The Relationship Between Cognitive Biases and Delusional Beliefs Across the Psychosis Continuum

by

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Thesis abstract

The Jumping to Conclusions (JTC) and evidence-integration biases have been found to be associated with delusions in schizophrenia, and are proposed to contribute to delusion formation and maintenance. Past meta-analyses had tested the relationship between JTC and delusions in psychosis groups, but the use of groups with mixed diagnoses made it unclear whether the association was between JTC and delusions, consistent with a causal role for biases, or between JTC and schizophrenia only. The evidence-integration biases had not been meta-analytically tested. This thesis determined by meta-analysis that the JTC and evidence-integration biases covary with the presence and absence of delusions in schizophrenia, and that JTC is associated with delusions in disorders other than schizophrenia, consistent with the causal account (Study 1). Nevertheless, significant heterogeneity in this and previous meta-analyses indicated potential problems with the most common means of identifying JTC, namely the beads task. Hence this research conducted the first formal assessment of the reliability of the beads task using multiple trials, and tested a new, modified version of the task that incorporates distractor sequences (Study 2). The traditional beads task was shown to have inadequate reliability, but the new task had significantly better reliability. Given the greater reliability of the new beads task, the relationship between it and delusion-proneness in non-clinical samples was reassessed (Studies 3 and 4). Contrary to what was expected from both the clinical and non-clinical literature, in two independent samples, delusion-proneness was associated with *less* JTC on the new task. A possible mechanism for this of higher odds literacy leading to both reduced delusion-proneness and increased apparent JTC was tested (Study 4), but was found not to account for this relationship. Preliminary data indicated that an alternative mechanism of generalised anxiety and risk-aversion driving increased delusion-proneness and information-gathering might account for this relationship, but requires further proof. Ultimately, testing the new task for convergent validity, and in clinical populations where the JTC-to-delusions relationship is more robust, will be necessary to verify that the new beads task measures data-gathering and identifies JTC as intended. This thesis adds to our knowledge of the relationship

between cognitive biases and delusions by clarifying the nature of this relationship in clinical samples, by identifying some of the psychometric limitations of the current beads task, and by developing a more reliable alternative task.

Declaration

I certify that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

Signed  ……

Benjamin McLean

Grad Dip Psyc, BPsycSci (Hons)

Date……03/03/2018.……

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List of Publications

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CHAPTER 1: General Introduction

Thesis topic

Delusions are a distressing yet common feature of schizophrenia and other psychotic illnesses (Landa, Silverstein, Schwartz, & Savitz, 2006; van Os, Hanssen, Bijl, & Vollebergh, 2001). Yet delusion-*like* ideas also occur, to varying degrees, in the general population (Freeman, 2006). This thesis explores the relationship of delusions and delusion-proneness to cognitive biases – thought processes that "depart from standards of logic and accuracy" (Haselton, Nettle, & Andrews, 2005, p. 725), yet serve a functional purpose under some circumstances. Specifically, this thesis investigates the relationship of the jumping to conclusions (JTC; Garety & Freeman, 2013) and evidence-integration biases (Speechley, Moritz, Ngan, & Woodward, 2012) to delusions, in both clinically-ill and general population groups. This thesis also appraises the most common measure of the tendency to JTC, namely the beads task (Huq, Garety, & Hemsley, 1988). This relationship is important as cognitive biases have been postulated to play a role in the formation and maintenance of delusions (Garety & Freeman, 2013). Hence, this thesis broadly aims to add to our knowledge of the relationship between cognitive biases and delusions.

The literature covering delusions, cognitive biases, and their interrelationship will now be briefly reviewed. The remainder of this chapter will specify the aims of this thesis, and outline the subsequent chapters.

Literature review

Delusions

Adhering to the doxastic model of delusions as beliefs (e.g. Bortolotti, 2010), theDiagnostic and Statistical Manual of Mental Disorders (DSM-5) defines delusions as "fixed beliefs that are not amenable to change in light of conflicting evidence" (American Psychiatric Association, 2013, p. 87). However, some researchers argue delusional subjects may not reason, act, or experience affect in a manner consistent with delusions being true beliefs, and other definitions exist (e.g. Currie & Jureidini, 2001). Nevertheless, the arguments supporting the doxastic model of delusions are

convincing (Bayne & Pacherie, 2005; Bortolotti, 2010; Bortolotti, 2012), and I adhere to this model throughout this thesis.

Various delusional themes are possible, for example, persecutory delusions (the belief one is being harmed, harassed, or persecuted by some other person or group), delusions of reference (the belief that non-personally-directed stimuli are in fact directed at oneself), grandiose delusions (the belief one has exceptional abilities or qualities), and erotomanic delusions (the belief someone famous is in love with oneself). The DSM-5 differentiates between bizarre delusions, which are clearly implausible and are not culturally-endorsed, and non-bizarre delusions, which are not implausible, but are nevertheless held without reasonable evidence. In part because not all delusions are bizarre, it can be difficult to differentiate between delusions and strongly-held, but non-delusional, beliefs – in this case the DSM-5 indicates that the point of difference may partly lie in the intractability with which the belief is held despite clear counter-evidence (American Psychiatric Association, 2013, p. 87). Hence, the belief that the police are harassing an individual may be a non-bizarre persecutory delusion (if there is sound evidence to the contrary!), whilst a belief that the local TV news program is communicating secret messages to oneself would be a bizarre delusion of reference. The toll of delusions on those experiencing them can be serious. Delusions frequently cause significant distress (Startup, Freeman, & Garety, 2007) (though not always; Smith, Freeman, & Kuipers, 2005), can lead to safety behaviours such as becoming house-bound (Freeman et al., 2007), sometimes trigger anger and violence (Coid et al., 2013), and may contribute to suicidality (Zalpuri & Rothschild, 2016). They can also have implications for occupational and social functioning (Gerretsen et al., 2015; Phalen, Dimaggio, Popolo, & Lysaker, 2017), and general psychological wellbeing (Broyd, Jolley, & Johns, 2016; Freeman, et al., 2014).

Delusions are a feature of a number of psychiatric illnesses. The DSM-5 includes delusions as one of the key features of schizophrenia spectrum and other psychotic disorders, which include schizophrenia, delusional disorder, and other forms of psychosis, but delusions can also occur in bipolar 1 and depression (American Psychiatric Association, 2013). Few prevalence figures are

available for delusions alone, however the prevalence of psychosis more generally is informative. The lifetime prevalence of non-affective psychosis may be around 0.31% - 0.37% (Kessler et al., 2005; van Os et al., 2001) and, for affective psychosis, 1.14% (van Os et al., 2001), with a total lifetime prevalence of clinical psychosis around 1.5%. The most common illness associated with psychosis, schizophrenia, has a lifetime prevalence of around 0.3-0.7% (Saha, Chant, Welham, & McGrath, 2005; van Os & Kapur, 2019), and around three-quarters of people with schizophrenia experience delusions (Landa et al., 2006).

Delusion-like ideas are not limited to psychiatrically-ill individuals however. In a significant review, Freeman (2006) found that from 1% to 3% of the general population had delusions of similar severity to clinically diagnosed individuals; a further 5% to 6% had delusions of a less severe nature; and a further 10% to 15% may have regular delusional ideation. This finding is supported by others also (Van Os, Hanssen, Bijl, & Ravelli, 2000; van Os & Reininghaus, 2016). Likewise, while clinical psychosis may affect around 1.5% of the population over the lifespan (van Os et al., 2001), the median lifetime prevalence of having a psychotic *experience* of some kind may be around 7.2% (Linscott & Van Os, 2013) or even higher (in a community sample, van Os et al., 2001 noted a lifetime prevalence of any psychosis or psychosis-like symptoms of 17.5%). Hence, it is likely that delusions occur on a continuum, with a portion of the general population entertaining delusional ideas at some point in time, with varying degrees of conviction.

It is possible to measure the prevalence and strength of delusion-like ideas in general-population samples using the Peters et al. Delusions Inventory (PDI; Peters, Joseph, Day, & Garety, 2004). The PDI is based on the clinically-oriented Present State Examination (Wing, Cooper, & Sartorius, 2012), but has been modified in that the wording of questions has been adjusted to reflect the less certain nature of delusion-*like* ideas. The PDI has strengths in that it has been used extensively for delusions research, making comparisons with other studies possible and, being a self-report measure, is efficient when used in research. It can also be applied to both clinical and non-clinical samples. However, its limitations include poor separation between clinical and non-

clinical samples (Peters et al., 2004), uncertainty as to whether it really measures delusional belief (Ross et al., 2016), and that it does not differentiate between types of delusional thinking as some delusions scales do (e.g., the Scale for the Assessment of Positive Symptoms; Andreasen, 1984). Despite its limitations, the PDI is used as a measure of delusion-proneness throughout this thesis, due to its ubiquity in the delusion-proneness and cognitive bias literature.

Two-factor account of delusion formation

One step towards ameliorating delusions and their impact is to understand their aetiology. Although the cause is undoubtedly complex and multifaceted, the fact that they are *beliefs* implicates aspects of reasoning and decision-making. The two-factor theory of delusions (Coltheart, 2007; Coltheart, Langdon, & McKay, 2011) identifies two factors that might contribute to the formation and maintenance of delusions. The first factor is exposure to a (possibly anomalous) internal or external experience, for which an explanation is sought by abductive reasoning, that is, by reasoning backward from the consequent – the experience – to the antecedent – a potentially delusional idea which could account for the experience. In some cases, the experience might be unusual and due to illness. For example, in the Cotard delusion, in which people think that they are dead, the autonomic nervous system may be severely under-responsive to stimuli (Ramachandran & Blakeslee, 1998), leaving the person feeling relatively devoid of arousal and "dead". Alternatively, the unexpected experience may be relatively commonplace, such as simply seeing a black car parked on the street. In either case, by abductive reasoning an explanation for the experience is sought, which, if true, could account for it. In the Cotard delusion, the lack of autonomic nervous system response suggests the bizarre explanation that "I am dead", whereas seeing a black car may suggest the explanation "I am being followed by the CIA".

The explanation for an experience arrived at by abductive reasoning does not have to be plausible however, and, if bizarre or unreasonable, would be rejected by most people. Hence for the formation of a delusion a second factor is necessary. The second factor in the two-factor theory is an impaired belief evaluation, which accounts for a failure to reject the explanation if it is

implausible (Coltheart et al., 2011). Impaired belief evaluation is an impairment in the ability to weigh the evidence for and against an explanation for a phenomenon, that is, for a belief. Evidence that is not appropriately weighed may include the belief's common-sense plausibility, as well as evidence from other trusted people (Coltheart et al., 2011; Davies, Coltheart, Langdon, & Breen, 2001; Langdon & Coltheart, 2000). The poor weighing of evidence may be expressed in a number of cognitive biases (Moritz et al., 2017). Several of the key biases associated with delusions are considered next.

The jumping to conclusions bias

Two cognitive biases have been reliably associated with clinical delusions and non-clinical delusion-proneness, namely the Jumping to Conclusions bias (JTC; Dudley, Taylor, Wickham, & Hutton, 2016; So, Siu, Wong, Chan, & Garety, 2016), and the Bias against Disconfirmatory Evidence (BADE; Sanford, Veckenstedt, Moritz, Balzan, & Woodward, 2014; Woodward, Moritz, Cuttler, & Whitman, 2006). The most-studied of these is JTC, which is the tendency to make a premature interpretation or decision based on inadequate evidence (Garety & Freeman, 2013). It has been suggested that JTC may contribute to the formation of delusions through the acceptance of (delusional) ideas based on inadequate evidence (e.g., Garety & Freeman, 1999; Peters & Garety, 2006; Van Dael et al., 2006). For example, in the case of the belief that the CIA are following oneself mentioned above, one would reasonably not expect to reach such a conclusion without considerable evidence (multiple sightings, neighbours being questioned, a clear motive for the CIA's involvement, etc.). However, if one were prone to JTC, the inadequate evidence of seeing one or two black cars on the street may be sufficient to support the interpretation that the CIA are investigating.

Several previous meta-analyses (Dudley et al., 2016; Ross, McKay, Coltheart, & Langdon, 2015; So et al., 2016) and numerous individual studies have found an association between JTC and delusions, supporting the possibility that JTC contributes to delusion formation. Meta-analyses comparing clinical samples (the majority of whom had diagnoses of schizophrenia) with healthy

non-clinical samples found medium effect sizes (Dudley et al. (2016) reported g = -0.53, and So et al. (2016) reported g = -0.60), while a correlational meta-analysis including general population groups and a variety of clinical groups by Ross et al. (2015) found a small but significant effect (r_s = -.10, approximate g = -0.20). Hence the finding that JTC is associated with delusions in clinical samples (for example for those with schizophrenia) compared with non-clinical samples appears relatively robust, and the likelihood that the association continues over ranges of delusion-proneness also has support.

That JTC then plays a *causal* role in delusion formation is less certain however, and alternative accounts are also possible. Most studies identifying an association between JTC and delusions have used groups with schizophrenia (So et al., 2016). Schizophrenia is associated with lowered IQ and cognitive performance deficits during acute phases (Andreou et al., 2015; Freeman et al., 2014; Nieuwenstein, Aleman, & de Haan, 2001), and the association of JTC with delusions has been found to disappear when cognitive performance deficits are controlled for (Lincoln, Ziegler, Mehl, & Rief, 2010). Thus it is possible that having schizophrenia contributes to JTC, and that JTC co-occurs with, but does not contribute to, delusions.

Evidence as to whether JTC is associated with schizophrenia rather than delusions specifically could be found by assessing JTC and delusions in schizophrenia groups with delusions and, separately, in non-schizophrenia groups with delusions. For example, if people with delusional disorder, of which cognitive deficits are not a feature, are found to JTC, it would support the idea that JTC is associated with delusions and not just with schizophrenia. However, the three meta-analyses cited above included groups with mixed diagnoses in their delusional category, so the possibility remains that JTC was associated with schizophrenia rather than with experiencing delusions per se. In an attempt to clarify this issue, Study 1's meta-analysis used more narrowly-defined clinical groups.

Another observation is that meta-analyses using the beads task have all shown significant heterogeneity in effect size (Dudley et al., 2016; Ross et al., 2015; So et al., 2016). Heterogeneity

could come from a number of sources, including the use of different samples and methods, and due to limitations of the beads task used to identify JTC (Huq et al., 1988; Phillips & Edwards, 1966; Volans, 1976). Before identifying some of the potential limitations of the beads task, the task itself will be briefly described.

The beads task measures *information gathering* – the amount of data collected before making a decision. A typical presentation of the task involves presenting participants with two jars containing beads of two colours, in equal and opposite ratios (for example a "mostly pink" jar containing 85 pink and 15 green beads, and a "mostly green" jar containing 85 green and 15 pink beads). Participants are informed that one jar has been chosen at random, and beads are drawn (purportedly at random, but actually in a predetermined sequence) from that jar. As each bead is drawn, participants have the option of making a decision as to which jar beads are being drawn from based on the evidence they have seen so far, or of requesting to see more beads. In many studies the task terminates when a decision has been made.

The variable of interest is commonly the number of beads requested before a decision is made, that is, *draws to decision* (DTD). Other variables are possible, however. As an alternative, or in addition to measuring DTD, categorical JTC can be specified as requesting two or fewer beads (Garety, Hemsley, & Wessely, 1991; Garety et al., 2005). In the *graded-estimates procedure* (e.g. Dudley, John, Young, & Over, 1997; Huq et al., 1988; Moritz & Woodward, 2005), as each bead is drawn participants are asked to rate the plausibility of each of the two jars being the chosen jar, either with complementary probabilities (i.e., two probabilities that sum to 100%), or by using independent probability ratings. In this case, the task does not terminate until a full sequence of beads has been drawn.

Further variations on the beads task include using different bead ratios, for example the "harder" ratio of 60:40 (Dudley et al., 1997), changing the stimuli for better comprehension of the task (e.g., Woodward, Munz, LeClerc, & Lecomte, 2009 considered different fish drawn from two lakes to be more comprehensible than beads drawn from jars), and using emotionally salient or self-

referent material (e.g., Warman, Lysaker, Martin, Davis, & Haudenschield, 2007 used positive and negative self-descriptors from mostly-positive or mostly-negative surveys).

In addition to the above variations in the task, another potential contributor to inter-study differences in results is the reliability of the beads task itself, which may be compromised by a number of factors. The first is miscomprehension. For example, Balzan, Delfabbro, Galletly, and Woodward (2012) found that some participants tended to over-adjust to changes in bead colour, that is, to jump to *new* conclusions, if they miscomprehended the task. Participants may have believed jars were swapping, and hence chosen the most likely jar based on the last bead seen. An expanded instruction set reduced this effect. However, their work shows that inter-study differences in task instructions are likely to increase inter-study heterogeneity, and inter-individual differences in comprehension of the instructions are likely to increase intra-study heterogeneity also.

While miscomprehension as a source of inter- and intra-study heterogeneity can be minimised by the use of careful instructions, perhaps assisted by practice trials, other sources of heterogeneity are possible, and their effect is not yet known. For example, the beads task is typically only presented as one trial. It is unclear whether DTD captured in a single trial is an adequate representation of true DTD, due to behavioural noise (Moutoussis, Bentall, El-Deredy, & Dayan, 2011). If a single trial is inadequate as an index of DTD, an aggregate measure of several trials may be more accurate. Yet, when multiple trials are administered, and while sometimes colours are swapped or more than one beads ratio is used, the *same* beads sequence is usually repeated (see for example Rocha & Queiros, 2013; Ross, Freeman, Dunn, & Garety, 2011) because using the same sequence is necessary for comparison purposes over repeated measures. However, such repetitions may allow participants to learn and remember salient features of the beads sequence. This might lead to participants changing their responses, perhaps by drawing fewer beads due to increased confidence in the outcome of the sequence. Despite the widespread use of the beads task, this issue had previously remained untested and unresolved. It was investigated in Study

2 by testing two psychometric properties (reliability and repeatability) of the standard beads task, and of a new beads task designed to prevent learning over repeated measures.

The evidence-integration biases

The second cognitive bias reliably associated with clinical delusions and non-clinical delusion-proneness is the Bias Against Disconfirmatory Evidence (BADE; Sanford et al., 2014; Woodward, Moritz, Cuttler, et al., 2006). BADE is the tendency, once a decision or interpretation has been made, to inadequately consider evidence against that interpretation (Sanford et al., 2014; Woodward, Moritz, Cuttler, et al., 2006). BADE is related to delusions in clinical samples (e.g., Sanford et al., 2014; Veckenstedt et al., 2011; Woodward, Moritz, & Chen, 2006), and with delusion-proneness in non-clinical samples (Buchy, Woodward, & Liotti, 2007). BADE may contribute to the intractability of delusions through the rejection of evidence that might contraindicate delusional ideas (Moritz & Woodward, 2006). For example, again using the illustration of the belief that the CIA are following oneself which arose in response to the sighting of a black car, a family member may point out that the neighbour has a black car, and that many other people also drive black cars – that is, they may provide evidence against the delusional interpretation. However, if one has a bias against accepting disconfirmatory evidence (BADE), this evidence may be rejected, and the delusion retained.

A principal component analysis indicated that BADE may be part of a broader *evidence-integration* construct, which reflects the ability to integrate disambiguating evidence (Speechley et al., 2012). There are two parts to the evidence-integration construct in addition to BADE. First, the Bias Against Confirmatory Evidence (BACE) is the tendency, once an interpretation or decision has been made, to inadequately consider evidence for another (true) interpretation. Second, the Liberal Acceptance bias (LA) is the tendency to overrate the plausibility of absurd interpretations or ideas. LA may contribute to delusion formation through the initial acceptance of implausible ideas, while BACE may contribute to the maintenance of delusions through the rejection of evidence that might otherwise support non-delusional ideas, such as the arguments for reality made by others.

Consistent with the suggestion that evidence integration contributes to delusions, BACE and LA have been found to be associated with delusions in clinical samples along with BADE (Eifler et al., 2014; Sanford et al., 2014; Speechley et al., 2012; Woodward, Moritz, Cuttler, et al., 2006), and evidence integration was found to discriminate between delusional and non-delusional groups (Speechley et al., 2012).

The usual procedure for measuring BADE, BACE, and LA is described in detail in Study 1, hence only briefly outlined here. It involves the progressive revelation of a series of "clues" or items of information, which together provide enough data for incorrect and absurd interpretations to be rejected, and for the correct interpretation to be identified from a set of possibilities. The evidence may be ambiguous or misleading initially, but later evidence makes the correct interpretation certain. Participants may demonstrate biased responding by, for example, persistently choosing interpretations that appear plausible initially but are later contraindicated by evidence (BADE), by failing to choose interpretations which are supported by later evidence (BACE), or by choosing absurd interpretations (LA).

As several studies have now assessed the relationship between BADE and delusions (e.g. Sanford et al., 2014; Veckenstedt et al., 2011; Woodward, Moritz, Cuttler, et al., 2006), but no meta-analysis has been completed, a meta-analysis of this relationship is timely. Further, as BADE is proposed to belong to the evidence-integration construct along with BACE and LA, it may be informative to include these biases together. Accordingly, the relationship of the evidence-integration biases with delusions was tested in Study 1 via a meta-analysis.

Evidence from therapy

That cognitive biases may contribute to delusion formation and maintenance has provided increased impetus to the development of cognitive approaches to delusions therapy. In particular, Metacognitive Training (MCT; Moritz & Woodward, 2007) is a relatively recent cognitive therapy for delusions which targets biased thinking, namely the JTC and BADE biases. MCT does this not by challenging participants' delusional beliefs directly, but by giving participants practice in

recognizing common biases and distortions of thinking, and in developing a wider range of thinking skills which are more robust to biases ("Metacognitive Training (MCT) for psychosis," 2018).

