evolutionary meta-analysis* [computer program]. URL [http://www.cebm.brown.edu/open\\_mee/](http://www.cebm.brown.edu/open_mee/). (Accessed 09 Nov 2014).
68. Wallace BC, Dahabreh IJ, Trikalinos TA, Lau J, Trow P, Schmid CH. Closing the gap between methodologists and end-users: R as a computational back-end. *J Stat Softw* 2012;49(5):1-15.
69. Viechtbauer W. Conducting meta-analysis in R with the metafor package. 2010; 36(3):1-48.
70. Team RC. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL <http://www.R-project.org/>. 2014.

71. Cochran W. The combination of estimates from different experiments. *Biometrics* 1954;10(1):101-129.
72. Higgins JPT, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analysis. *BMJ* 2003;327(7414):557-560.
73. Huedo-Medina TB, Sanchez-Meca J, Marin-Martinez F, Botella J. Assessing heterogeneity in meta-analysis: Q statistic or I2 index? *Psychol Methods* 2006;11(2):193-206.
74. Int'Hout J, Ioannidis J, Borm GF. The Hartung-Knapp-Sidik-Jonkman method for random effects meta-analysis is straightforward and considerably outperforms the standard DerSimonian-Laird method. *BMC Med Res Methodol* 2014;14(25):1471-2288.
75. Thompson SG, Higgins JP. How should meta-regression analyses be undertaken and interpreted? *Stat Med* 2002;21(11):1559-1573.
76. Egger M, Smith GD, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. *BMJ* 1997;315(7109):629-634.
77. Sterne JA, Sutton AJ, Ioannidis JP, et al. Recommendations for examining and interpreting funnel plot asymmetry in meta-analyses of randomised controlled trials. *BMJ* 2011;343:d4002.
78. Terrin N, Schmid CH, Lau J. In an empirical evaluation of the funnel plot, researchers could not visually identify publication bias. *J Clin Epidemiol* 2005;58(9):894-901.
79. Maher BA. Delusion. In: Adams HE & Sutker PB, eds. *Comprehensive Handbook of Psychopathology*, 3rd ed. New York, NY: Springer; 2004:309-340.
80. Balzan RP, Delfabbro PH, Galletly CA, Woodward TS. Over-adjustment or miscomprehension? A re-examination of the jumping to conclusions bias. *Aust NZ J Psychiat* 2012;46(6):532-540.
81. van der Leer L, McKay R. "Jumping to conclusions" in delusion-prone participants: an experimental economics approach. *Cogn Neuropsychiatry* 2014;19(3):257-267.
82. van der Leer L, Hartig B, Goldmanis M, McKay R. Delusion-proneness and 'jumping to conclusions': relative and absolute effects. *Psychol Med* in press.
83. Whitman JC, Menon M, Kuo SS, Woodward TS. Bias in favour of self-selected hypotheses is associated with delusion severity in schizophrenia. *Cogn Neuropsychiatry* 2013;18(5):376-389.
84. Woodward TS, Munz M, LeClerc C, Lecomte T. Change in delusions is associated with change in "jumping to conclusions". *Psychiatry Res* 2009;170(2-3):124-127.
85. Woodward TS, Moritz S, Cuttler C, Whitman JC. The contribution of a cognitive bias against disconfirmatory evidence (BADE) to delusions in schizophrenia. *J Clin Exp Neuropsych* 2006;28(4):605-617.
86. Speechley WJ, Whitman JC, Woodward TS. The contribution of hypersalience to the "jumping to conclusions" bias associated with delusions in schizophrenia. *J Psychiatr Neurosci* 2010;35(1):7-17.
87. Sanford N, Veckenstedt R, Moritz S, Balzan RP, Woodward TS. Impaired integration of disambiguating evidence in delusional schizophrenia patients. *Psychol Med* 2014;44(13):2729-2738.

- 88.** Jolley S, Thompson C, Hurley J, et al. Jumping to the wrong conclusions? An investigation of the mechanisms of reasoning errors in delusions. *Psychiat Res* 2014; 219(2): 275-282.