By nature of their pre-post designs, MCT treatment studies have the potential to provide evidence of whether JTC and BADE play a causal role in delusions. Reduced delusions following therapy targeting JTC and BADE would be consistent with a causal role for bias, whereas unchanged delusions following therapy would be more consistent with an epiphenomenal relationship between biases and delusions, perhaps by their co-occurrence in schizophrenia as previously discussed. A narrative review has indicated that most treatment studies of MCT found the intervention to be effective in reducing delusions and other positive symptoms, and to be well-received by participants (Moritz et al., 2014). While one meta-analysis largely found the effects of MCT to be non-significant (Van Oosterhout et al., 2016), it may not have included all relevant studies (Moritz, Werner, Menon, Balzan, & Woodward, 2016). A more recent meta-analysis supported the efficacy of MCT, indicated that it was well-accepted by participants, and found it had a small to moderate positive effect on delusions and on positive symptoms more generally (Eichner & Berna, 2016). Overall, the outcome of MCT treatment studies support a causal role for biases in delusions.

Greater certainty regarding the relationship of specific cognitive biases to delusions is likely to inform the forward development or refinement of such cognitive therapies for delusions to maximise outcomes. For example, demonstrating a causal rather than epiphenomenal relationship between JTC and delusions would support its continued identity as a therapeutic target. The strength of the relationship between BADE and delusions is currently somewhat uncertain because studies are few and findings have been mixed, and whether challenging this bias should form a significant component of therapy should arguably be contingent on the strength of this relationship. And if BACE and LA prove to be reliably related to delusions, these biases may justifiably become targets for cognitive therapy also.

Research aims

As outlined above, delusions are a costly aspect of psychotic and some other psychiatric illnesses. Yet the implication of cognitive biases in the formation and maintenance of delusions has led to a promising new cognitive therapy. Nevertheless, treatments will no doubt progress most effectively where theory can inform therapy, and significant questions remain regarding the relationship of cognitive biases to delusions (including the strength and reliability of the association between biases and delusions, and whether biases are associated with delusions specifically). Significant questions also remain regarding how JTC is measured, and what this implies regarding the size and direction of the association between JTC and delusions. Answers to these questions were approached in this thesis via a number of aims, as follows.

The first aim was to establish the relationship of JTC, BADE, BACE, and LA with clinical delusions (Study 1). As mentioned, two meta-analyses (Dudley et al., 2016; So et al., 2016) found that for groups with psychosis, DTD was negatively related to delusions (a meta-analysis by Ross et al., 2015 also found a negative association in an overall sample that included those with current delusions, but the association for the current-delusions subgroup itself failed to reach significance). However, each meta-analysis combined studies and groups with differing diagnoses, leaving open the possibility that JTC is associated with a diagnosis of schizophrenia (due to, for example, cognitive deficits; Andreou et al., 2015) rather than with having delusions. Hence in the case of JTC (for which more data are available), the aim was to determine whether JTC is associated with delusions specifically, and not only with a diagnosis of schizophrenia. With respect to BADE, BACE, and LA, no meta-analysis had yet been completed, and the aim was to assess their relationship to delusions meta-analytically for the first time. If a relationship between the evidence-integration biases and delusion-proneness can be confirmed, this will lend support to including these biases in cognitive approaches to the treatment of psychosis.

As noted above, multiple JTC meta-analyses using the beads task have shown significant heterogeneity in effect size (Dudley et al., 2016; Ross et al., 2015; So et al., 2016), which raises

questions about the reliability of the beads task. Hence, the second aim of this thesis was to test the reliability of the beads task in a repeated-measures design, and to compare it with an alternative version of the task that addressed some of the factors that might detrimentally affect reliability (Study 2). In addition, the large majority of studies using the beads task to measure JTC use a single trial of the task, which may compound any reliability issue. Hence, the impact of repetitions and of practice trials was also assessed.

In light of the uncertainty surrounding the reliability of the standard beads task, and the development of a potentially more reliable version of the task (Study 2), the third aim of this thesis was to reassess the nature of the Peters' delusions inventory to draws-to-decision (PDI-DTD) relationship in non-clinical samples (Studies 3 and 4). This aim is important as much JTC research is conducted on non-clinical samples, for two reasons. First, the recruitment and retention of non-clinical samples is naturally much easier than clinical samples. Second, just as psychotic characteristics are understood to occur on a continuum (Meehl, 1962; Claridge, 1997), delusions and delusion-like ideas appear to occur on a continuum through the healthy general population and into the clinically-ill (Freeman, 2006). Hence high-delusion-proneness may, for some people, represent a state premorbid to clinical delusions (White & Mansell, 2009), and findings from non-clinical delusions research are often assumed to extrapolate to clinical populations (e.g. Colbert & Peters, 2002; Linney, Peters, & Ayton, 1998; Warman et al., 2007).

Hence this thesis seeks to clarify the relationship of JTC, BADE, BACE and LA with delusions in clinical samples, to study the psychometric properties of the standard beads task and an alternative, and by using the more reliable and repeatable task to investigate the relationship of JTC with delusion-proneness in non-clinical samples. In this way, this thesis seeks to provide a clearer picture of the relationship between biases and delusions across the spectrum from clinical to non-clinical populations.

Thesis outline

This thesis consists of five chapters in addition to this introduction. Chapter 2 presents the results of Study 1, a clinical-studies meta-analysis of the JTC, BADE, BACE, and LA biases (McLean, Mattiske, & Balzan, 2017). In this study, several meta-analyses per bias were used to test differences between combinations of the following groups: schizophrenia with current delusions, schizophrenia without current delusions, other psychiatric illnesses with current delusions, other psychiatric illnesses without current delusions, and healthy controls. An Appendix to this thesis also includes a supplementary materials section in the form of forest plots identifying the contribution of individual studies to each meta-analysis result.

Chapter 3 presents Study 2, in which the repeatability, reliability, and believability of the standard beads task was tested over repeated measures. An alternative version of the beads task was concurrently assessed. The alternative version incorporated "distractor" sequences, in order to reduce the likelihood that participants would recognize features of the beads sequence over repeated trials, and change their response set. The study was conducted online, and drew participants from an online crowdsourcing site.

Chapter 4 presents Study 3, in which the PDI-DTD relationship in a non-clinical sample was reassessed using the new distractor-sequences beads task. This study was also conducted online, and drew participants from the same online crowdsourcing site as Study 2.

Chapter 5 reports Study 4, in which the PDI-DTD relationship observed in Study 3 was tested for replication, and a potential mechanism for the PDI-DTD relationship in non-clinical samples was tested. In order to access a different sample to Study 3 and provide an independent test of the PDI-DTD relationship, Study 4 drew participants from a university experiment participation pool. Finally, Chapter 6 presents an integrated critical discussion of the findings of this thesis.

All chapters, other than 1 and 6, have been formatted as manuscripts for publication. Chapter 2 has been published. Chapters 3, 4, and 5 have been submitted for publication.

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CHAPTER 2: Study 1 – Association of biases and delusions meta-analysis

Association of the Jumping to Conclusions and evidence integration biases with delusions in psychosis: A detailed meta-analysis

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Declaration of conflict of interests: R.P.B. has conducted Metacognitive Training (MCT) and undertaken studies on MCT, JTC, and BADE, for which he has received funding from Flinders University and the Trevor Prescott Freemasons Memorial Scholarship. B.F.M. has conducted Metacognitive Training (MCT) for which he has been paid as a Research Assistant. J.K.M. declares she has no conflicts of interest in relation to the subject of this study.

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Abstract

We completed a meta-analysis to investigate the relationship between delusions in psychosis and four cognitive biases: 'jumping to conclusions' (JTC), the 'bias against disconfirmatory evidence' (BADE), the 'bias against confirmatory evidence' (BACE), and 'liberal acceptance' (LA). Building on the work of Dudley et al (2015) we compared more narrowly defined groups. We identified 35 JTC, 8 BADE, 7 BACE, and 6 LA studies for inclusion. Groups with schizophrenia who were currently experiencing delusions demonstrated greater JTC, BADE, BACE, and LA than groups with schizophrenia who were not currently experiencing delusions, who in turn demonstrated no more JTC than healthy control groups. Hence JTC, BADE, BACE, and LA co-vary with delusions in cross-sectional samples of people with schizophrenia. Groups who were experiencing delusions due to other psychiatric illnesses also demonstrated greater JTC than healthy controls, and equivalent JTC to groups with schizophrenia currently experiencing delusions. Hence JTC is associated with delusions across a range of diagnoses. Groups with other, non-delusional psychiatric illnesses demonstrated less JTC, BADE, BACE, and LA than groups with schizophrenia currently experiencing delusions, less JTC than groups experiencing delusions due to other diagnoses, and no more JTC, BADE, BACE, or LA than healthy control groups. Hence JTC, BADE, BACE, and LA were not associated with psychiatric illnesses in general. Our results indicate all four biases are associated with delusions specifically rather than merely with a diagnosis of schizophrenia or with being psychiatrically ill, consistent with the possibility that they contribute to delusional severity.

Key Words: bias against disconfirmatory evidence, bias against confirmatory evidence, liberal acceptance, schizophrenia, delusional disorder, cognitive bias

Two cognitive biases are reliably associated with delusions in schizophrenia. The first is the Jumping to Conclusions (JTC) bias, in which interpretations or judgments are made early and based on inadequate evidence (Garety & Freeman, 2013). The second is the Bias Against Disconfirmatory Evidence (BADE), in which there is a failure to adequately re-evaluate an initial interpretation of events in the face of increasing evidence against that interpretation (Sanford, Veckenstedt, Moritz, Balzan, & Woodward, 2014; Woodward, Moritz, Cuttler, & Whitman, 2006).

The meaning of the association between JTC, BADE, and delusions in schizophrenia remains uncertain, however. It is plausible that JTC, BADE, and delusions arise independently as aspects of schizophrenia, and that JTC and BADE are merely spuriously related to delusions. Alternatively, biases in perception and judgement may contribute to the formation and maintenance of delusions by affecting the manner in which evidence for ideas is weighted, accepted, or ignored (Garety & Hemsley, 1994). According to this hypothesis, JTC contributes to delusion formation through the early acceptance, with inadequate evidence, of incorrect hypotheses (Freeman & Garety, 1999). BADE could contribute to the persistence and intractability of delusions by decreasing the likelihood that delusional beliefs will be re-evaluated when contrary evidence is provided (Moritz & Woodward, 2006).

Despite the high face validity of the hypothesis that JTC and BADE contribute to delusion formation and maintenance, the evidence is mixed as to whether JTC and BADE are associated with delusions specifically (as a causal relationship would suggest), or merely with having schizophrenia (consistent with a spurious association). Two recent meta-analyses investigated the association of JTC with delusions. Dudley, Taylor, Wickham, and Hutton (2015) compared groups with mixed diagnoses (schizophrenia and delusional disorder) with healthy and psychiatric controls. Likewise, Ross, McKay, Coltheart, and Langdon (2015) assessed the relationship of JTC with delusions in mixed-diagnosis groups (schizophrenia, schizo-affective or bipolar disorder, major depression with delusions). However, by assessing JTC in mixed-diagnosis groups, neither meta-analysis clearly indicates whether JTC is associated with delusions in multiple diagnoses, or is only associated with

delusions in schizophrenia. No BADE meta-analysis has previously been published. The present meta-analysis addresses these limitations, exploring whether JTC and BADE are together associated with current delusions in multiple diagnoses. The association of these biases with delusions in multiple diagnoses would demonstrate this relationship is not limited to schizophrenia, and would support a causal relationship.

JTC is most frequently measured by the beads task. Applying this task with people with schizophrenia, Huq, Garety, and Hemsley (1988) showed participants two jars of coloured beads. Each jar contained pink and green beads in an 85:15 ratio, with one jar containing mostly pink beads and the other mostly green beads. The jars were hidden from view and beads were drawn from one of the jars in a purportedly random but in fact pre-determined sequence. With each draw, participants were invited to indicate whether they had decided which jar (mostly pink or mostly green) beads were being drawn from. Huq et al. (1988) found that participants with current delusions required fewer draws-to-decision (DTD) than those without current delusions, demonstrating a JTC bias. Variants of the beads task have utilised alternative stimuli, such as coloured fish in lakes (Speechley, Whitman, & Woodward, 2010; Woodward, Munz, LeClerc, & Lecomte, 2009) or emotionally-salient stimuli (Dudley, John, Young, & Over, 1997a; Young & Bentall, 1997). Some versions of the task have incorporated an expanded instruction set to minimise potential miscomprehension regarding the nature of the task (Balzan, Delfabbro, Galletly, & Woodward, 2012b).

To measure BADE, most studies have used the well-established procedure outlined by Woodward, Moritz, and Chen (2006). Participants read a brief, ambiguous scenario and then rate and re-rate the plausibility of four interpretations as more evidence is provided. Two lure interpretations initially appear very plausible but become implausible as more evidence is provided; the true interpretation appears less plausible initially but, with more evidence, becomes the most plausible, and an 'absurd' interpretation remains implausible throughout. Higher BADE is demonstrated when participants fail to adequately down-rate the plausibility of lure interpretations.

Some earlier studies used successive pictures (Woodward, Moritz, et al., 2006) or fragmented pictures (Moritz & Woodward, 2006) to present a disambiguating scenario. Typically, two other biases are measured at the same time – a bias against confirmatory evidence (BACE), in which participants fail to adequately up-rate the plausibility of the true interpretation despite additional supporting evidence, and liberal acceptance (LA), where the plausibility of absurd interpretations is overrated (Moritz & Woodward, 2004). Principal Component Analysis has suggested BADE, BACE, and LA are non-independent aspects of a single "evidence integration" cognitive process (Sanford et al., 2014; Speechley, Moritz, Ngan, & Woodward, 2012; Woodward, Moritz, et al., 2006).

While many studies have noted elevated JTC in schizophrenia samples, a much smaller number of studies have tested for a specific relationship with delusions by comparing schizophrenia samples with and without current delusions. In an early meta-analysis of four clinical studies, Fine, Gardner, Craigie, and Gold (2007) found a significant relationship between JTC and delusions when comparing delusional versus non-delusional groups with schizophrenia, suggesting that JTC is specifically related to delusions rather than to schizophrenia generally. Some later studies have supported this finding (Bentall et al., 2009; Corcoran et al., 2008; Langdon, Still, Connors, Ward, & Catts, 2014; van der Gaag et al., 2013), as did a recent systematic review (Garety & Freeman, 2013, although many studies included in the review compared currently-deluded schizophrenia samples with non-delusional, non-schizophrenia samples, so that a schizophrenia diagnosis and the presence of delusions were confounded). JTC has also been associated with delusion-proneness in non-clinical samples (Balzan, Delfabbro, Galletly, & Woodward, 2012a; Balzan et al., 2012b; Colbert & Peters, 2002), providing further tentative support for a causal relationship.

However, other studies comparing schizophrenia groups with versus without delusions have found no relationship between JTC and delusions beyond an association with schizophrenia itself (Menon, Addington, & Remington, 2013; Menon, Pomarol-Clotet, McKenna, & McCarthy, 2006), supporting a spurious explanation for the link between JTC and delusions. So et al. (2012) tested

whether JTC co-varied with delusional conviction over time in a year-long longitudinal study, but found no change in JTC even though delusional conviction decreased slightly. Similarly, belief flexibility (or the ability to think of alternative explanations for delusions) did not change over time, weakening the case for a causal relationship between biased thinking and delusions – although belief flexibility was negatively correlated with conviction at all time points, suggesting it could be a risk factor for more intractable delusions. The change in delusional conviction over the duration of the study was small, however, and perhaps insufficient to be reflected in changes in bias.

With respect to BADE, the question of whether it is related to delusions specifically or merely with schizophrenia in general has not been investigated to the same depth as for JTC. Nevertheless, some studies found that BADE was related to delusional severity (Sanford et al., 2014), and to delusions specifically rather than to a diagnosis of schizophrenia per se (Speechley et al., 2012; Woodward, Moritz, et al., 2006). In contrast, other studies have found no difference in BADE between schizophrenia samples with versus without current delusions (Eifler et al., 2014; Woodward, Moritz, Menon, & Klinge, 2008).

Overall the majority of studies support the possibility that JTC and BADE are meaningfully (and not merely spuriously) associated with delusions, however the literature is far from unanimous. As mentioned, two recent meta-analyses sought to address this problem. In their meta-analysis of between-groups and correlational studies, Dudley et al. (2015) found a small difference in draws-to-decision (DTD) between groups with schizophrenia who were and were not currently experiencing clinician-reported delusions, and a trend-level correlation between JTC and delusion severity in currently delusional samples with schizophrenia. This is consistent with a meaningful relationship, at least in the context of schizophrenia. However, when including other diagnoses with delusions as a symptom, such as delusional disorder, Dudley et al. (2015) used a heterogeneous 'psychosis' group, which included those with schizophrenia both with and without current delusions, plus those with delusional disorder. They compared this heterogeneous group with healthy and psychiatric controls, but it is unclear whether elevated JTC in this group was related to delusions only for those

with schizophrenia, or for those with other diagnoses also. By considering such groups separately, our meta-analysis is able to assess whether JTC is associated with delusions in the context of multiple diagnoses, a key prediction of the hypothesis that JTC contributes to delusion severity.

Similarly, in a meta-analysis of correlational studies, Ross et al. (2015) found a small correlation between JTC and self-reported delusional ideation in clinical and non-clinical samples, although it was not significant in the key current-delusions subgroup (probably due to the small number of studies that met their inclusion criteria). Again, this finding is consistent with the possibility of a meaningful relationship between JTC and delusions. However, Ross et al. (2015) also used a heterogeneous clinical sample which included diagnoses of schizophrenia, schizo-affective or bipolar disorder, and major depression with delusions, and it is unclear whether JTC was associated with delusions across multiple diagnoses, or only associated with delusions in schizophrenia.

We build on the meta-analyses of Ross et al. (2015) and Dudley et al. (2015) by making comparisons between more narrowly-defined groups, allowing us to address in detail when and for whom cognitive biases are related to delusions. Specifically, we compared groups with schizophrenia with and without current delusions, groups with current delusions due to non-schizophrenia diagnoses, groups without delusions but with other psychiatric diagnoses, and healthy control groups.

The comparison of groups with schizophrenia with and without current delusions deserves additional consideration. One prediction of the causal hypothesis would be that cognitive biases co-vary with delusion severity over time. A meta-analysis of longitudinal studies would provide the ideal test of this, but few longitudinal studies are available. Nevertheless, cross-sectional data comparing groups with schizophrenia with and without current delusions may be used to approximate a longitudinal comparison, due to the high prevalence of delusions during psychotic episodes, and the alternation of psychotic episodes with periods of recovery or remission over the

course of illness (Jobe & Harrow, 2005; Marengo & Harrow, 1987; Robinson, Woerner, McMeniman, Mendelowitz, & Bilder, 2004). Clinically significant delusions are a common symptom of schizophrenia, and may be experienced by over 70% of people during psychotic episodes (Lewis, Escalona, & Keith, 2009), though rates as high as 97% were reported in one study (Gourzis, Katrivanou, & Beratis, 2002). Yet psychotic symptoms may remit for a time in as many as 88% of people with schizophrenia within a 12-month period (Nuechterlein et al., 2006). Hence the majority of those with schizophrenia who are in remission and not currently experiencing delusions will have experienced a longitudinal decrease in delusional severity.

We made three key comparisons, as follows. (1) We compared groups with schizophrenia with and without current delusions (and compared the latter with healthy control groups), to determine whether the biases co-vary with delusions and illness severity, and might therefore causally contribute to delusions during acute phases. (2) We compared groups currently experiencing delusions due to non-schizophrenia diagnoses with other groups, to determine whether the biases are associated with delusions across multiple diagnoses, or perhaps spuriously associated with delusions only in the context of schizophrenia. (3) Finally, we compared groups that are psychiatrically ill but not experiencing delusions with other groups, to determine whether these biases could simply be associated with being psychiatrically ill. By estimating how JTC and BADE are differentially associated with schizophrenia, delusions, illness, and health, we inform the question of whether and how cognitive bias is related to delusions.

While JTC and BADE have both been associated with delusions, they are usually studied in isolation. They have not been investigated meta-analytically together, and indeed no BADE meta-analysis exists to date. By including BADE, BACE, and LA along with JTC in the current meta-analysis we hope to draw broader conclusions regarding their possible role in delusion formation and maintenance.

Methods

Selection criteria

JTC studies were included if they used the beads task or its variants (fish/lakes or emotionally-salient stimuli – JTC is observed at similar strength for both neutral and emotionally-salient tasks; Jacobsen, Freeman, & Salkovskis, 2012), and reported group mean DTD or the within-group correlation between DTD and delusion severity. Data from tasks of all ratios were accepted, as Ross et al. (2015) found that bead ratio did not moderate the relationship between JTC and delusion strength. BADE studies which used either the ambiguous scenarios task (Woodward, Moritz, & Chen, 2006) or a similar task using ambiguous pictures (Moritz & Woodward, 2006; Woodward, Moritz, et al., 2006) were included.

For both JTC and BADE, studies were included only if they compared currently delusional and currently non-delusional groups with schizophrenia, or compared one of these groups with delusions not due to schizophrenia, non-delusional psychiatric, or healthy control groups. Groups with either delusional disorder or major depressive disorder with delusions (Corcoran et al., 2008) were included as having current delusions not due to schizophrenia. Groups with current delusions and mixed diagnoses (schizophrenia and delusional disorder etc.) were included as having schizophrenia with current delusions if schizophrenia was the majority diagnosis (Corcoran et al., 2008; Fraser, Morrison, & Wells, 2006; Peters & Garety, 2006; Young & Bentall, 1997). Similar to previous meta-analyses (Dudley et al., 2015; Ross et al., 2015), no distinction was made among delusion subtypes.

Longitudinal JTC data were included when participants who were currently experiencing delusions at baseline were no longer experiencing delusions at follow-up (Menon, Mizrahi, & Kapur, 2008; Peters & Garety, 2006). Only baseline data were used from longitudinal studies in which participants were still experiencing delusions at follow-up (Ross, Freeman, Dunn, & Garety, 2011; Waller, Freeman, Jolley, Dunn, & Garety, 2011). There were no BADE longitudinal studies.

Search strategy

JTC studies and unpublished data meeting our selection criteria were identified from the recent comprehensive literature search completed by Dudley et al. (2015), from Garety and Freeman (2013), and from a search of the Pubmed and PsycINFO databases using the search terms delusions, schizophrenia, psychosis, or paranoia, in combination with jump(ing) to conclusions or JTC.

BADE studies were identified from a search of the Pubmed and PsycINFO databases, using the search terms delusions, schizophrenia, psychosis, or paranoia, in combination with bias against disconfirmatory evidence, bias against confirmatory evidence, BADE, BACE, or evidence integration. Additional data were requested from the authors of BADE studies that appeared to meet the inclusion criteria but did not report adequate descriptive statistics. Data from included JTC and BADE studies were coded by the lead author.

Statistical methods

JTC was operationalised as the mean DTD when available (Dudley et al., 2015), for both neutral and emotionally-salient stimuli. BADE was calculated as the mean change in plausibility rating of lure interpretations between the first and last piece of evidence (Woodward, Moritz, & Chen, 2006), BACE as the change in plausibility rating of true interpretations between the first and last piece of evidence, and LA as the average plausibility rating of absurd interpretations. Several studies have alternatively operationalized LA as the willingness to make a decision for a plausible option based on lower-than-average confidence (Moritz, Woodward, Jelinek, & Klinge, 2008; Moritz, Woodward, & Lambert, 2007; Woodward, Moritz, Cuttler, & Whitman, 2006). While informative, these studies were not included in our meta-analysis because of fundamental differences in the way in which LA was measured.

Cohen's *d* effect size was calculated for each cognitive bias contrast using the between-groups method (Cohen, 1988) for both between-groups and repeated-measures studies, and arithmetically averaged when multiple effect sizes were reported. Correlations (including

Spearman's rho) were converted to Cohen's *d* according to the method of Rosnow and Rosenthal (1996), and group sizes of half the original group rounded down to the nearest whole number were recorded to account for dichotomization. Data from healthy delusion-prone and non-delusion-prone subgroups were recombined by weighted mean averaging and the pooling of standard deviations. All Cohen's *d*s were then corrected to unbiased Hedges' *g* (Hedges, 1981).

Hedges' *g* were combined in a random-effects meta-analysis using the Exploratory Software for Confidence Intervals (ESCI; Cumming, 2011) to determine an overall effect size for each comparison. In addition, the likelihood of publication bias in the schizophrenia with current delusions versus healthy controls, and schizophrenia with and without current delusions comparisons was assessed by visual inspection of funnel-plot symmetry.

Results

Included studies

34 of 54 JTC studies from Dudley et al. (2015) met our inclusion criteria. One further study (Corcoran et al., 2008) was identified for inclusion from Garety and Freeman (2013), but no additional papers were identified via the Pubmed and PsycINFO databases on 21st October 2015. The 35 included JTC studies and their published contrasts are listed in Table 1.

A search of the Pubmed and PsycINFO databases for BADE papers was completed on 22nd September 2015, and identified 27 studies, of which 13 were selected for further review based on their abstracts. Of these, eight studies met our inclusion criteria (Table 2).

Publication bias

Inspection of the funnel plots (figure 1) indicates a possible slight publication bias for the schizophrenia with current delusions versus healthy controls JTC comparison, but not the schizophrenia with versus without current delusions comparison. The funnel plots suggest little to no publication bias has influenced the BADE results.

Table 1

Included JTC studies, comparisons, and effect-size measures

source	comparison[a]							
	SD/HC	SD/SND	SND/HC	PD/HC	SD/PD	SD/PND	PD/PND	PND/HC
Andreou et al. (2013)	*g*[b]							
Andreou et al. (n.d.)		*g*						
Baskak et al. (2015)	*g*							
Bentall et al. (2009)	*g*	*g*	*g*			*g*		*g*
Buck, Warman, Huddy, & Lysaker (2012)		*r*						
Colbert et al. (2010)	*g*	*g*	*g*					
Conway et al. (2002)				*g*				
Corcoran et al. (2008)	*g*	*g*	*g*	*g*	*g*	*g*	*g*	*g*
Dudley et al. (1997a)	*g*					*g*		*g*
Dudley, John, Young, & Over (1997b)	*g*					*g*		*g*
Dudley et al. (2011)		*g*						
Fear & Healy (1997)				*g*			*g*	*g*
Fraser et al. (2006)	*g*					*g*		*g*
Garety (1991)	*g*			*g*	*g*	*g*	*g*	*g*
Huq et al. (1988)	*g*					*g*		*g*
Jacobsen et al. (2012)	*g*					*g*		*g*
Langdon, Ward, & Coltheart (2010)	*ρ*	*ρ*						
Langdon et al. (2014)		*r*						
Lim, Gleeson, & Jackson (2012)		*r*						
Lincoln, Ziegler, Mehl, & Rief (2010)	*g*	*g*	*g*					
Menon et al. (2006)	*g*	*g*	*g*					
Menon et al. (2008)[, c]		*g*						
Menon et al. (2013)	*g*							
Moritz & Woodward (2005)	*g*	*g*	*g*			*g*		*g*
Mortimer et al. (1996)		*r*						
Peters & Garety (2006)[,]	*g*	*g*	*g*			*g*		*g*
Peters, Thornton, Siksou, Linney, & MacCabe (2008)		*g*						
Ross et al. (2011)	*g*							
So & Kwok (2015)	*g*							
Startup, Freeman, & Garety (2008)	*g*							
van der Gaag et al. (2013)		*r*						
Waller et al. (2011)		*r*						
Warman et al. (2007)	*g*							
Warman, Martin, & Lysaker (2013)		*r*						
Wittorf et al. (2012)		*r*						*g*
Total participants (*n*)	1131	834	385	152	86	409	123	558
Total studies (*k*)	21	20	7	4	2	10	3	12
Heterogeneity variance (I^2)	58.2%	0.0%	47.3%	0.0%	0.0%	0.0%	15.7%	22.1%
Heterogeneity significance (*p*)	.000	.530	.077	.792	.951	.669	.306	.227

Note: [a]SD = schizophrenia with current delusions, HC = healthy controls, SND = schizophrenia without current delusions, PD = other psychiatric illnesses with current delusions, PND = other psychiatric illnesses without current delusions.

[b]*g* = Hedges' *g* reported or calculated; *r*, *ρ* = correlation or Spearman's correlation reported.

[c]Longitudinal data.

Table 2

Included BADE, BACE, and LA studies, comparisons, and effect-size measures

source	comparison[a]							
	SD/HC	SD/SND	SND/HC	PD/HC	SD/PD	SD/PND	PD/PND	PND/HC
Woodward, Moritz, & Chen (2006)[c]	*g*[b]	*g*	*g*					
Woodward, Moritz, et al. (2006)	*g*	*g*	*g*					
Woodward et al. (2008)	*g*	*g*	*g*			*g*		*g*
Veckenstedt et al. (2011)	*g*	*g*	*g*			*g*		*g*
Riccaboni et al. (2012)[d]		*r*						
Eifler et al. (2014)	*g*	*g*	*g*					
Sanford et al. (2014)	*g*	*g*	*g*			*g*		*g*
Speechley et al. (2012)	*g*	*g*	*g*			*g*		*g*
BADE:								
Total participants (*n*)	369	466	455	0	0	221	0	247
Total studies (*k*)	7	8	7	0	0	4	0	4
Heterogeneity variance (I^2)	38%	49.5%	0.0%			20.0%		0.0%
Heterogeneity significance (*p*)	.139	.054	.689			.290		.801
BACE:								
Total participants (*n*)	369	426	455	0	0	221	0	247
Total studies (*k*)	7	7	7	0	0	4	0	4
Heterogeneity variance (I^2)	0.0%	0.0%	19.4%			0.0%		14.5%
Heterogeneity significance (*p*)	.487	.549	.282			.468		.319
LA:								
Total participants (*n*)	338	383	409	0	0	221	0	247
Total studies (*k*)	6	6	6	0	0	4	0	4
Heterogeneity variance (I^2)	50.6%	8.9%	48.6%			0.0%		32.5%
Heterogeneity significance (*p*)	.072	.359	.083			.509		.217

Note: [a]SD = schizophrenia with current delusions, HC = healthy controls, SND = schizophrenia without current delusions, PD = other psychiatric illnesses with current delusions, PND = other psychiatric illnesses without current delusions.

[b]*g* = Hedges' *g* reported or calculated; *r* = correlation reported.

[c]BADE and BACE data only

[d]BADE data only.

Preliminary analyses

Subgroup analyses were performed where possible to determine whether studies using different methodologies could appropriately be combined. The core schizophrenia with versus without current delusions comparison was used for all subgroup analyses. There was no significant difference (Δg = 0.149 [-0.137, 0.434]) between studies that reported between-groups DTD (g = 0.275 [0.106, 0.444]) and those reporting the correlation between DTD and delusion strength (g =

0.424 [0.194, 0.654]), confirming the validity of converting correlational data to Hedges' *g* and combining with the between-groups studies.

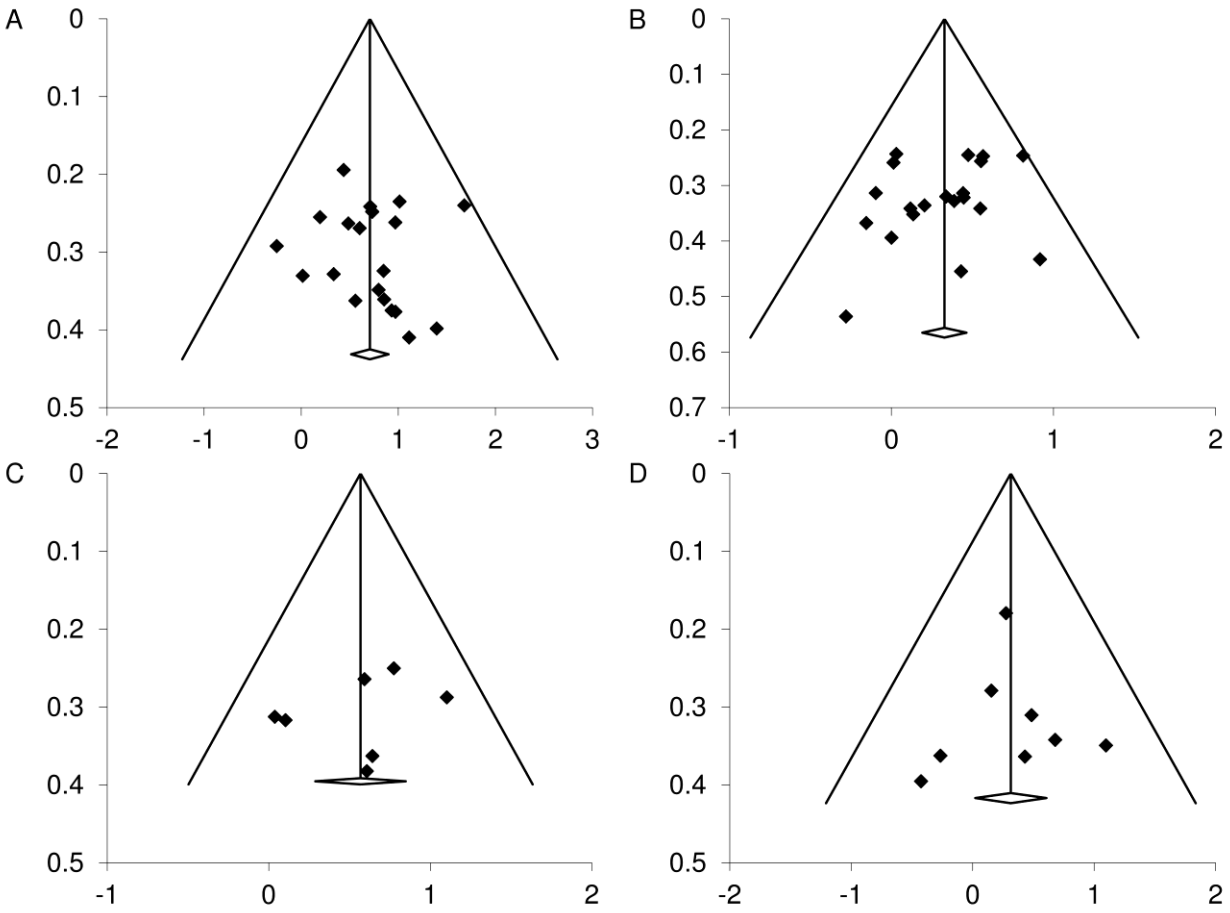

Figure 1. Funnel plots showing standard error (y axis) against effect size (Hedges' *g,* x axis) for the JTC comparison between (A) groups with schizophrenia with current delusions and healthy control groups, (B) groups with schizophrenia with and without current delusions, and the BADE comparison between (C) groups with schizophrenia with current delusions and healthy control groups, (D) groups with schizophrenia with and without current delusions.

There was a small difference in effect sizes between longitudinal and between-groups JTC studies (Δg = 0.177 [0.056, 0.463]), and hence some caution in interpretation is suggested. Specifically, the longitudinal subgroup demonstrated a small but non-significant effect (*g* = 0.167 [-0.273, 0.608]), with poor precision due to the inclusion of only two studies. The cross-sectional subgroup demonstrated a small effect with much greater precision (*g* = 0.344 [0.201, 0.487]).

Despite the small difference in effect sizes, inclusion of the two longitudinal studies in the meta-analysis increased overall precision, and we consider the combined between-groups and longitudinal data to be valid.

Analysis of heterogeneity

Significant heterogeneity was observed for the schizophrenia with current delusions versus healthy controls JTC meta-analysis (Table 1). When an unusually high (Warman, Lysaker, Martin, Davis, & Haudenschield, 2007) and low-effect (Colbert, Peters, & Garety, 2010) study were removed from the analysis, heterogeneity was no longer significant, while effect size remained consistent. No obvious methodological differences were noted for either study which might account for extreme results, and they were included in subsequent analyses. No significant heterogeneity was observed for any other JTC, BADE, BACE, or LA comparisons (Table 1, 2).

Replication of the basic relationship

The majority of studies and two recent meta-analyses (Dudley et al., 2015; Ross et al., 2015) attest that there is a relationship, whether direct or spurious, between cognitive bias and delusions in schizophrenia. As a prerequisite to further investigations we also tested this relationship, and found that groups with schizophrenia and current delusions showed greater JTC, BADE, BACE, and LA than healthy control groups, with a medium effect size (figure 2). Forest plots for all meta-analyses are included in the supplementary material (included as an Appendix to this thesis). Our results replicate Dudley et al. (2015) and Ross et al. (2015) by confirming a relationship between having schizophrenia with delusions and elevated JTC, and additionally confirm this same relationship for the BADE, BACE, and LA biases also.

Key comparisons results

Groups with schizophrenia and current delusions demonstrated greater JTC, BADE, BACE, and LA than groups with schizophrenia who were not currently experiencing delusions, with a small effect size (see figure 2 for all key comparisons). In fact, schizophrenia groups without current

delusions demonstrated no more JTC than healthy control groups, although they demonstrated more BADE with a small effect, a small trend towards more BACE, and more LA with small to medium effect.

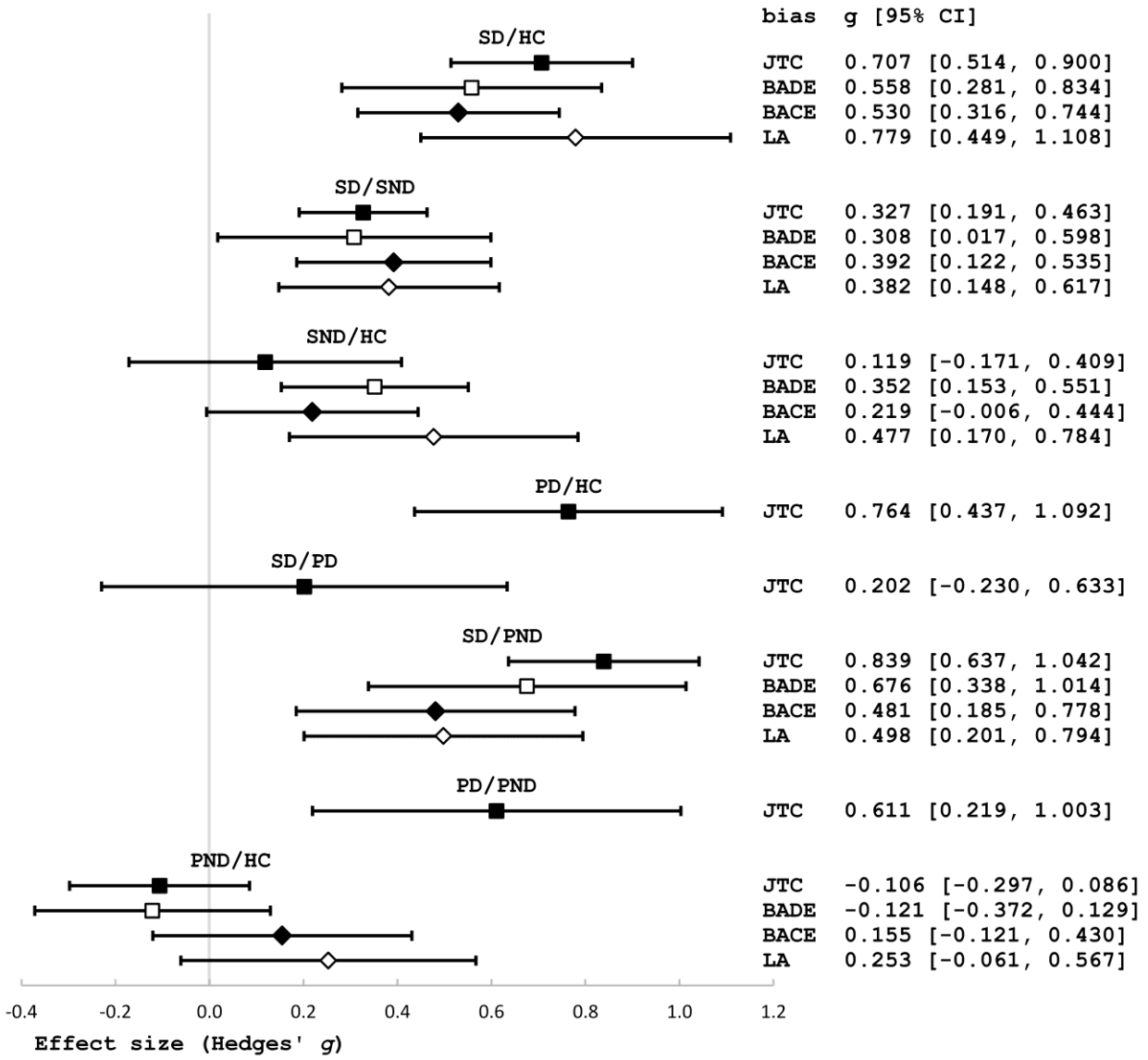

Figure 2. Plot and values of Hedges' *g* effect size and 95% CI for group differences in jumping to conclusions (JTC), bias against disconfirmatory evidence (BADE), bias against confirmatory evidence (BACE), and liberal acceptance (LA). SD = schizophrenia with current delusions, HC = healthy controls, SND = schizophrenia without current delusions, PD = other psychiatric illnesses with current delusions, PND = other psychiatric illnesses without current delusions.

Groups who were experiencing delusions due to psychiatric disorders other than schizophrenia also demonstrated greater JTC than healthy control groups, with a medium effect size

(no BADE, BACE, or LA data were available for this comparison). These groups demonstrated equivalent levels of JTC to groups with schizophrenia who were currently experiencing delusions.

Groups with other psychiatric illnesses who were not experiencing delusions demonstrated less JTC and BADE with a large effect size, and less BACE and LA with a small to medium effect size than groups experiencing delusions due to schizophrenia. Groups with other psychiatric illnesses who were not experiencing delusions also demonstrated less JTC, with a medium effect size, than groups experiencing delusions owing to other diagnoses (no BADE, BACE, or LA data was available), and demonstrated no more JTC, BADE, BACE, or LA than healthy control groups.

Discussion

This meta-analysis compared narrowly-defined groups across the JTC, BADE, BACE, and LA spectrum of cognitive biases, in order to determine (1) whether these biases co-vary with delusions, consistent with the possibility they contribute causally to delusions, (2) whether these biases are associated with delusions in illnesses other than schizophrenia, to demonstrate whether the association is with a diagnosis of schizophrenia or with delusions in particular, and (3) whether these biases could merely be associated with being psychiatrically ill.

Do biases co-vary with delusions over time?

The co-variability of biases with delusions over time would ideally be tested using longitudinal data, but only two longitudinal studies met the inclusion criteria and a separate analysis was of limited value owing to imprecision. Combined with the minimal longitudinal data available, we took the alternative approach of approximating longitudinal information using cross-sectional data. Groups with schizophrenia and current delusions demonstrated greater JTC (consistent with Dudley et al., 2015), BADE, BACE, and LA than groups with schizophrenia who were not currently experiencing delusions, although the difference was small. Further, for the first time in a meta-analysis, we have shown that groups with schizophrenia without current delusions demonstrated no more JTC than healthy control groups (though they showed more BADE and LA than healthy

control groups with small effect, and a trend towards more BACE). The medium JTC effect found by Dudley et al. (2015) for their psychosis group versus healthy controls comparison (g = −0.53 [−0.69, −0.36]) lies between our results for schizophrenia groups with current delusions versus healthy controls, and for schizophrenia groups without current delusions versus healthy controls, as might be expected considering the mixed delusional status of their psychosis group. Together, our results suggest that JTC, BADE, BACE and LA are not simply stable features of schizophrenia. They appear elevated during times of worse delusions, and appear lower (BADE, BACE, LA) or comparable to normal levels (JTC) as delusions abate. This is consistent with the possibility that these biases contribute causally to delusions during acute phases of illness. Additionally, the presence of some biases (at reduced levels) in non-delusional groups suggests people with schizophrenia may also have a trait vulnerability to biases, which could be targeted by interventions during all phases of illness.

A significant limitation of this meta-analysis however is that it included longitudinal data from only two studies, and while longitudinal information was approximated using cross-sectional data, questions remain about the validity of this approach. It is possible that the schizophrenia groups without current delusions included participants for whom delusions were never a prominent feature of their schizophrenia, and that perhaps delusional severity is relatively stable over time (Marengo, Harrow, Herbener, & Sands, 2000). If this were the case, cross-sectional data from groups with and without current delusions would not reflect changes in delusion severity, but stable individual differences in symptomatology. As such, our results would demonstrate an association between biases and individual differences in the development of delusions, suggesting cognitive bias might be a risk factor for delusions in psychosis. Only longitudinal data can unequivocally show whether the biases truly co-vary over time with delusions in schizophrenia, and hence whether they may act as causal agents or risk factors for worse delusions.

Are biases associated with delusions across multiple diagnoses?

JTC was equally elevated in delusional groups with schizophrenia and other illnesses, suggesting that JTC is not spuriously related to delusions merely owing to their co-occurrence in schizophrenia. Rather, the finding that JTC was associated with delusions across diagnoses is consistent with the possibility that JTC contributes to the development of delusions, and suggests the association could be strong enough that JTC might even be a necessary (though not sufficient) factor for the development of delusions. Unfortunately, no relevant BADE, BACE or LA data were available, but would make a worthy focus for future research. It is also possible that biases contribute to certain types of delusions and not others. For example, Garety et al. (2012) found that JTC was more strongly associated with grandiose delusions than with persecutory delusions. Understanding whether the biases feature differently in different subtypes of delusions would be another worthy focus for future research, potentially leading to more targeted and effective cognitive therapies.

Are biases simply elevated in psychiatric illnesses?

An association of biases with delusions in both schizophrenia and other delusional disorders could nevertheless occur if these biases were simply a consequence of having a psychiatric illness more generally. If this were the case, the biases should be elevated in groups with psychiatric diagnoses which are not associated with delusions also. However, groups with psychiatric illnesses not associated with delusions demonstrated less JTC, BADE, BACE, and LA than groups experiencing delusions, whether the delusions were due to schizophrenia (all biases) or other diagnoses (only JTC data available). Additionally, groups with psychiatric illnesses who were not experiencing delusions demonstrated no more JTC, BADE, BACE or LA than healthy control groups. As these biases are not elevated in psychiatric illnesses more generally, merely having a psychiatric illness cannot account for cognitive bias in those experiencing delusions.

General discussion

Our results are consistent with the hypothesis that cognitive biases play a causal role in delusions. The hypothesis finds indirect support in treatment studies also. Metacognitive Training, a cognitive therapy that focuses on reducing JTC and BADE, has been shown by meta-analysis to weaken delusional severity in people with schizophrenia (Eichner, 2015; Eichner & Berna, 2016).

The similar pattern of occurrence of the BADE, BACE, and LA biases supports their interpretation as parts of a unified evidence integration construct (Sanford et al., 2014; Speechley et al., 2012). That JTC also demonstrates a similar pattern of occurrence to the integration biases suggests they may share a common underlying cognitive mechanism, while remaining independent constructs (Moritz et al., 2010). One mechanism proposed to underlie JTC and BADE is the hypersalience of evidence which matches a hypothesis (Balzan et al., 2012a; Balzan, Delfabbro, Galletly, & Woodward, 2013; Speechley et al., 2012; Speechley et al., 2010). Hypersalient evidence-hypothesis matches could lead to reduced data-gathering and premature decision-making (JTC), or strengthen a weak hypothesis against counter-evidence (BADE). Though not discussed in the literature, perhaps BACE arises when the hypersalience of evidence-hypothesis matches renders evidence for new alternative (and perhaps true) hypotheses comparatively less salient. The theory could even explain LA, as the hypersalience of positive evidence for an absurd hypothesis might overwhelm the non-specific common-sense evidence most people presumably draw upon to discount very unlikely scenarios.

Conclusion

Our meta-analysis demonstrates that JTC, BADE, BACE, and LA are associated with delusions across multiple diagnoses, and not merely with having a schizophrenia diagnosis nor with having a psychiatric illness more generally. The association of these biases with delusions specifically is consistent with the possibility these biases contribute to delusions. Additionally, our meta-analysis implies that these biases could co-vary with delusions over time, increasing in strength and contributing to the development and maintenance of delusions during acute phases of

illness. The suggestion that cognitive biases play a role in the development and maintenance of delusions in a range of psychiatric illnesses has high apparent validity, and remains a parsimonious and convincing explanation for the close association of JTC and BADE with delusions.

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CHAPTER 3: Study 2 – Towards a reliable repeated-measures beads task

Towards a reliable repeated-measures beads task for assessing the jumping to conclusions bias

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Abstract

The beads task is the most utilized measurement tool in the sizeable body of research linking the jumping to conclusions bias with delusions in psychosis – yet the reliability of the task has never been investigated. We investigated the repeatability, reliability, and believability of the task. We also tested an alternate version of the task which used distractor sequences to make the target sequence less memorable, and assessed the impact of using a practice trial. Healthy participants ($N = 212$) were randomised into two groups. The "target-sequence-only" group completed ten trials using the AAABAAAABA "target" sequence. The "distractor-sequences" group completed ten trials composed of the target sequence and three distractor sequences. The distractor-sequences task was more believable, repeatable, and reliable than the target-sequence-only task; in contrast, the repeatability and reliability of the target-sequence-only task was low. Excluding first-trial data (a "silent" practice trial) also improved repeatability. Our data indicate the standard beads task may not be reliable over repeated measures. However, by including distractor sequences, the beads task can be made more believable, repeatable, and reliable. These improvements to the beads task are both relevant to single trial studies, and will be especially useful to repeated-measures longitudinal, experimental, and treatment studies.

Key words: beads task; jumping to conclusions; repeated measures; repeatability; reliability; psychosis.

The beads task (Huq, Garety, & Hemsley, 1988) is used to measure the *jumping to conclusions* bias (JTC), in which some people gather less information than others might do before making a decision. Typically, participants are presented with two jars containing beads of two colours in equal but opposite ratios. One jar is chosen at random, and beads are drawn one at a time (purportedly at random, but actually in a predetermined sequence) from the jar. At each draw, participants either make a decision as to which jar beads were being drawn from, or request to see more beads. The amount of data gathered is most often measured as the number of beads drawn before a decision is made ("draws to decision" – DTD), though other criteria are possible, such as Liberal Acceptance, in which participants make a decision at a low level of confidence (Moritz, Woodward, & Lambert, 2007). The beads task has been key in the large body of research linking JTC with delusions in psychosis (Dudley et al., 2016; McLean, Mattiske, & Balzan, 2017; Ross, McKay, Coltheart, & Langdon, 2015). However, despite the sizeable beads-task literature (a search of PubMed Central for the terms "*JTC"*, "*jump(ing) to conclusions"*, or "*beads task"* returned 1390 full-text journal hits), the reliability of the beads task has never been investigated.

In the large majority of beads-task studies only a single trial of the beads task is presented – and when more than one trial is presented, the same sequence of beads is generally used repeatedly (e.g. Peters & Garety, 2006; Menon, Mizrahi, & Kapur, 2008; Ross, Freeman, Dunn, & Garety, 2011; Waller, Freeman, Jolley, Dunn, & Garety, 2011). Yet it is unclear whether DTD captured over single or multiple trials is a genuine reflection of a participant's true DTD. Concerningly, two recent meta-analyses have shown that responses on the beads task vary with the number of trials provided (Dudley et al., 2016; Ross et al., 2015). Additionally, there is some evidence that between-group differences in JTC may only be observable on a single trial, and may disappear over multiple trials (Krug et al., 2014; Rausch et al., 2014). That the beads task may not be consistent across repeated measures signals possible problems with the psychometric properties of the task both in single-trial studies, and in longitudinal, treatment, and experimental studies that employ repeated administrations. Thus, our first objective was to assess consistency over multiple trials.

Changes in response to the beads-task over repeated measures might occur for a variety of reasons. Perhaps participants' responses change when they discover the predetermined nature of the bead sequence with which they are presented. Participants repeatedly exposed to the AAABAAAABA sequence in common use (the "target" sequence) may soon observe that the first few beads are always of one colour, and that the first colour is always the majority colour, and begin to make earlier decisions than previously. Bead colours are usually changed from trial to trial to try and prevent this (see for example Ross, Freeman, Dunn, & Garety, 2011; Waller, Freeman, Jolley, Dunn, & Garety, 2011), however simply changing bead colours may not effectively hide the single repeating target sequence.

Alternatively, perhaps early beads-task responses are influenced by the range of unknowns which participants undoubtedly face when completing this task for the first time. Supporting this idea, evidence from the broader area of cognitive psychology has found that practice effects over the first two trials of a range of cognitive assessment tools can produce significant changes, while responses over later trials are more consistent (Collie, Maruff, Darby, & McStephen, 2003). If this is the case, it is of particular concern that the beads task is usually only administered once, and with no practice trial (Dudley et al., 2016).

Other measures of JTC have the potential to avoid the problem of repeating identical sequences, such as the box task (Balzan, Ephraums, Delfabbro, & Andreou, 2017; Moritz et al., 2017), however the task is relatively new and its validity has not yet been established. The non-serial data-gathering paradigm of van der Leer, Hartig, Goldmanis, and McKay (2017), in which participants request the full number of fish they wish to see drawn from a lake in one go, could also avoid the issues with repeating sequences. Again however, this task is a significant divergence from the standard beads task, and requires further validation. In the meantime, the beads task is in many ways the standard method of identifying JTC, and its limitations over repeated measures need to be established and improved.

To address the potential problem of participants recognising the key characteristics of the beads-task target sequence over repeated measures (which may result in changes in response), we proposed interleaving this sequence between fixed pseudo-random distractor sequences. While it might be possible to effectively distract participants from the recurring nature of a single target sequence by embedding it in, say, sets of truly random sequences (van der Leer, Hartig, Goldmanis, & McKay, 2014), and random sequences could even be the same for all participants to reduce between-subjects' variability, this would not effectively address the problem of repeated-measures designs. Using random distractor sequences over repeated measures, participants would by necessity be exposed to different random sequences at each trial. Then the specific content of each random sequence, for example whether colours tended towards being evenly distributed or more one-sided, would be liable to induce a response set towards more or less conservatism in making a decision, increasing within-subjects' variability. Instead, we expected repeated pseudo-random distractor sequences to reduce the salience of the target sequence and, therefore, participants' recognition of its main features, while minimising both between- and within-subjects' variability. We tested this solution using a two-group (target-sequence-only and distractor-sequences groups) repeated-measures design, in which each group completed 10 trials of their respective beads task. In addition, to assess the efficacy of a practice trial to address the potential problem of participants responding less reliably on initial trials, we compared the consistency of two consecutive trials conducted with and without a practice trial.

In order to assess the efficacy of distractor sequences in disguising the fact that the beads sequences were non-random, we recorded participants' self-reported belief that they were random. To assess the consistency over repeated trials of the target-sequence-only and distractor-sequences tasks, we measured the repeatability and reliability of the beads task over repeated measures. Here repeatability means that a measure returns stable or consistent values over trials under conditions in which a construct's true level should not change (e.g., measurements taken close in time, under identical conditions, with no intervention between measurements). This was operationalised as the

mean squared error (MSE) over repeated measurements, reflecting intra-individual stability. Reliability on the other hand is the ability to discriminate between levels of a variable in the presence of noise (Portney & Watkins, 2015). This was operationalised as the Intraclass Correlation Coefficient (ICC(1,1), Shrout & Fleiss, 1979), which is the proportion of total variance explained by the true variance due to genuine differences between people.

The impact of having a reliable repeated-measures beads task would be significant. Such a task is needed for longitudinal, experimental, and treatment studies, and whenever aggregate measures are to be calculated for increased accuracy and precision.

Methods

Participants

240 participants on the Prolific online crowdsourcing platform completed our experiment. Participants were paid £2.20 for participation. Study participation N was determined by funding and time constraints. Analyses were not commenced until the study was closed to participants.

Beads task

Every participant completed ten trials of either the target-sequence-only or distractor-sequences beads task. The target-sequence-only group completed ten trials using only the target sequence (AAABAAAABA), while the distractor-sequences group completed ten trials using the target sequence plus three additional distractor sequences (i.e., the target sequence was presented ten times to this group also, but along with three distractor sequences each time it was presented). Comparing the two groups on an equal number of target sequences necessitated the distractor-sequences group completing 40 beads-task sequences compared with the 10 completed by the target-sequence-only group. The distractor sequences included one sequence for which the first bead colour was the minority colour, as this would occur from time to time under truly random conditions. The distractor sequences were AABAAABAAA, BAAAABAAAA, and AAAABAABAA, with the target sequence being presented between the first and second distractor sequences. New trials were identified via on-screen text, and each trial used a unique pair of bead colours.

For each sequence, the identity of the majority colour "A" and its association with the left or right-hand jar were pseudo-randomised. Participants were instructed to make a decision once they felt confident they knew which jar beads were being drawn from. articipants were then presented with a single bead, along with the query "Would you like to make a decision regarding which jar beads are being drawn from?". Participants could either select "no, I would like to see another bead", or "yes, I have made a decision". Whenever participants requested another bead, the next bead in the sequence (to a maximum of ten beads) was displayed on screen, along with any previous beads to ensure responses were not affected by memory capacity (Freeman et al., 2014). When participants elected to make a decision, the jar they chose along with the DTD were recorded, and the sequence was stopped[1]. If no jar was chosen after the 10th bead, a DTD of 11 was recorded and the participant was progressed to the next sequence. This continued until participants completed ten trials of one sequence (target-sequence-only group) or ten trials of four sequences (distractor-sequences group).

Procedure

Participants accessed the online experiment via their own computer device, and were randomised to either the target-sequence-only condition or the distractor-sequences condition. After informed consent was established and basic demographic data were collected, participants were presented with detailed instructions explaining the beads task appropriate to their group, and a comprehension check consisting of a two-item test of their understanding of the task (see Experiment 10, Crump, McDonnell, & Gureckis, 2013). The purpose of the comprehension check was to prompt those who miscomprehended the instructions to re-read them and improve their understanding of the task, rather than to exclude participants on the basis of initial miscomprehension. Hence if a participant failed the comprehension check it was repeated until a correct answer was recorded, and it was not used as an exclusion criterion. Participants then completed ten beads-task trials.

[1] Participants were not asked for their degree of confidence once they had made their decision.

Following completion of the beads task, the Peters Delusions Inventory (PDI, Peters, Joseph, Day, & Garety, 2004) was administered (PDI data are not reported in this study), along with an attention check part-way through the 21 items. Participants then completed Likert scales (from 0 = definite disbelief to 4 = definite belief) indicating their belief in the non-swapping of beads-task jars mid-trial and in the randomness of sequences. Those who did not express definite belief in either aspect were asked to estimate the trial on which they first questioned the task, and how this affected their responses (whether causing them to increase, decrease, or maintain DTD) (not reported in this study). Finally, an instructional manipulation check (IMC, Oppenheimer, Meyvis, & Davidenko, 2009) was provided to test whether participants were, at this stage of the experiment, reading instructions in their entirety. As this IMC involved a "trick" question and could prompt systematic thinking (Hauser & Schwarz, 2015) it was presented last, so as not to affect participants' responses on other measures.

Statistical analyses

Each group's relative belief in the randomness of sequences was established by an independent-samples *t*-test, and its association with repeatability was assessed by a Spearman's ρ correlation. We assessed the impact of a practice trial by comparing the within-subjects' repeatability of trials 1 and 2 (equivalent to a two-trial design with no practice trial) against the repeatability of trials 2 and 3 (equivalent to a two-trial design with a "silent" practice trial). We used non-parametric tests (see below) to check for both systematic (change in DTD) and random (MSE) changes in response over trials to establish whether a practice trial provided greater repeatability. We then tested the repeatability of each task over multiple trials by comparing MSE between groups. Due to the non-normal distribution of the DTD and MSE data (see below), all DTD and MSE comparisons were made using the nonparametric Wilcoxon Signed-ranks test (related-samples) or Mann-Whitney U test (independent samples). Non-parametric effect sizes were expressed as rank-biserial correlations (Mann-Whitney U tests) or matched-pairs rank-biserial correlations (Wilcoxon Signed-ranks tests) calculated according to the formulas of Glass (Glass, 1965) and Kerby (2014) respectively. The

rank-biserial correlation (*r*) is an easily-interpreted 'common language effect size' (McGraw & Wong, 1992) which is calculated as $P_{for}/P_{total} - P_{against}/P_{total}$, i.e., the proportion of ranked pairs favouring a hypothesis minus the proportion of ranked pairs favouring its antithesis (Kerby, 2014)[2]. This results in a value within the range [1, -1] expressing the strength of favourable evidence.

To assess reliability, we computed the Intraclass Correlation Coefficient (ICC(1,1), Shrout & Fleiss, 1979) of DTD over increasing ranges of trials, beginning at trial 2. This provides the average reliability of any one trial within the given trial range. We calculated ICC(1,1) by the ANOVA estimation method (Donner & Wells, 1986). However, it was necessary to hold the estimated true variance constant, because being a ratio of true variance to total variance, ICC values are not comparable if the estimated true variance is permitted to change over trial ranges or between groups (Cohen & Doveh, 2005; Hanges & Lyon, 2005). We estimated true variance from the mean square between and mean square error of the distractor-sequences group over trials 2 to 3[3] (Shrout & Fleiss, 1979).

Results

Data screening

Nineteen participants were excluded for either failing the attention check ($n = 5$), and/or the IMC more than twice ($n = 9$), and/or for answering more than 30% of target trials incorrectly ($n = 7$). We then inspected box-plots of the DTD and MSE ten-trial averages, and found a small number of extreme responses more than four inter-quartile ranges from the median. These extreme responses (4 MSE responses from the target-sequences group, and 2 MSE and 4 DTD responses from the distractor-sequences group) may reflect responding that was influenced by miscomprehension or a major individual difference on an unmeasured third variable rather than true construct levels, and were excluded from the data. Following the application of exclusion criteria, only two participants failed the comprehension check more than five times. Final participants were 94 females and 118

[2] Tied pairs were counted as 0.5 for and 0.5 against.
[3] Chosen as our results indicate they are the least affected by error

males ranging between 18 and 64 years old. Groups were well-balanced demographically (see Table 1). The distribution of mean trial-2-to-10 DTD and of mean trial-pair MSE over trials 2-to-10 were mostly significantly positively skewed and leptokurtic (Kim, 2013; Tabachnick & Fidell, 2007, pp. 79-80), so nonparametric tests were used for DTD and MSE comparisons. Both groups indicated probable to certain belief that jars were not swapped during trials (target-sequence-only group: M = 3.60, SD = 0.84, 95% CI [3.44, 3.76]; distractor-sequences group M = 3.40, SD = 1.08, 95% CI [3.19, 3.60]), and it appears unlikely miscomprehension of the task (Balzan, Delfabbro, & Galletly, 2012; Balzan, Delfabbro, Galletly, & Woodward, 2012) was a significant issue. Trial-to-trial DTD is shown on Figure 1.

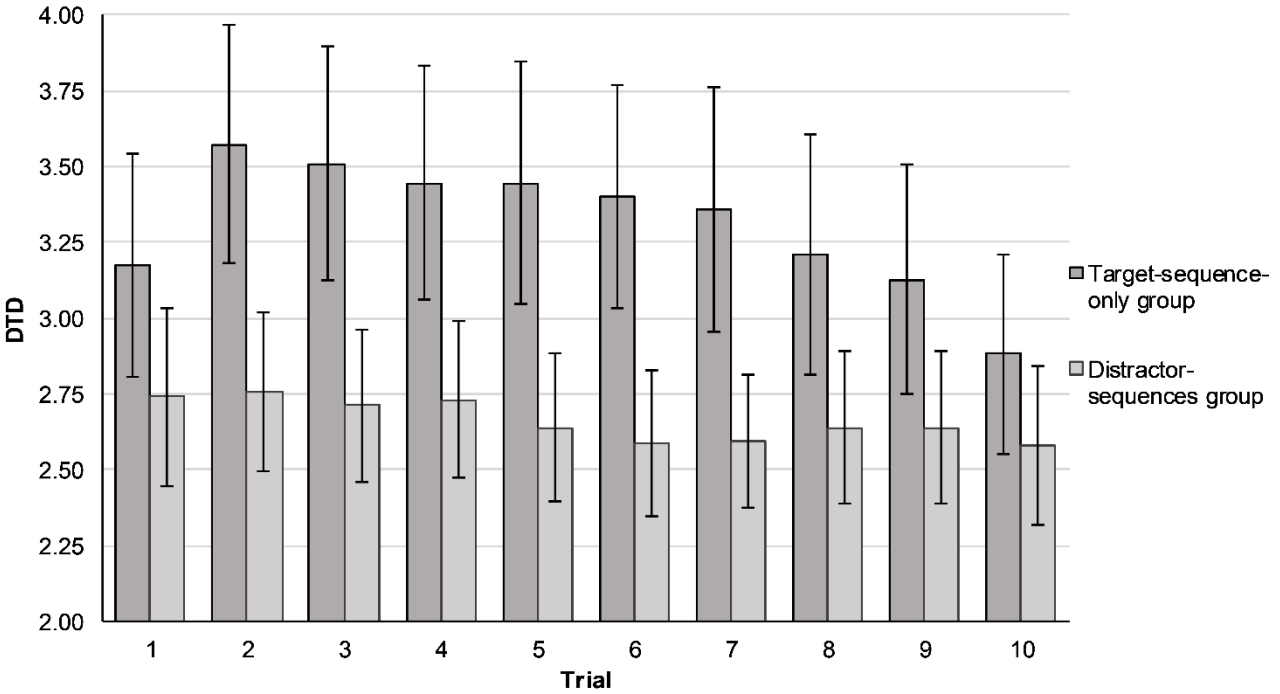

Figure 1. Mean DTD for each group at each trial, with 95% confidence intervals.

Table 1

Demographics and descriptive statistics

	n	gender	age	Mean trial 2-10 DTD			Mean trial 2-10 trial-pair MSE		
			M [95% CI]	*Mdn* [IQR]	Skew. *z*	Kurt. *z*	*Mdn* [IQR]	Skew. *z*	Kurt. *z*
Target-sequence-only group	106	46 female, 60 male	32.3 [29.9, 34.9]	3.11 [2.08, 4.89]	3.55**	1.58	0.23 [0.00, 0.94]	15.30**	1.58
Distractor-sequence group	106	48 female, 58 male	31.4 [29.0, 33.8]	2.78 [2.00, 3.44]	7.30**	9.44**	0.16 [0.00, 0.40]	13.41**	30.56**

** significant at the .01 level (i.e., z > 2.330).

Belief in the task

The primary purpose of introducing distractor trials to the beads task was to hide the non-random nature of the target sequence. Belief in the randomness of sequences was significantly higher for the distractor-sequences group (M = 2.32, SD = 1.45, 95% CI [2.04, 2.60], indicating ambivalent to probable belief) than for the target-sequence-only group (M = 1.68, SD = 1.44, 95% CI [1.40, 1.96], indicating ambivalent to probable *disbelief*), $t(210) = -3.23$, $p = .001$, Hedges' $g = 0.44$.

Practice trial

The effect of a practice trial was assessed by comparing the repeatability of a practice-task (trials 2-3, discarding trial 1 data) and no-practice-task (trials 1-2) subset of trials. We considered both within-subjects' (MSE) and systematic data (group-level change in DTD, Figure 1), as it is possible for a stable group-level response to hide significant but random within-subjects' changes, or for non-significant but systematic within-subjects' changes to result in significant group-level changes. For the target-sequence-only group, a Wilcoxon signed-ranks test showed that change in DTD was greater over the no-practice-task trials than over the practice-task trials, indicating that group DTD was more consistent over trials when trial 1 was treated as a practice trial (Table 2). However, within-subjects' MSE over the practice-task trials was not significantly different from MSE over the no-practice task trials, indicating that a practice trial did not improve within-subjects' repeatability in this group. For the distractor-sequences group, there was no significant difference in change in DTD over the no-practice-task trials compared with the practice-task trials, indicating that a practice trial did not improve group-level repeatability. However, within-subjects' MSE over the practice-task trials was less than MSE over the no-practice task trials, indicating that a practice trial improved within-subjects' repeatability in this group. Together these results showed that using a practice trial increased group-level (target-sequence-only task) and within-subjects' (distractor-sequences task) repeatability, and trial-1 data were therefore excluded from subsequent analyses.

Table 2

Descriptive and test statistics for repeatability with and without a practice trial

			Mdn [IQR]	*M [95% CI]*	*Z*	*p*	*r*
Change in DTD	Target-sequence-only group	With practice trial	0.00 [0.00, 0.00]	-0.07 [-0.28, 0.14]	-2.54	.011	-.160 [a]
		Without practice trial	0.00 [0.00, 1.00]	0.42 [0.20, 0.63]			
	Distractor-sequences group	With practice trial	0.00 [0.00, 0.00]	-0.05 [-0.17, 0.08]	-0.21	.831	-.028 [b]
		Without practice trial	0.00 [0.00, 0.00]	0.02 [-0.19, 0.22]			
MSE	Target-sequence-only group	With practice trial	0.00 [0.00, 0.25]	0.34 [0.22, 0.46]	-1.15	.251	-.085 [c]
		Without practice trial	0.00 [0.00, 0.25]	0.29 [0.18, 0.41]			
	Distractor-sequences group	With practice trial	0.00 [0.00, 0.25]	0.28 [0.17, 0.38]	-3.45	.001	-.189 [d]
		Without practice trial	0.00 [0.00, 0.25]	0.11 [0.06, 0.15]			

Comparisons are a: group-level changes – target sequence only group; b: group-level changes – distractor-sequences group; c: within-subjects' changes – target sequence only group; d: within-subjects' changes – distractor-sequences group;

Repeatability comparison

To test whether distractor sequences improved repeatability we calculated the MSE of each group over ranges of trials commencing at trial 2 (Figure 2). Mann-Whitney U tests showed that the MSE of the distractor-sequences group was significantly less than that of the target-sequences-only group for all trials (U = 4457.5-4622.5, Z = -2.20--3.09, p = .002-.028, r = .170-.207), indicating that the distractor-sequences group made smaller changes in DTD response over all ranges of repeated trials than did the target-sequences-only group. Hence using distractor sequences produced a more repeatable beads task. As we had predicted that increased belief in the randomness of beads sequences would lead to increased repeatability of responses, we tested whether increased repeatability was associated with increased belief. A Spearman's rho correlation indicated higher belief was significantly associated with lower MSE in the target-sequence-only group, ρ = -.387, p < .001. No association was evident in the distractor-sequences group, ρ = -.004, p = .969, however the majority of participants in this group may have had sufficient belief in the randomness of sequences to respond authentically, and with high repeatability (68% expressed ambivalent to certain belief in the randomness of sequences).

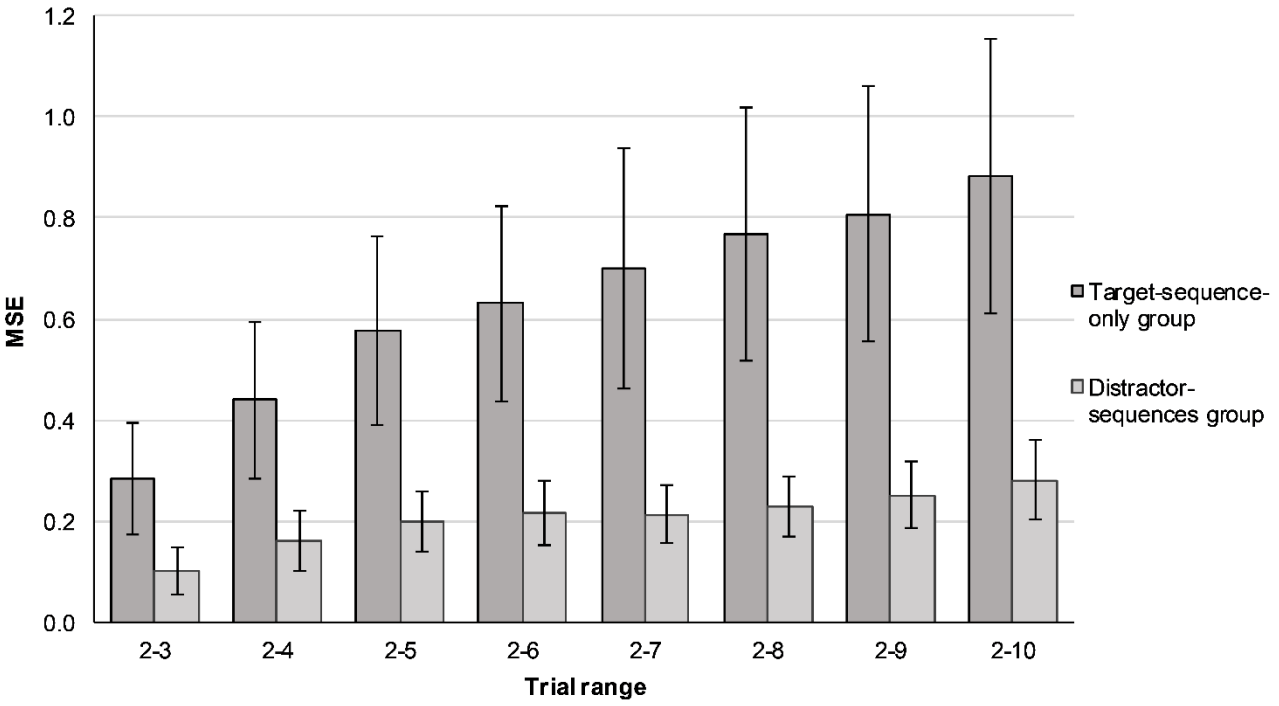

Figure 2. Mean MSE for each group over various ranges of trials, with 95% confidence intervals.

Reliability comparison

To compare groups on their reliability (the ability to discriminate between levels of a variable in the presence of noise) we computed the Intraclass Correlation Coefficient (the ratio of true to total variance) of DTD over various ranges of trials, beginning at trial 2 (Figure 3). The reliability of responses to the target sequence in the distractor-sequences task was, for all trial ranges, greater than that of the target-sequence-only task. For the distractor-sequences task, true between-subjects' differences explained 89% of the total variance in scores over trials 2 to 3, and over all ten trials explained 84% of the variance in scores on average. In contrast, for the target-sequence-only task, true between-subjects' differences explained only 74% of the variance in scores over trials 2 to 3[4], and over all ten trials just 62% of the variance in scores on average – poor reliability for a standardized task, repeated without delay under identical conditions.

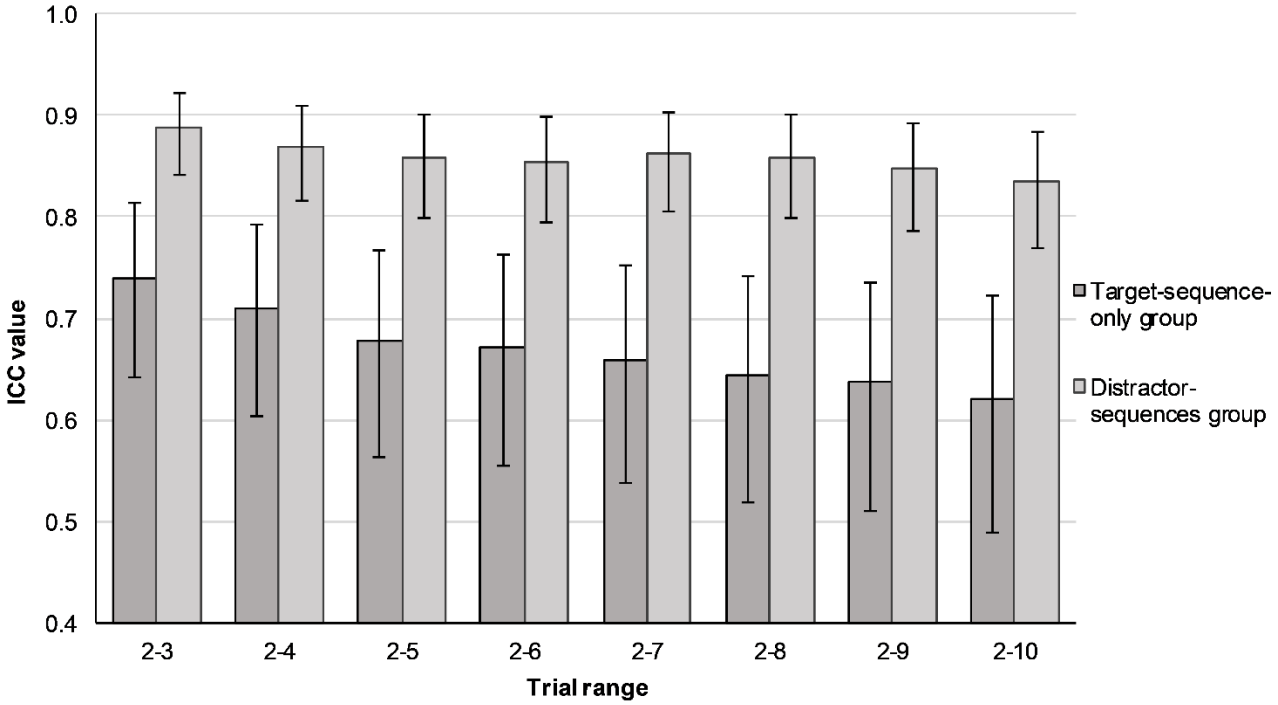

Figure 3. ICC(1,1) reliability of both beads tasks over increasing trial ranges, with 95% confidence intervals.

[4] 71% when no practice trial was used (as is common in the field).

Discussion

The beads task is commonly implemented as a single beads sequence, whether in single-trial or pre-/post-intervention designs, but may suffer from reliability and validity problems. We assessed the stability of DTD over multiple repetitions of a single beads sequence, tested the effect of distractor sequences on the repeatability and reliability of the beads task, and explored whether distractor sequences increased participants' belief in the authenticity of the task. We also assessed the impact of using a practice trial.

Repeatability

The original beads task, consisting as it does of only one non-random sequence of beads, is likely to be ill-suited to repeated measures. Participants exposed to this sequence over multiple trials, especially in quick succession, can hardly be expected *not* to realise the sequence is pre-determined. Our expectation was that this realisation would lead to changes in response to the task, and poor repeatability, over repeated measures – but that increasing believability by using distractor trials might be one way to increase repeatability. The MSE (representing within-subjects' changes over trials) of the target-sequence-only group increased monotonically with every repetition of the task (Figure 2), indicating poor repeatability, as we predicted. Meanwhile, as expected, using distractor sequences resulted in better repeatability, no matter how many trials participants completed (up to the nine trials tested).

Repeatability is a necessary quality for a repeated measure. Improving the repeatability of the beads task will make it more useful as a measure of data-gathering and JTC over the repeated measures necessary to conduct longitudinal, experimental, and treatment studies. Such studies are becoming increasingly important in the field of delusions research, where JTC has been linked with greater delusional severity in people with psychosis (Dudley et al., 2016; McLean et al., 2017; Ross et al., 2015). To date this association has been observed mainly in observational and correlational studies, but longitudinal, experimental, and treatment studies are of increasing interest for inferring causality (e.g. Moritz et al., 2013; Pos et al., 2017; Rocha & Queiros, 2013; Ross et al., 2011), and

the importance of having a repeatable beads task is correspondingly greater. Our data indicate that the distractor-sequences beads task is safely repeatable over at least nine trials with little deterioration. These trials were conducted in immediate succession, and represent a conservative test of repeatability; adequate repeatability over longer time-periods is all-the-more likely to be achievable.

Reliability

The reliability of a measure places limits on its ability to differentiate between levels of a construct in the presence of noise, and hence is critical to its usefulness. The distractor-sequences beads task was considerably more reliable than the target-sequence-only task (Figure 3). In particular, the reliability of the target-sequence-only task was low for such a standardised task, repeated without delay under identical conditions. Hence, the distractor-sequences beads task is significantly better able to reliably separate people on their tendency to gather data and on the JTC construct.

The greater reliability and repeatability of the distractor-sequences beads task supports its use in the repeated-measures longitudinal, experimental, and treatment studies so necessary to the delusions and cognitive bias field at present (Rausch et al., 2016). It will also maximise the precision benefits available by averaging multiple DTD measurements (Cumming, 2012, p. 377), and better allow for exploring subtle effects such as the uncertain relationship between DTD and delusion-proneness in healthy samples (see for example the small effect size and variety of study results in the meta-analysis by Ross et al., 2015). Future research should establish the reliability and repeatability of the distractor-sequences beads task over greater time intervals however, as while some experimental designs may call for rapid repetitions, many experimental designs, including treatment studies, are conducted over extended time intervals (i.e., weeks or months).

While the high repeatability and reliability of the distractor-sequences task are encouraging, because the use of distractor sequences quadruples the number of sequences participants face compared to the standard beads task, the consequences of fatigue or disengagement with the task must also be considered. Fatigue may have the capacity to change what the task is measuring, away

from the intended variable of the tendency to gather information – although that the distractor-sequences group did not significantly change DTD or have large MSE over 10 trials would tend to indicate against this. Nevertheless, the task has not been tested in clinical samples, and it is quite possible that participants with schizophrenia for example, with attendant cognitive deficits (Freeman et al., 2014; Ochoa et al., 2014), may find the extra trials more fatiguing. Thus, the distractor-sequences task would benefit from further validation in both clinical and non-clinical samples.

Task believability

Our purpose in introducing distractor trials to the beads task was to hide the non-random nature of the target sequence, thus increasing the believability of the task, and so increasing task repeatability and reliability. The results support our argument that distractor sequences would increase task believability - the distractor-sequences group demonstrated a stronger belief in the randomness of beads sequences than the target-sequence-only group with a near medium effect size.

Increased believability was associated with greater repeatability of responses in the target-sequences-only group, and we speculate that greater belief in the task was one factor which lead to greater repeatability and reliability. Belief in the task also impacts upon task validity. For the beads task to be valid as a measure of data gathering, participants must believe there is a genuine unknown (which jar beads are being drawn from), which they can solve by gathering genuine data (by requesting beads). When this is not the case, responses may be less valid. For example, perhaps participants choose more beads once they question the authenticity of the task to see if the sequence is random or not; others may choose less beads in the knowledge more beads will not provide additional information on jars. Such changes in response may be evident in the higher within-subjects' MSE of the target-sequence-only group. Hence uncertain belief may lead to inauthentic responses and low task validity, along with poor repeatability and decreased reliability.

It is possible that when the beads task is administered only once using a single sequence, participants might have high belief in the randomness of the single sequence to which they are

exposed. Nevertheless, meta-analyses (Dudley et al., 2016; Ross et al., 2015) have shown DTD tends to change with the number of beads-task trials, indicating that DTD results from a single trial may not be accurate, however believable the single trial. In contrast, the distractor-sequences beads task improves repeatability and reliability of the task over repeated measures, while maintaining a high level of task believability.

Our believability data have limitations however. Simply asking the question "Do you think beads were presented to you in random sequences?" may have implied to participants that bead sequences were not random, and hindsight bias (Guilbault, Bryant, Brockway, & Posavac, 2004) or desirability factors (Ganster, Hennessey, & Luthans, 1983; Podsakoff, MacKenzie, Lee, & Podsakoff, 2003) may have led some participants to underestimate or understate the degree to which they believed that sequences were random. Future studies might address this limitation by measuring belief in the randomness of sequences by methods less subject to hindsight bias and desirability effects, for example by indirect questioning (Fisher, 1993; Jo, Nelson, & Kiecker, 1997). Nevertheless, self-reported belief in the randomness of sequences was higher in the distractor-sequences group, counter to social desirability.

Practice trial

In their meta-analysis, Dudley et al. (2016) considered the use of practice or multiple trials a key factor in the validity of studies which measured JTC using the beads or equivalent tasks, and our results certainly support their assessment. We found that participants in both groups changed their responses significantly more over trials 1-to-2 than over trials 2-to-3, indicating that a practice trial can improve the repeatability of responses to the beads task.

While some beads-task studies have used a practice trial (e.g. Brankovic & Paunovic, 1999; Dudley et al., 2011), the large majority have not (Dudley et al., 2016). The lack of a practice trial and hence decreased repeatability may have weakened results in some cases. For example Balzan, Delfabbro, Galletly, et al. (2012) noted in their repeated-measures study without a true practice

trial[5] that practice effects may have contributed to observed changes, a concern which our study would support. Alternatively, it is possible that implementing a practice trial may attenuate between-group differences in JTC, and the impact of a practice trial on group JTC differences requires further research.

It is possible a practice trial could help correct aspects of miscomprehension regarding the beads task, such as the potential for participants to mistakenly think jars are swapping whenever bead colours swap mid-trial (Balzan, Delfabbro, & Galletly, 2012; Balzan, Delfabbro, Galletly, et al., 2012). However, our task instructions were extensive on all key aspects, and participants reported believing jars did not swap mid-trial. The benefit of a practice trial may instead be mostly in familiarising participants with the task, thereby reducing the impact of any factors which could differentially affect participant responses as their familiarity and comfort with the task changes. Future research should also test the effect of providing a practice trial on the graded-estimates version of the beads task, in which miscomprehension was first observed (Balzan, Delfabbro, & Galletly, 2012; Balzan, Delfabbro, Galletly, et al., 2012).

It must be noted that our practice trial was not identified as such to participants. Instead we excluded data from the first trial in a series, an approach that was used by Brankovic and Paunovic (1999) to ensure comprehension and to demonstrate the randomness of the beads sequence to participants. Hence the practice-trial results strictly apply only to situations in which a "silent" practice trial of an identical nature to other trials is provided but not identified as such to participants. Arguably, participants may perceive and treat explicitly-declared practice trials differently from silent practice trials they presume are being scored, and future studies should test whether a silent practice trial or an explicitly declared practice trial provides the better reliability. The effect of providing feedback following a practice trial could also be investigated.

[5] Participants were shown a demonstration trial

General conclusions

To our knowledge, no beads-task studies have attempted to mask the obvious, non-random nature of the target sequence other than by simple colour or ratio changes. By surrounding the target sequence with three distractor sequences, we have developed a beads task that is demonstrably more believable, repeatable, and reliable. We propose that with further validation, the distractor-sequences beads task, accompanied by a "silent" practice trial, be used in place of the traditional beads task – both whenever a single measure of the data gathering construct is needed, and especially when repeated or aggregate measures are required.

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CHAPTER 4: Study 3 – Jumping to conclusions in the less delusion-prone?

Jumping to conclusions in the less-delusion-prone? Preliminary evidence from a more reliable beads task

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Abstract

Background. Several meta-analyses have shown that people with psychosis tend to gather less information (i.e., they make fewer draws to decision, or DTD) on the beads task than healthy controls. A single small meta-analysis found a similar but smaller negative association between delusion-proneness and DTD in healthy samples, but this is less certain. We used the new and more reliable "distractor sequences" beads task to clarify the nature of the relationship between delusion-proneness and DTD in a healthy sample.

Methods. Healthy participants ($N = 203$) completed the distractor sequences beads task and the Peters Delusions Inventory (PDI), which measures delusion-proneness.

Results. PDI and DTD were positively correlated, and those who jumped to conclusions (DTD ≤ 2) had lower PDI than those who did not. Comparing PDI quartiles on DTD provided some evidence the positive association did not extend to the highest PDI quartile.

Conclusions. We found that DTD and delusion-proneness were positively related in our non-clinical sample, which was unexpected. In light of the well-established negative PDI-DTD relationship in clinical samples, our finding may reflect a PDI-DTD relationship that differs between healthy and delusional groups (with the presence of clinical delusions acting as a moderator), or one which reverses sign at some level of PDI (with PDI level or a related variable acting as a moderator). In either case, the mechanism by which PDI is positively correlated with DTD is unclear, and requires further investigation.

Key words: beads task; jumping to conclusions; JTC; delusions; delusion-proneness; psychosis.

It is well-established that people with psychosis tend to gather less information and are more likely to jump to conclusions (JTC) on the beads task than healthy controls (Dudley, Taylor, Wickham, & Hutton, 2016; So, Siu, Wong, Chan, & Garety, 2016). McLean, Mattiske, and Balzan (2017) showed that the association was between JTC and having delusions specifically, rather than with having schizophrenia or a mental illness more generally. In contrast, the relationship of delusion-proneness to JTC in healthy samples is less certain. In the only meta-analysis of healthy samples, Ross, McKay, Coltheart, and Langdon (2015) reported that high delusion-proneness (as indicated by higher scores on the Peter's Delusions Inventory, or PDI, Peters, Joseph, Day, & Garety, 2004) was associated with decreased data-gathering, or making fewer draws-to-decision on the beads task (DTD), similar to the association in clinically delusional samples. However, the effect was small[6], and the results from individual studies varied considerably. In five of the 23 included studies, the non-significant effect was in the opposite direction to the relationship observed in clinical samples, i.e., in the direction of *lower* delusion-proneness being associated with JTC. The lack of clear results in healthy samples may be in part due to between-study differences in the beads task itself (such as task instructions, inclusion of a practice trial, or number of trials), and differences in sample PDI.

A further factor contributing significant heterogeneity to beads-task results may be weaknesses of the beads task itself. McLean, Mattiske, and Balzan (2018) found that even within a single repeated-measures study, the standard beads task was unreliable (i.e., had poor ability to discriminate between levels of DTD in the presence of noise, Portney & Watkins, 2015), and demonstrated poor trial-to-trial stability in DTD. Such limitations are likely to contribute to inter-study differences in results between single-trial studies also. This issue may be compounded in healthy samples, as the relationship appears to be weaker in non-clinical compared to clinical

[6] It should be noted their clinical meta-analysis also found a small though non-significant association between DTD and PDI – however only eight studies were included (compared to 23 general-population studies) and the finding was much less precise.

samples (compare the larger effect size reported for clinical samples reported by McLean et al. (2017) and Dudley et al. (2016) with the null effect reported in the largest general-population study to date (Ross et al., 2016)[7]), and the relationship in non-clinical samples may not be sufficiently strong to consistently give results clearly discernible above noise.

Hence beads task limitations, along with task and sample differences may have contributed heterogeneity to measurements of the relationship between delusion-proneness and JTC in non-clinical samples. McLean et al. (2018) developed an alternative version of the beads task which may potentially address the limitations of the task itself. The key practical difference in their task was the use of three distractor sequences alongside the 'target' sequence (the sequence used to measure DTD). They identified that, without distractor sequences and over repeated measures, there was a high likelihood of participants realising the sequence was fixed rather than random, perhaps due to participants recognising characteristics of the target beads sequence, and potentially resulting in them changing their responses as a consequence. Hence the purpose of providing distractor sequences was to reduce the likelihood that participants would recognise the target sequence was pre-determined, thus keeping participants' responses authentic. The distractor-sequences beads task, along with a practice trial, was significantly more repeatable and reliable than the original task, and increased the extent to which participants believed in the randomness of beads sequences. Since the distractor-sequences task can be repeated reliably, a more precise measure can also be calculated by aggregating multiple trials even in single-measure studies (Cumming, 2012). If heterogeneous responses to the original, less reliable beads task have obscured the nature of the PDI-DTD relationship in healthy samples, the distractor-sequences version may provide a clearer estimate of this relationship.

In this study, we measured the PDI-DTD relationship in a healthy general-population sample

[7] The between-groups effect-sizes reported for clinical studies would ideally be compared with between-groups non-clinical effect sizes. Unfortunately this is not possible, as Ross et al. (2016) report a correlational effect-size only.

using the more reliable distractor-sequences beads task, to better define the relationship of DTD to PDI in healthy people. As delusions and delusion-like ideas probably occur on a continuum (Freeman, 2006; Van Os, Hanssen, Bijl, & Ravelli, 2000), we predicted that the well-established negative relationship between PDI and DTD in clinical samples would be mirrored by a similarly negative, but possibly weaker relationship in our healthy sample. Hence we expected to find a small negative relationship similar to that reported in the Ross et al. (2015) meta-analysis.

Methods

Participants

In total, 214 participants on the Prolific online crowdsourcing platform completed our experiment. Data from 112 participants were previously reported in McLean et al. (2018) (the "distractor-sequences group"), and data from an additional 102 participants, with N determined by funding and time constraints, were collected under identical conditions for the purpose of this study. Participants were paid £2.20 for participation. Analyses were not commenced until the study was closed to participants.

Measures

The reliable distractor-sequences beads task method was used to measure participants' tendency to gather information before making a decision. Similar to Huq, Garety, and Hemsley (1988), for each sequence (whether target or distractor) of the beads task, participants were shown images of two jars filled with two colours of beads. The beads were present in each jar in equal and opposite ratios – for example for our first sequence, jar A contained black and yellow beads in the ratio 85:15 (a majority of black beads), while jar B contained the same colour beads but in the ratio 15:85 respectively (a majority of yellow beads). One jar was randomly selected, and beads were drawn one-by-one from the selected jar in a purportedly random, but in fact pre-determined, sequence. After each bead was drawn, participants were invited to either request another bead, or decide which jar beads were being drawn from based on the evidence they had seen so far. Once

participants had decided on a jar, the total number of draws-to-decision (DTD) was recorded as an expression of the tendency to gather information before making a decision, and the sequence was stopped. A maximum of 10 draws were provided, and a DTD of 11 was recorded if participants had not decided after the 10th bead.

Each trial of the distractor-sequences beads task was composed of four such beads-task sequences - a target sequence (AAABAAAABA), and three pseudo-random distractor sequences (one presented before and two after the target sequence). Following McLean et al. (2018) an aggregate measure of DTD was calculated, being the mean of responses to the target sequences from the first four trials following exclusion of a practice trial. Additionally, categorical jumping to conclusions (JTC) was defined as DTD $\leq$ 2.00 (i.e., the decimal average equivalent of deciding on the first or second bead, as categorical JTC is often defined when single trials are used).

Delusion-proneness was measured on the 21-item Peters et al. Delusions Inventory (PDI, Peters et al., 2004). The PDI measures the presence or absence of delusion-like beliefs, and the distress, preoccupation, and conviction which accompanies each belief. While subscale scores are used in some instances, this study uses the PDI total score, as it represents a global measure of delusional ideation appropriate to comparing individuals on their degree of proneness to delusions (Peters, Joseph, Day, & Garety, 2004).

Procedure

The procedure used for this study was the same as that used for the "distractor sequences" group in McLean et al. (2018). The experiment was delivered online, and after informed consent was established and basic demographic data were collected, participants were provided with detailed beads-task instructions. Participants then completed a two-item comprehension check (see Experiment 10, Crump, McDonnell, & Gureckis, 2013) to test their understanding that jars contained a fixed ratio of mixed-colour beads, and that jars would not swap mid-sequence. Participants repeated the comprehension check until both questions were answered correctly. They

then completed ten beads-task trials, each of which consisted of an initial distractor sequence, the target sequence, and two additional distractor sequences. The identity of the "correct" jar for each sequence was pseudo-randomised. Bead colours were changed between trials.

Following the beads task, participants completed the PDI. Participants also completed a scale measuring their belief in the non-swapping of beads-task jars mid-trial and in the randomness of sequences (not reported in this study). Finally, an Instructional Manipulation Check (IMC, Oppenheimer, Meyvis, & Davidenko, 2009) was provided to test whether participants were, at this stage of the experiment, reading instructions in their entirety.

Analyses

Due to the non-normal distribution of PDI and DTD, all analyses were conducted using non-parametric tests. An initial assessment of the PDI-DTD relationship was made using a Spearman's rho correlation. We assessed the effect of categorical JTC on PDI by a between-groups comparison of those who did and those who did not JTC, using a Mann-Whitney U test. It is common in the literature to compare low- and high-delusion-prone sub-groups on DTD (Colbert & Peters, 2002; Van der Leer, Hartig, Goldmanis, & McKay, 2015). To facilitate this, and in order to assess whether the PDI-DTD relationship was consistent over the PDI range of our sample, we divided participants into PDI quartiles. Division into quartiles structured the predictor variable into ordinal, independent groups, and we used the Jonckheere–Terpstra test (Jonckheere, 1954) (see Hollander, Wolfe, & Chicken, 2013 pp. 215-224 for a recent explanation) to test for a significant trend across these groups. PDI quartiles were also compared on DTD using Mann-Whitney U tests in a series of post-hoc analyses. Non-parametric effect sizes were expressed as rank-biserial correlations calculated according to the formula of Glass (Glass, 1965). All analyses were performed on SPSS software version 23.

Results

Data validation

214 participants recruited via the Prolific online marketplace completed the experiment. Five participants were excluded for failing the comprehension check more than five times. The five-highest PDI values (PDI ≥ 196) and single-highest DTD value (DTD = 9.60) were more than three inter-quartile ranges (IQR) from the upper quartile. As scoring 196 or more on the PDI could reflect clinical levels of delusions outside the intended sample characteristics, and requesting 9.60 beads per trial could represent serious miscomprehension of the beads task,, these data were excluded as outliers. No additional bivariate outliers were detected by the 'robust non-linear regression' method (ROUT, Motulsky & Brown, 2006), and final $N = 203$. Data were significantly non-normal, and non-parametric analyses were used for all analyses.

Analysis of the DTD-PDI relationship

Correlation. A Spearman's rho correlation indicated that distractor-task DTD was positively related to PDI, $\rho = .161$, $p = .021$. This relationship was in the opposite direction to our hypothesis that DTD would be negatively related to PDI, as has been observed in clinical samples.

JTC comparison. We compared the PDI of participants who jumped to conclusions (DTD ≤ 2.00, $n = 71$) with those who did not ($n = 132$). A Mann-Whitney U test revealed those who jumped to conclusions had lower-ranked PDI ($Mdn = 26.0$, IQR = [11.0, 56.0]) than those who did not jump to conclusions ($Mdn = 42.0$, IQR = [20.0, 69.8]), $U = 3680.5$, $Z = -2.52$, $p = .012$, $r = .215$. This was again in the opposite direction to that predicted by clinical studies.

Effect of delusion-proneness. A Jonckheere–Terpstra test found a statistically significant trend of increasing DTD with PDI quartile (see Table 1), $T_{JT} = 8691.0$, $Z = 2.07$, Kendall's tau = .113, $p = .038$. Post-hoc Mann-Whitney U tests revealed that those in the 1st PDI quartile had lower DTD than those in the 3rd PDI quartile, $U = 867.0$, $Z = -2.79$, $p = .005$, $r = -.320$ (with eight comparisons implying a Bonferroni critical value of $p < 0.0063$; Miller, 1981). No other PDI

quartile pair differed on DTD (including the lowest- and highest-PDI quartiles – $U = 1019.0$, $Z = -1.60$, $p = .110$, $r = -.184$, though the non-significance of this result may be in part due to the higher variance in DTD of the 4th quartile). Quartiles three and four had the same median DTD, possibly indicating the positive PDI-DTD relationship did not extend to these higher levels of PDI.

Table 1

PDI quartile descriptive statistics

PDI quartile	*n*	PDI range	DTD *Mdn* [IQR]	DTD *M* [95% CI]
1	49	0-16	2.20 [1.50, 3.00]**	2.57 [2.14, 3.01]
2	51	17-37	2.60 [1.60, 4.00]	2.85 [2.41, 3.29]
3	52	38-62	3.00 [2.25, 3.95]**	3.24 [2.84, 3.64]
4	51	63-189	3.00 [2.00, 4.20]	3.01 [2.55, 3.47]

**significant difference at the $p < .01$ level

Discussion

Distractor-task DTD and PDI were positively correlated in our sample, i.e., greater PDI was associated with more DTD. This was unexpected, as it is in the reverse direction to the relationship most commonly observed in clinical samples (Dudley et al., 2016; McLean et al., 2017; So et al., 2016), and to that reported in a meta-analysis of non-clinical samples (Ross et al., 2015). Similarly, there was a significant trend of increasing DTD with PDI quartile, though post-hoc analyses revealed significant between-groups differences only for the 1st and 3rd quartile, possibly suggesting non-linearity in the relationship: quartiles three and four had the same median DTD, and perhaps the PDI-DTD relationship flattens at this level of PDI. Additionally, we found that participants who jumped to conclusions (i.e., DTD ≤ 2) were lower on delusion-proneness than those who did not JTC. Our data are consistent with an overall positive PDI-DTD relationship, which may be more strongly expressed over the first three PDI quartiles (i.e., PDI ≤ 62).

Our finding of a positive PDI-DTD relationship differs to the conclusion of the only meta-analysis assessing this relationship in healthy samples (Ross et al., 2015). While it remains possible our data do not accurately represent the PDI-DTD relationship, counting against this possibility our study included a considerable sample. Additionally, the effect size reported in the meta-analysis by Ross et al. (2015) was small (Hedges' g = -0.10) and encompassed a wide variety of results, including some in a positive direction, lending uncertainty to their findings. In contrast, we found somewhat larger effect sizes for the positive relationship.

That PDI is positively related to distractor-task DTD in healthy samples as our data indicate, but is negatively related to DTD in clinical samples (a robust finding in the literature, though this relationship needs replication using the distractor-sequences beads task), implies there is a change in the PDI-DTD relationship at some level of PDI. Speculatively, it is possible the PDI-DTD relationship is positive over lower ranges of PDI, but becomes negative at higher PDI. As above, our analysis of DTD over PDI quartiles supports this possibility as the results indicate a potential degree of nonlinearity. This being the case, clinical samples, which are higher on average on PDI (Peters et al., 2004), may largely reflect this negative relationship. A change in the relationship between PDI and DTD at different levels of PDI may also partially explain the variety of results reported by studies of healthy samples, and the overall weak association reported by Ross et al. (2015) – different samples of the general population with differing PDI ranges may generate somewhat different PDI-DTD relationships.

It is also possible that non-linearity in the PDI-DTD relationship, if present, may be due to moderation of this relationship by the presence or absence of psychosis (i.e., greater PDI is associated with reduced data-gathering, but *only in samples with clinical delusions* – otherwise greater PDI is associated with increased data-gathering). If so, it is possible to speculate on a mechanism by which illness status could act as a moderator. Morrison et al. (2005) found that among healthy participants, delusion-proneness was positively associated with paranoia. Perhaps paranoia is subsequently associated with a greater inclination to gather data on the beads task in

order to allay suspicions about the identity of the chosen jar. In contrast, this same association may not occur in clinical samples due to liberal acceptance. According to the liberal acceptance account of JTC (Moritz et al., 2017; Moritz & Woodward, 2004), people with delusions are willing to make a decision or form a conclusion at lower levels of confidence, and on the basis of less evidence, than healthy people, and hence require fewer beads before making a decision in the beads task, leading to JTC. Hence among healthy samples, delusion-proneness might be associated with more DTD due to (non-clinical) paranoia, while in clinical samples, delusion severity may be associated with the liberal acceptance of possibilities and fewer DTD.

Rather than the strict presence or absence of a psychotic illness, it is also plausible that it is levels of delusion proneness, or another variable associated with PDI, which moderates the PDI-DTD relationship (i.e., greater PDI is associated with reduced data-gathering, but *only in samples with sufficiently high PDI* – otherwise greater PDI is associated with increased data-gathering). Again, it is possible to speculate on mechanisms by which this moderation could occur. Jumping to conclusions on the beads task, i.e., deciding on one or two beads, is mathematically justifiable – at least when the task is unincentivized and wrong guesses attract no cost – as by the second bead in the 85:15 task participants have seen evidence for a jar with a Bayesian normative estimate of 97% (Fear & Healy, 1997). Hence participants who are more risk literate (i.e., have a better understanding of concepts as such as ratio, probability, and risk - Reyna, Nelson, Han, & Dieckmann, 2009) may draw fewer beads than others. Concurrently, risk-literate individuals may be less prone to the formation of delusion-like beliefs, as by definition delusions include content which is unlikely to be true (though the probability may not be calculable). Hence at low PDI, the negative relationships between risk literacy and both PDI and DTD may result in a positive PDI-DTD relationship, while at higher PDI, risk literacy may no longer have this effect (and the expected negative relationship between PDI and DTD may dominate).

Such moderations and mechanisms are at present purely speculative however, because the distractor-sequences beads task is new, and the PDI-DTD relationship in clinical samples has not

yet been replicated using the distractor-sequences beads task. Replication of the expected negative relationship in a clinical sample would support the possibility that the distractor-sequences task measures the same construct as the standard beads task, that the PDI-DTD relationship is indeed positive in healthy samples, and that the sign of the PDI-DTD relationship genuinely does change at some level of PDI or between healthy and clinically-delusional samples. As it is, it remains possible that *task differences* have led to a positive PDI-DTD relationship in healthy samples, and that when the distractor-sequences beads task is used with clinical samples a positive PDI-DTD relationship will also result.

Summary

Our data indicate that, on the distractor-sequences beads task and over the PDI range of our non-clinical sample, PDI and DTD are positively correlated. This is in contrast to the negative relationship typically observed in clinical samples (Dudley et al., 2016; McLean et al., 2017; So et al., 2016), and in a meta-analysis of non-clinical samples (Ross et al., 2015). Our finding may reflect a PDI-DTD relationship that differs between healthy and delusional groups (with the presence of clinical delusions acting as a moderator), or one which reverses sign at some level of PDI (with PDI level or a related variable acting as a moderator). In either case, the mechanism by which PDI is positively correlated with distractor-task DTD at low levels of PDI is unclear, and requires further investigation.

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CHAPTER 5: Study 4 – More jumping to conclusions in the less-delusion-prone

Jumping to conclusions in the less-delusion-prone: Further evidence from a more reliable beads task

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Abstract

Background.

A single meta-analysis has found that healthy people with higher delusion-proneness tend to gather less information (i.e., make fewer draws to decision, or DTD) on the beads task, although the findings of contributing studies were mixed, and the pooled effect size was small. However, using a new and more reliable "distractor sequences" beads task, we recently found a positive relationship between delusion-proneness and DTD in a healthy sample. In the current study, we re-tested this relationship in a new sample, and tested the possibility that the relationship is driven by participants' ability to understand and use odds or likelihood information ("odds literacy").

Methods. Healthy participants ($N = 167$) completed the distractor sequences beads task, the Peters Delusions Inventory (PDI) which measures delusion-proneness, a measure of odds literacy, and the Depression, Anxiety, and Stress scale.

Results. PDI and DTD were positively correlated, and comparing PDI quartiles on DTD confirmed a statistically significant trend of increasing DTD with PDI quartile. Odds literacy was positively rather than negatively associated with both DTD and PDI. Anxiety was positively correlated with PDI and DTD.

Conclusions. We replicated our earlier finding that DTD and delusion-proneness were positively related in a non-clinical sample, but found that increased odds-literacy did not drive lower PDI and DTD, and hence did not explain their covariance. It is possible however that anxiety and co-occurring risk aversion drive increased delusion-proneness and information-gathering, potentially accounting for the positive relationship between PDI and DTD.

Key words: beads task; jumping to conclusions; JTC; delusions; delusion-proneness; psychosis.

A number of cognitive biases appear related to, and possibly contribute to, delusions in people with psychosis. Of these, evidence is strongest for the jumping to conclusions (JTC) bias, in which people with active delusions seek less information before making a decision than people without active delusions (Dudley, Taylor, Wickham, & Hutton, 2016; McLean, Mattiske, & Balzan, 2017a; So, Siu, Wong, Chan, & Garety, 2016).

The JTC bias is measured by the beads task (Huq, Garety, & Hemsley, 1988). In this task participants are presented with two jars, each containing beads of two colours, present in equal but opposite ratios (e.g., 85:15). Participants are informed that one jar has been chosen at random, and beads are drawn one at a time from the chosen jar in a supposedly random, but in fact pre-determined sequence. As each new bead is drawn, participants may decide which jar beads were being drawn from, or request to see another bead. The number of beads drawn before a decision is made, or "draws to decision" (DTD), operationalises participants' tendency to gather information before making a decision. In addition, JTC is usually defined as a DTD of only one or two beads.

Delusions and delusion-like ideas are theorised to occur on a continuum (Freeman, 2006; Van Os, Hanssen, Bijl, & Ravelli, 2000), and in both clinical and non-clinical populations. Hence it is reasonable to assume that, given JTC is associated with delusions in clinical populations, it should also be associated with delusion-proneness in non-clinical populations. A meta-analysis supported this expectation of increased JTC with higher delusion-proneness, though the pooled effect size was small, and the contributing effect sizes varied considerably (Ross, McKay, Coltheart, & Langdon, 2015).

However, in our recent study using a large non-clinical sample ($N = 203$) and a more reliable version of the beads task (McLean, Mattiske, & Balzan, 2018), JTC was associated with *lower* delusion-proneness (McLean, Mattiske, & Balzan, 2017b). In that beads task, the single pseudo-random "target" sequence used for measuring DTD was surrounded by three "distractor" sequences, in order that participants might not recognise the repetitious nature of the target sequence when the beads task was administered repeatedly for repeated-measures studies, or for calculating an

aggregate measure. We found that delusion-proneness (quantified using the 21-item Peters et al. Delusions Inventory, or PDI; Peters, Joseph, Day, & Garety, 2004) was positively correlated with DTD, r_S = .16. We also found that those who jumped to conclusions were lower on delusion-proneness than those who did not JTC. The direction of this result was unexpected, as it contradicts the findings of the Ross et al. (2015) meta-analysis, as well as the prediction of a negative PDI-DTD relationship made by extrapolating the findings of clinical research. Hence the first aim of this study was to test the PDI-DTD relationship in a second non-clinical sample.

Our second aim was to test a potential mechanism for the positive relationship, if replicated, between PDI and DTD. One such mechanism, proposed by McLean et al. (2017b), was the ability to understand and apply odds or likelihood information to decision-making, an ability which we term odds literacy. Similar to health numeracy (Reyna & Brainerd, 2007; Reyna, Nelson, Han, & Dieckmann, 2009), we envisage odds literacy to cover numerical aspects such as fractions, percentages, frequencies, probabilities, and decimals, applied in odds or likelihood situations. Odds literacy may limit the ability of participants to make appropriate beads-task decisions in-so-far as the beads task is probabilistic in nature. Higher odds literacy may drive both fewer DTD, and reduced delusion-proneness, as follows.

Most studies report that non-clinical samples are conservative on the beads task. For example (and quite typically), Jacobsen, Freeman, and Salkovskis (2012) reported healthy-participant DTD of M = 3.88, SD = 1.86. Much higher DTD have also been reported (see for example Menon, Addington, & Remington, 2013, M = 7.88, SD = 2.8). Yet if the task is unincentivized and wrong guesses attract no cost, drawing fewer beads is justifiable in probabilistic terms – seeing the evidence of two same-colour beads drawn from jars with an 85:15 ratio allows for choosing a jar with 97% confidence (Fear & Healy, 1997), with confidence rising to 99% by the third bead. It seems possible that more odds-literate people, with a better understanding of the degree of certainty that two or three same-colour beads provides, would choose fewer beads than the average, while less odds-literate people may choose more. (Note that once a participant has

asked for 4 beads they are quite likely to choose more, as the 4th bead in the usual target sequence is different-coloured.) In this sense, it could be argued it is participants who chose more beads, and who do not JTC, who are biased (Maher, 1992).

Hence, those with better odds-literacy may choose fewer beads. Concurrently, as delusional thinking involves the acceptance of ideas that are unlikely to be true, more odds-literate individuals may be less likely to entertain delusion-like ideas. If odds literacy drives fewer DTD and concurrently drives lower delusion-proneness, it may partially or fully explain the positive relationship observed between PDI and DTD.

In this study, we re-tested the relationship between delusion-proneness and data-gathering in a non-clinical sample, again using the reliable distractor-sequences beads task. We also tested the possibility that the positive relationship between DTD and delusion-proneness was driven by odds literacy.

Method

Participants

Participants were recruited via a university experiment participation portal. The experiment was open to participants seeking course credit and to participants completing experiments for remuneration, who were paid $15 AUD for participating. Study participation N was determined by funding and time constraints. Analyses were not commenced until the study was closed to participants.

Measures

Draws-to-decision. Our distractor-sequences beads task (McLean et al., 2018) was used to measure DTD. For each sequence, target or distractor, participants were shown images of two jars, with each jar containing coloured beads in complementary ratios (for example for the first sequence, jar A contained 85:15 black and yellow beads, while jar B contained 85:15 yellow and black beads; later trials used other colour pairs). For each sequence, one jar was randomly selected, and beads were drawn one-by-one from the selected jar in pseudo-random order. After each bead

was drawn, participants could either request another bead, or decide which jar beads were being drawn from, at which point the total number of draws taken to reach a decision (DTD) was recorded and the sequence was stopped. Participants could request a maximum of 10 beads and, if they had not decided after the 10^{th} bead, a DTD of 11 was recorded.

Each trial of the distractor-sequences beads task was composed of four beads-task sequences – a pseudo-random distractor sequence, the target sequence (AAABAAAABA) used to measure DTD, and a further two pseudo-random distractor sequences (distractor sequences were used to reduce the likelihood of participants recognising the non-random nature of the target sequence). Similar to McLean et al. (2018), data from the first trial were discarded as a "silent" (or unannounced) practice trial, and an aggregate measure of DTD was calculated as the mean of responses to the next three trials. JTC was defined as DTD ≤ 2.00.

Delusion-proneness. Delusion-proneness was quantified using the 21-item Peters et al. Delusions Inventory (PDI, Peters et al., 2004), a self-report measure which totals the presence or absence of 21 delusion-like beliefs, and the distress, preoccupation, and conviction which accompanies each belief. While subscale scores are used in some instances, this study used the PDI total score, as it represents a global measure of delusional ideation appropriate to comparing individuals on their degree of proneness to delusions (Peters, Joseph, Day, & Garety, 2004).

Odds Literacy. Following Låg, Bauger, Lindberg, and Friborg (2014), we combined scales and items from three sources in an attempt to achieve discrimination between participants over a wide range of odds-literacy abilities. First, we included the relatively easy three-item general numeracy subscale and seven-item risk-literacy subscale of Lipkus, Samsa, and Rimer (2001). Second, as relatively high proportions of their sample were able to answer all questions correctly, we added the much-more-challenging four-item Cognitive Reflection Test (CRT-4) of Toplak, West, and Stanovich (2014) to provide discrimination at the most challenging end of the scale. The CRT-4 is primarily intended as a measure of the ability to override intuitive responding and engage in effortful processing of problems, i.e., to engage in the Type 2 rather than Type 1 processing of dual

process theory (Evans & Stanovich, 2013). However, the four items are also highly numerical in nature, and provide mathematical problems at the challenging end of the scale that have been tested in a university population. Thirdly, to provide discrimination at medium levels of difficulty, we selected eight likelihood-specific items from the collection of 15 'Heuristics and biases tasks' collated by Toplak, West, and Stanovich (2011). Specifically, we included the sample size hospital and squash problems, gambler's fallacy 1 and 2, the conjunction problem, covariation detection, probabilistic reasoning denominator neglect, and the probability matching problem. The odds literacy measure was thus composed of 22 items (see Appendix A), which were reordered so that participants initially faced a series of easier questions, and then an even distribution of easier and harder questions throughout the remainder of the questionnaire.

Depression, Anxiety, Stress Scale short (21-item) version. The Depression, Anxiety, Stress Scale (DASS; Lovibond & Lovibond, 1995) short-version is a well-validated 21-item self-report questionnaire which elicits participants' assessments of their feelings over the last week in the domains of depression, anxiety, and stress. We included the DASS and, in particular, the DASS Anxiety subscale as anxiety may affect DTD (Johnstone, Chen, & Balzan, 2017; Lincoln, Lange, Burau, Exner, & Moritz, 2009).

Procedure

The experiment was delivered online, with participants accessing the experiment site on their own device. Informed consent was first gained and basic demographic data were collected. Participants were then given detailed beads-task instructions and a two-item comprehension check to confirm their understanding that jars contained an 85:15 ratio of mixed-colour beads, and that jars would not swap mid-sequence. Participants could not proceed further with the experiment until both questions were answered correctly. They then completed four beads-task trials, each of which consisted of an initial distractor sequence, the target sequence, and two further distractor sequences. Following the beads task, participants completed the BADE task (not reported in this study), the

PDI, the odds literacy measure, the Wordsum measure of vocabulary (not reported in this study), the DASS, and an Instructional Manipulation Check (not reported in this study).

Results

Data validation and descriptive statistics

169 participants completed the experiment online. Two participants were excluded for failing the comprehension check more than five times, and final $N = 167$. Of these, 107 participants completed the experiment for course credit, and 60 for payment. Participants were 141 females and 26 males, aged between 17 and 50 ($M = 22.3$, $SD = 6.8$).

Odds literacy (see Table 1) was normally distributed, and appeared to provide good discrimination of participants' abilities over the possible range of the scale (0-22). DTD, PDI, DASS, and DASS Anxiety all exhibited non-normality that was corrected by a square-root transformation prior to performing parametric correlation analyses. Our sample was on the 72nd percentile for overall DASS and the 63rd percentile for DASS Anxiety (median values c/w Australian norms for 18-24 year-olds; Crawford, Cayley, Lovibond, Wilson, & Hartley, 2011).

Table 1

Descriptive statistics

	M	SD	*Mdn*	[IQR]
Odds Literacy	11.8	3.4	12.0	[9.0, 14.0]
DTD	3.5	1.9	3.0	[2.0, 5.0]
PDI	60.9	38.8	54.0	[35.0, 79.0]
DASS	17.3	12.2	16.0	[7.0, 26.0]
DASS Anxiety	4.4	4.0	3.0	[1.0, 7.0]

Replication of the positive PDI-DTD relationship

To facilitate comparison with the results of McLean et al. (2017b), we performed the same set of analyses of the PDI-DTD relationship. A Spearman's rho correlation indicated that distractor-sequence task DTD was positively related to PDI, $r_s = .24$, $p = .002$. A Mann-Whitney U test

comparing those who jumped to conclusions (DTD ≤ 2.00, n = 43, Mdn = 47.0, IQR = [21.0, 76.0]) with those who did not (n = 124, Mdn = 57.0, IQR = [39.3, 84.3]) just failed to reach significance, U = 2137.5, Z = -1.94, p = .053, r (rank-biserial correlation) = .198. We divided participants into quartiles by PDI score to test for the effect of different levels of PDI on DTD (see Table 2). A Jonckheere–Terpstra test found a statistically significant trend of increasing DTD with PDI quartile, T_{JT} = 6250.0, Z = 2.94, Kendall's tau = .176, p = .003. A post-hoc series of Mann-Whitney U tests revealed that those in the 1st PDI quartile had lower DTD than those in all other quartiles, i.e., lower than the 2nd PDI quartile, U = 619.0, Z = -2.37, p = .018, r = -.298, 3rd PDI quartile, U = 574.0, Z = -2.78, p = .005, r = -.349, and 4th PDI quartile, U = 557.0, Z = -2.78, p = .005, r = -.353.

Table 2

PDI quartile descriptive statistics

PDI quartile	n	PDI range	DTD Mdn [IQR]	DTD M [95% CI]
1	42	0-35	2.50 [1.58, 3.67]*	2.74 [2.29, 3.19]
2	42	36-54	3.33 [2.33, 4.50]	3.64 [3.05, 4.24]
3	42	55-79	3.00 [2.67, 5.00]	3.75 [3.20, 4.31]
4	41	80-189	3.67 [2.17, 5.17]	3.96 [3.32, 4.60]

*Quartile 1 was significantly different from quartiles 2, 3 and 4, as described in the text.

Association of odds literacy with DTD and PDI

Pearson's correlations showed that transformed DTD was positively related to odds literacy, r = .191, p = .013, as was transformed PDI, r = .187, p = .016. The positive relationships between odds literacy and both DTD and PDI were contrary to our hypothesis that increased odds literacy would be associated with reduced DTD and lower PDI.

Association of anxiety with DTD and PDI

As our hypothesis that odds literacy would lead to fewer DTD and lower delusion-proneness was not supported, we developed a post-hoc explanation for the positive association of DTD with PDI. It is possible that, within healthy samples, higher general anxiety may be associated with a preference for risk-avoidant strategies, driving a desire to choose the "correct" jar in beads-task studies, and leading to higher DTD (Johnstone et al., 2017; Schlier, Helbig-Lang, & Lincoln, 2016). Concurrently, anxiety may also be associated with higher levels of delusion-proneness (Johnstone et al., 2017; Lincoln et al., 2009; So, Freeman, & Garety, 2008), causing DTD and PDI to be positively related. As this explanation was not identified a-priori we did not measure risk avoidance. DASS anxiety however was positively correlated with both transformed DTD ($r = .156$, $p = .044$) and transformed PDI ($r = .349$, $p < .001$), providing some support for this explanation.

Discussion

Replication of the positive PDI-DTD relationship

Our current data replicated our prior finding of a positive correlation between PDI and distractor-task DTD, and our comparison of participants who jumped to conclusions with those who did not revealed a trend in PDI values in the same direction as our statistically-significant prior finding (McLean et al., 2017b). Our data therefore replicate our prior finding that DTD and PDI are positively related in non-clinical samples. This relationship is in the opposite direction to the relationship typically observed in clinical samples.

As we have previously noted (McLean et al., 2017b), the distractor-sequences beads task has not yet been used with a clinical sample. It is possible that, when tested in a clinical sample, the distractor-sequences beads task may indicate a positive PDI-DTD relationship in this group also. This would be contrary to the well-established negative PDI-DTD relationship found in clinical samples when the standard beads task is used (Dudley et al., 2016; McLean et al., 2017a; So et al., 2016), and might indicate that the distractor-sequences task measures a somewhat different construct to the standard task. Weighing against this possibility, however, the distractor-sequences

beads task was closely modelled on the standard task, and it is difficult to see how it might access an entirely different construct. Alternatively, upon testing in a clinical sample, the distractor-sequences beads task may replicate the expected negative PDI-DTD relationship. Were this to be the case, it would lend weight to the finding that the PDI-DTD relationship is indeed positive in healthy samples.

Testing the odds-literacy mechanism

In this study, we tested the hypothesis that increased ability to understand and apply likelihood and odds-related concepts drives both decreased DTD and PDI in healthy samples. We had theorized that, as choosing fewer beads than average on the beads task is in fact quite reasonable in Bayesian terms (Fear & Healy, 1997), more odds-literate participants would choose fewer beads (i.e., odds literacy and DTD would be negatively related). Contrary to our hypothesis however, DTD and odds literacy were positively related in our sample. It is possible that participants did not make numerical estimations or have accurate intuitions of the Bayesian probabilities involved in the beads task, and that their decisions of when to choose a jar were based on other factors.

Odds literacy was also positively correlated with PDI, contrary to our hypothesis. Perhaps a trait such as conscientiousness drove both higher odds literacy and PDI scores. As the odds literacy task is long and challenging, scores may have reflected participants' conscientiousness in sticking with the task, as well as the intended numerical ability. Conscientiousness could likewise have contributed to higher PDI scores, as the PDI is also a lengthy measure, and only requires detailed ratings of endorsed items. Hence it is faster to complete if participants under-report their delusion-like experiences, perhaps leading more conscientious participants to score higher on the PDI.

An alternative hypothesis

Our results indicate that higher odds literacy does not drive decreased DTD and decreased PDI, but an alternative explanation for the positive relationship between distractor-task PDI and DTD can be suggested. Speculatively, within healthy samples, higher general anxiety may be

associated with a preference for risk-avoidant strategies, driving a desire to choose the "correct" jar in beads-task studies, and leading to higher DTD in an effort to do so. Concurrently, anxiety may also be associated with higher levels of delusion-proneness, causing DTD and PDI to be positively related.

There is some evidence that anxiety is associated with higher levels of delusion-proneness. Dudley et al. (2011) found anxiety was related to the presence of active delusions in a clinical psychosis sample. Johnstone et al. (2017) found trait social anxiety was positively correlated with PDI in a healthy sample, and So et al. (2008) found that baseline DASS anxiety and Subjective Units of Distress Scale (SUDS) anxiety was significantly higher in their delusional than non-delusional sample. In our data also, DASS anxiety was positively correlated with transformed PDI, supporting this aspect of the argument.

It is likely that anxiety is also associated with increased risk avoidance (Maner et al., 2007; Maner & Schmidt, 2006; Raghunathan & Pham, 1999). This may lead to increased DTD on the beads task, if risk-avoidant participants choose a greater number of beads in order to ensure they make the "right" decision when choosing a jar, as evidence from social anxiety studies suggests they might (Johnstone et al., 2017; Schlier et al., 2016). We did not measure risk-aversion however as this hypothesis was not a-priori. It should also be noted that experimentally-induced anxiety may be associated with decreased DTD (Ellett, Freeman, & Garety, 2008; Lincoln et al., 2009), however we would argue that experimentally-induced anxiety may be experienced very differently to general anxiety, which has a less certain relationship with DTD (Dudley et al., 2011; Wittorf et al., 2012).

It should also be noted that while people with psychosis are generally more anxious (Dudley et al., 2011; So et al., 2008), anxiety may not increase information-gathering in samples with clinical delusions. According to the liberal acceptance account of JTC (Moritz et al., 2017; Moritz & Woodward, 2004), people with psychosis may be more likely to decide on a jar at a lower level of confidence, and on the basis of less information, than healthy people, resulting in JTC. Perhaps in clinical samples this mechanism overrides the tendency for anxiety to trigger risk-avoidance and

increased DTD, accounting for the common finding of increased JTC in clinically-delusional samples.

Hence, we speculate it is possible that anxiety may trigger greater information-gathering responses in healthy individuals due to risk-avoidance. With anxiety being concurrently associated with higher levels of delusion-proneness, perhaps anxiety and risk avoidance together drive the unexpected positive relationship between DTD and PDI which we have previously reported (McLean et al., 2017b), and have replicated herein.

Conclusion

Our replication of McLean et al. (2017b) lends confidence to the finding that, when the distractor-sequences beads task is used, PDI and DTD are positively related in healthy samples. This relationship is in the opposite direction to the relationship reported for clinical samples, in which delusions are associated with reduced DTD, that is, with JTC. The positive distractor-task PDI-DTD relationship in healthy people is not however a consequence of an increased understanding of odds and likelihoods driving reduced DTD and PDI. Perhaps, and speculatively, generalised anxiety and risk-aversion drive increased delusion-proneness and information-gathering respectively, as our preliminary data suggest. Testing the distractor-sequences task in clinical samples, in which the PDI-DTD relationship is comparatively robust, will provide clarity as to whether the task is measuring data-gathering as intended, and this remains a priority.

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CHAPTER 6: Discussion

A substantial body of research and theory links specific cognitive biases to the development of delusions and delusion-proneness. Despite relatively robust evidence however, a number of questions remain unresolved. Some of those questions were addressed in this thesis. Broadly, they were whether the biases covary with delusions, whether they relate to delusions only in schizophrenia-spectrum disorders, whether the most commonly used measure of JTC is reliable, and whether an alternative measure of JTC produces valid and more reliable results. What this thesis found regarding these questions is discussed as sections within this chapter.

Cognitive biases in clinical samples

Meta-analysis of biases and delusions

While it is well-established that the JTC bias, and with less certainty the BADE, BACE, and LA biases are associated with delusions in schizophrenia (e.g., Dudley, Taylor, Wickham, & Hutton, 2016; Eifler et al., 2014; Sanford, Veckenstedt, Moritz, Balzan, & Woodward, 2014a; Speechley, Moritz, Ngan, & Woodward, 2012), it was unclear whether these biases are associated with delusions over time and across diagnoses, consistent with the causal account. If cognitive biases contribute causally, bias strength should covary with delusion strength over time. However, given the scarcity of true longitudinal studies, Study 1's meta-analysis (McLean, Mattiske, & Balzan, 2017) approximated longitudinal information largely using cross-sectional data. It found that the JTC, BADE, BACE, and LA biases are elevated during acute delusional periods relative to periods of remission, and are lower (BADE, BACE, LA) or comparable to normal levels (JTC) when delusions are in remission. This is consistent with the possibility that these biases contribute causally to delusions during acute phases of illness. Additionally, higher levels (though not as high as delusional groups) of BADE and LA in non-delusional groups with schizophrenia relative to

healthy controls suggests people with schizophrenia may also have a trait vulnerability to biases. Clearly, a weakness of this approach was the use of cross-sectional studies where true longitudinal data were most appropriate, and leaves open the possibility that the biases are associated with stable differences in susceptibility to delusions. However, with the availability of a beads task that is reliable over repeated measures (Study 2), it is hoped that more longitudinal studies will be completed in the future.

Logically, if cognitive biases do contribute to delusion formation, their effect on delusions should not be confined to schizophrenia-spectrum disorders. Therefore, a second key prediction of Study 1 was that cognitive biases would be associated with delusions across diagnoses. Several previous meta-analyses had considered JTC in combined groups with mixed diagnoses including schizophrenia, but the mixing of diagnoses limited their ability to distinguish whether JTC is associated with delusions among all the included diagnoses, or in schizophrenia only (Dudley et al., 2016; Ross, McKay, Coltheart, & Langdon, 2015; So, Siu, Wong, Chan, & Garety, 2016). Hence, Study 1 considered groups with delusions due to schizophrenia and groups with delusions due to other illnesses separately. Study 1 found JTC was associated with delusions across diagnoses, against the possibility that JTC is associated only with schizophrenia due to some feature of schizophrenia itself (e.g., cognitive deficits; Andreou et al., 2015), and consistent with the possibility that JTC contributes to the development of delusions in general (no BADE, BACE or LA data were available). The Study 1 effect size of Hedges' g = -0.71[8] accords with the meta-analyses effect sizes found by Dudley et al. (2016) (g = -0.53) and So et al. (2016) (g = -0.61) for the difference between healthy samples and samples of people with delusions due to psychosis. However, it is much larger than the statistically non-significant correlation between DTD and PDI reported by Ross et al. (2015) for the current delusions group of r_s = -.12 (equivalent to Cohen's d ≈ 0.24,

[8] Sign swapped to match other meta-analyses

additionally Cohen's d and Hedges' g are approximately equivalent when sample sizes are > 20; Rosnow & Rosenthal, 1996). This discrepancy may be due to Study 1 measuring differences in DTD between highly disparate groups (e.g., schizophrenia with delusions versus healthy controls), whereas the Ross et al. (2015) meta-analysis deliberately tested the PDI-DTD correlation within a series of relatively homogeneous groups at different levels of delusionality, in order to investigate the continuum model. In addition, Ross et al. (2015) used the self-report PDI as a measure of delusion strength rather than the clinician-rated measures used in the Dudley et al. (2016) and So et al. (2016) meta-analyses. The use of self-report measures may have influenced effect sizes in clinical groups as psychosis is characteristically accompanied by poor insight into one's condition (Amador & David, 2004).

Finally, Study 1 showed that the JTC, BADE, BACE and LA biases were not elevated in non-delusional psychiatric illnesses (e.g., non-psychotic depression, generalised anxiety disorder, panic disorder), indicating that merely having a psychiatric illness does not account for cognitive bias in those experiencing delusions. Together, these findings strengthened the argument that JTC, BADE, BACE and LA play a role in delusion formation.

Cognitive deficits and delusions

Study 1 indicates that delusions are closely associated with biases, consistent with the possibility that biases contribute to delusions. However other possibilities for the association of biases and delusions must also be considered. Conceivably, biases and delusions may arise independently in psychosis, perhaps as a result of cognitive deficits, and biases are not antecedent to delusions. Supporting the possibility that biases are associated with deficits, in a mixed sample of participants with schizophrenia and healthy controls, Eifler et al. (2014) found BADE was negatively associated with executive function and processing speed, although they also found BADE was positively associated with some other aspects of cognitive functioning.

Evidence for the association of JTC with cognitive deficits is more extensive. González et al. (2017) found people with psychosis who jumped to conclusions had neuropsychological deficits in the attention, psychomotor speed, working memory, and executive functioning domains, while neither delusions nor positive symptoms overall were associated with JTC. Falcone et al. (2014) found that JTC was associated with lower IQ and poorer working memory in both a first-episode psychosis and a control sample. Garety et al. (2013) found, in a schizophrenia sample with current delusions, that JTC was associated with poorer working memory (although not associated with premorbid IQ), and only weakly associated with delusion strength. Similarly, Freeman et al. (2014) found that JTC was associated with poorer working memory (along with IQ), but not with delusion strength. Freeman et al. (2014) suggested that the tendency for those with low working memory to JTC might therefore be due to the significant memory load associated with gathering and weighing data on the beads task, whereas making a (premature) decision would alleviate the memory load. Plausibly, low working memory capacity may contribute to delusions also, if individuals accept delusional ideas before adequate evidence has been gathered and considered in order to their reduce working-memory load. By this means, biases and delusions could be correlated but not sequentially related.

It is plausible that working memory and other cognitive deficits could contribute to cognitive bias in schizophrenia, for which cognitive deficits can be significant (Freeman et al., 2014; Ochoa et al., 2014), and hence to the co-occurrence of biases and delusions. However, Study 1 indicated that biases are associated with delusions across multiple diagnoses, including such non-schizophrenia diagnoses as delusional disorder, of which cognitive deficits are not a feature. Hence, if cognitive deficits contribute towards biases and/or delusions, which they may, Study 1 indicates that such deficits do not explain biases in full, nor account in full for the association between biases and delusions. Nevertheless, it is

quite plausible that unaccounted-for variations in working memory and other cognitive deficits may have contributed to the heterogeneity of results observed in the literature.

Alternative measures of JTC

The association of JTC with working memory and other cognitive deficits underlines the need for a measure of JTC that is less sensitive to working memory limitations. By controlling for working memory, it may be possible to determine whether JTC exists independently of working-memory deficits, and to achieve a less variable picture of the strength of the relationship between JTC and delusions. Minimising working memory as a confound was a motive behind the many implementations of the beads task which have kept previously-drawn beads displayed. However, perhaps more could be done. For example, the box task (Balzan, Ephraums, Delfabbro, & Andreou, 2017; Moritz, Göritz, et al., 2017), in which participants merely have to identify the majority colour, is conceptually simpler than the beads task, which relies upon a backstory of two jars of mixed beads, and may not be as dependent on working memory. Other possibilities for measuring JTC while reducing working-memory load include decision-making scenarios that do not rely on what information has been revealed so far. For example, in one study, letters and numbers were gradually revealed, and a decision made when these could be identified – presumably there is little working-memory load involved with, at each stage, deciding whether a letter or number can be identified (Ziegler, Rief, Werner, Mehl, & Lincoln, 2008).

Metacognitive training and causality

Further research into the beads task and working memory may be able to clarify to what extent, if any, working memory contributes to JTC. However, it has less power to demonstrate whether JTC plays a causal role in delusions. That question can be better informed by the outcome of interventions designed to reduce cognitive biases, such as Metacognitive Training (MCT; Moritz & Woodward, 2007). MCT takes a non-

confrontational[9] cognitive approach to training clients towards non-biased thinking. With respect to JTC, clients practice developing multiple explanations for events and seeking more evidence before drawing a conclusion. A recent narrative review indicated that MCT had an on-average positive effect on biases (though results are few and somewhat mixed; Moritz et al., 2014), and a meta-analysis of treatment studies indicated that MCT had a small to moderate beneficial effect in reducing delusions (Eichner & Berna, 2016), supporting the proposition that reducing the cognitive biases associated with delusions can reduce delusion severity. However, like individual studies, meta-analyses also yield mixed results. For example, van Oosterhout et al.'s (2016) meta-analysis found no significant benefit of MCT for delusions. Overall, inconsistent findings might reflect methodological differences such as sample selection criteria, study design, and therapy delivery, but they also point to the potential value of therapy refinements, and the identification of moderators affecting therapeutic outcomes (e.g., see Moritz et al., 2018).

Along with longitudinal observational studies (including assessing whether biases precede the development of delusions), further MCT and cognitive treatment studies may be the clearest ethical means of directly assessing the causal role of biases in delusions. Future studies may demonstrate whether changes in bias mediate the effect of MCT on delusions, and whether MCT primarily affects the positive rather than the negative symptoms of schizophrenia (for some preliminary evidence see Moritz et al., 2013; Moritz et al., 2014). Both these findings would support the possibility that biases contribute to delusions. The importance of treatment studies in demonstrating causality additionally underlines the need for reliably repeatable measures of information-gathering and JTC, such as the distractor-sequences beads task.

[9] Does not directly address an individual's unique delusional ideas

Towards a unified account of biases in delusions

While inadequate evidence-gathering may lead to delusion-formation, additional mechanisms are likely to contribute, both to delusion formation and maintenance. For example, the positive effects of MCT cannot be attributed solely to changes in JTC, as MCT also targets BADE (Moritz & Woodward, 2007). Two principal component analyses of the BADE task (Sanford, Veckenstedt, Moritz, Balzan, & Woodward, 2014b; Speechley et al., 2012) have identified a single "evidence integration" construct, which incorporates the failure to accept interpretations when provided with evidence, the failure to reject interpretations when provided with counter-evidence, and failure to reject absurd interpretations. These aspects of evidence integration closely reflect BADE, BACE, and LA respectively. It was evident in Study 1 that the pattern of relationships between delusions and the BADE, BACE and LA biases were very similar, perhaps as each of these biases involves failures in weighing and integrating evidence, and supporting the validity of a single evidence-integration construct.

As Study 1 was the first meta-analysis to consider BADE, BACE, and LA, and did so while assessing JTC also, it was in a unique position to compare the co-occurrence of the evidence-integration biases and JTC with some confidence. The relationship of JTC with delusions demonstrated a similar pattern to that of the evidence-integration biases, which is consistent with there being one unifying account underlying the role of biases in delusions. Such a mechanism could be the two-stage liberal acceptance account of delusions (Moritz, Pfuhl, et al., 2017; Moritz & Woodward, 2004).

In Stage 1 of the liberal acceptance account (Moritz, Pfuhl, et al., 2017; Moritz & Woodward, 2004), people with psychosis have a lowered decision threshold. That is, they may accept hypotheses that healthy people would reject or query. This lowered decision threshold occurs as a result of overestimating the likelihood of implausible scenarios, and a

willingness to accept hypotheses at lower levels of confidence. Hence, upon considering a delusional idea, people with psychosis may overestimate its likelihood, and with a lowered acceptance threshold for any idea, may accept it as possible. This stage is reflected in Study 1 in the JTC and LA biases. The LA bias reflects giving high plausibility-ratings to implausible scenarios, and the JTC bias reflects the aggregate effect of high plausibility ratings and lower acceptance thresholds to produce the acceptance of a hypothesis (a particular jar) at a stage of the beads task that others would reject (a low DTD). Note that some studies using the graded estimates procedure have also demonstrated a lowered acceptance threshold consistent with the liberal acceptance account (e.g. Moritz & Woodward, 2005; Moritz, Woodward, & Lambert, 2007).

In Stage 2 of the liberal acceptance account, confidence in a specific delusional idea grows through consolidation of the belief, and through discarding alternative hypotheses. Consolidation may occur through a confirmation bias as people preferentially attend to confirmatory evidence and ignore disconfirmatory evidence (Balzan, Delfabbro, Galletly, & Woodward, 2013). This stage is, in part, represented in Study 1 by the BADE, in which disconfirmatory evidence for a preferred but incorrect interpretation is not adequately integrated. BACE, in which evidence for a true interpretation is inadequately integrated, may also contribute to delusion formation as part of the discarding of alternative hypotheses, though this was not explicitly suggested by Moritz, Pfuhl, et al. (2017).

If the liberal acceptance account is correct, the results of Study 1 should support each of the account's assertions regarding the biases tested. This was the case, as detailed above. In addition, if the liberal acceptance account is correct, since it is a unified account of the overall contribution of bias to delusions, the pattern of results for each individual contributing bias should be similar. This was found to be the case, despite JTC and the evidence-integration biases being assessed on entirely different measures, with the minor caveat that

unlike JTC, the evidence-integration biases did not quite reduce to normal levels in people with psychosis who were in remission. Hence the findings of Study 1 support the liberal acceptance account of delusion formation.

As acknowledged by Moritz, Pfuhl, et al. (2017), the liberal acceptance account of delusions bears a strong resemblance to the second component of the two-factor theory of delusions (Coltheart, 2007; Coltheart, Langdon, & McKay, 2011). As discussed in Chapter 1, in the two-factor theory, a possibly-anomalous internal or external experience is, by abductive reasoning, given a delusional explanation (the first factor), but it is a process of impaired belief evaluation (the second factor) which allows the delusional idea to be accepted and maintained, despite counter-evidence. It may be that the liberal acceptance account, composed of a variety of cognitive biases, is an accurate conceptualization of the impaired belief evaluation factor of the two-factor theory of delusions. Hence, the JTC and evidence integration biases may conceptually lie within the liberal acceptance account of delusions, which perhaps may comprise the second, impaired belief evaluation factor of the two-factor theory of delusions.

Investigation of the standard beads task

Heterogeneity in findings

The beads task is the mainstay of JTC research. Research into the relationship between delusions and JTC is characterized by heterogeneity, and in the case of delusion-proneness in particular by mixed results. Despite consistently finding a relationship between delusions and JTC, all clinical meta-analyses have reported medium to high heterogeneity in effect sizes between clinically ill and healthy control groups (see Study 1, and Dudley et al., 2016; So et al., 2016). In their non-clinical meta-analysis of the relationship between delusion-proneness and DTD, the small effect reported by Ross et al. (2015) was also accompanied by significant low-to-moderate heterogeneity (I^2 = 40%, p = .03; the overall

effect reported in their meta-analysis also has significant heterogeneity, but this could also be due to being composed of data from a mix of clinical and non-clinical groups). Of the 23 included studies, five reported nonsignificant positive correlations between delusion-proneness and DTD, contrary to the expected direction, 13 reported nonsignificant negative correlations, and only five reported significant negative effects.

In each of the above meta-analyses, heterogeneity may come from a number of sources, including sample differences and differences in the beads tasks used to measure DTD. In addition, heterogeneity might also reflect issues with the repeatability and reliability of the beads task itself. This thesis tested its repeatability and reliability, but first, the likely contribution of sample and task differences will be briefly revisited.

Part of the observed heterogeneity is likely to result naturally from the inclusion of different samples, with different PDI and beads-task scores. This may be compounded however by the small sample sizes commonly encountered in delusions and even delusion-proneness research. For example, in their general-population meta-analysis, one quarter of Ross et al.'s (2015) groups contained 36 or fewer people. Study 1 made use of groups with as few as 13 people (Garety, Hemsley, & Wessely, 1991), and similar groups were used in the other clinical meta-analyses, perhaps in part due to the difficulty in recruiting clinical samples. Small samples will deviate more regularly from the law of averages, and increase heterogeneity.

Different samples may also add to heterogeneity if the PDI-DTD relationship is non-linear, that is, if the correlation of PDI to DTD changes with PDI level. Van Dael et al. (2006) found that JTC increased non-linearly with the level of delusions, and JTC was disproportionately common at higher levels of delusions. If PDI and DTD are non-linearly related, different samples, with different PDI ranges, can be expected to produce different

PDI-DTD relationships. No meta-analysis to date has tested PDI as a moderator of the PDI-DTD relationship, but this could be a factor that contributes to heterogeneity.

Heterogeneity may also occur due to beads-task differences. For example, Balzan, Delfabbro, and Galletly (2012) found that responses on the beads task were changeable depending on the instruction-set and participants' understanding of the task, and Ross et al. (2015) found some (weak) evidence of effect sizes being dependent on the number of beads-task trials. Several studies have found that the ratio of beads used, whether "hard" (such as 60:40) or "easy" (such as 85:15) changes participants' responses to the task (Dudley, John, Young, & Over, 1997; Lincoln, Ziegler, Mehl, & Rief, 2010; Menon, Pomarol-Clotet, McKenna, & McCarthy, 2006). Specifically, and unsurprisingly, all participants choose more beads when hard ratios are used. However, Ross et al. (2015) also found *no* evidence that using easy versus hard ratios moderated the PDI-DTD effect size. Similarly, other variations of the beads-task procedure may not influence results. Balzan et al. (2012) found no effect of whether the task was computerized or not, and the fish variant of the task has produced similar associations between PDI and DTD as the beads versions (Woodward, Munz, LeClerc, & Lecomte, 2009).

Repeatability, reliability, and belief

As proposed earlier, significant heterogeneity could also reflect problems with the reliability of the beads task itself. The beads task is the most common means of measuring data-gathering and JTC, yet surprisingly little was known about its reliability. In order to determine whether the beads task is a reliable measure, Study 2 used a repeated-measures design to test the repeatability (the stability or consistency of a measure over repeated trials) and reliability (the ability of a measure to discriminate between levels of a variable in the presence of noise; Portney & Watkins, 2015) of the task. The standard beads task had lower-than-expected reliability and repeatability over repeated measures, which in turn reflected

poorly upon its reliability when conducted over a single trial also. It was concurrently found to have poor believability over repeated measures.

As a measure of repeatability or within-subjects' consistency over trials, the mean square error (MSE; lower is more consistent) rose monotonically with each new trial. There are a number of possible reasons for suboptimal consistency over trials. Foremost amongst these, at least over rapidly repeated measures, is that participants exposed to the same undisguised sequence of beads realize the beads sequence is fixed (not random). In Study 2, participants reported ambivalent belief to probable disbelief in the randomness of the beads sequence, and may have changed their responses over time as a consequence. Some participants chose more beads and some chose fewer beads, increasing variability more than systematically changing group mean DTD. However, participants in Study 2 faced 10 beads-task trials in rapid succession, which is not typical of studies (this was done to test the limits of repeatability of the beads task, rather than to approximate any one typical study design). Thus, consideration must also be given to the reliability of the task over fewer trials, perhaps through the use of trial-to-trial measures, as most studies only present one or two trials.

Of concern, the standard beads task demonstrated a rapid change in DTD between Trial 1 and 2. The change in DTD between Trial 1 and 2 cannot realistically be explained by a decrease in belief in the randomness of the beads sequence however, as participants would not have had sufficient opportunity to recognize its repetitive nature. Rather, it may be that a number of trials are required before responses stabilize, perhaps due to issues of comprehension and familiarity with the task. Balzan et al. (2012) found that participants were prone to misunderstanding the beads task, mistakenly believing that jars were "swapping", and that participants who misunderstood the task were more likely to JTC. While mistakenly believing jars are swapping is not likely in the first two trials (beads are all one colour), unfamiliarity and miscomprehension with respect to other aspects of the task may remain.

Perhaps after experiencing one or two trials participants are more familiar with and better understand the task, and respond more authentically. Whether they then choose more or fewer beads may be an individual characteristic. That differing or changing levels of comprehension and familiarity could significantly affect participant responses on the beads task on the one or two trials usually provided is of concern – such changes are very likely to have increased the heterogeneity of results as discussed. However, Study 2 also tested the psychometric properties of an alternative beads task – the distractor-sequences beads task.

The distractor-sequences beads task

Improved repeatability, reliability, belief

Study 2 identified that an alternative beads task composed of distractor bead sequences alongside the target sequence could provide much improved repeatability and reliability compared with the standard beads task. Participants completing this task had ambivalent to probable belief that the beads sequences were random, a significantly better level of belief than that reported by those completing the standard beads task. Presumably, the increased believability was due to the variety of sequences seen, making it less likely that participants would remember salient features of any one sequence when it was repeated. Part of the improvement in repeatability and reliability may have been due to the sequences appearing more unpredictable therefore, leading participants to commit effort to each individual trial rather than modifying their approach based on information from previous trials.

The improvements in reliability and repeatability in the distractor-sequences task were also evident over the first two trials. Mean DTD did not change over Trials 1-2 or 2-3, and MSE over all trials was significantly lower than for the standard beads task. If, as suggested earlier, participants sometimes miscomprehend the beads task and only respond reliably once they adequately comprehend it, this result indicates the distractor-sequences task may

increase comprehension from the earliest trials, perhaps due to practice over the multiplicity of sequences per trial. When a practice trial was used, participants completing the distractor-sequences task were exposed to five sequences before being scored on a target sequence, which may have maximized comprehension of the task. In comparison, participants on the standard beads task would have been exposed to only one sequence.

While the reliability and repeatability of the distractor-sequences task was better than the standard task, small but significant MSE remained, reflecting a degree of intra-individual change in DTD over trials (mean DTD did not change significantly over trials). While not tested in Study 2, it is plausible that those whose responses changed differed systematically from those whose responses did not change, or that those who increased in DTD differed systematically from those who decreased in DTD, perhaps even differing on such relevant measures as delusion-proneness. For this reason, the number of trials implemented when using the distractor-sequences task should be considered a balance between the improved psychometrics of an averaged measure, and avoiding the introduction of fatigue, disinterest, or a change in strategy, as the effects of these are, as yet, unknown. Repetition and associated fatigue or concentration issues could also potentially be minimised by using two rather than three distractor sequences per trial, though this would require validation.

Validity testing

The distractor-sequences beads task proved more reliable and repeatable than the standard task. However, whether the distractor-sequences task is actually measuring the data-gathering construct is not yet certain. One method to gather evidence for or against this is to test the distractor-sequences beads task in clinical samples. The JTC effect in clinical compared with nonclinical samples is comparatively robust (Dudley et al., 2016; So et al., 2016). If the distractor-sequences beads task is an adequate measure of data-gathering, its use in studies comparing clinical and non-clinical samples should on average replicate that people

with delusions demonstrate JTC (though perhaps a number of such experiments may be necessary to confirm the JTC effect, due to the high degree of heterogeneity observed in similar experiments using the standard task discussed earlier). Testing the distractor-sequences task in clinical samples is discussed at greater length below.

It may also be possible to gather evidence about whether the distractor-sequences task is measuring data-gathering by testing its convergent validity, by correlating DTD with other measures of data-gathering in the same study. Divergent results when compared with one other measure of data-gathering would be non-diagnostic (it would be unclear whether the beads task or the other measure was failing to measure data-gathering). However convergent results with a number of other measures, or divergent results from a number of other, inter-correlated measures, would provide evidence of the validity or invalidity, respectively, of the distractor-sequences task as a measure of data-gathering. Some possible means for making these comparisons are as follows.

The distractor-sequences task could be compared with the BADE-based measure of JTC introduced by Moritz et al. (2010). They measured JTC by recording the number of BADE-procedure decisions made after the first of the three sentences of the BADE task was provided. In a principal component analysis, they found that BADE-task JTC weighed onto a jumping-to-conclusions component, with a loading of .78, on which beads-task JTC also loaded with weight .50 (they did not report the correlation between BADE-based JTC and beads-task JTC). In many ways, a BADE-based measure of JTC may reflect a more ecologically-valid measure of JTC, involving as it does the natural-language-based exploration of scenarios, compared with the somewhat contrived task of choosing jars based on beads evidence.

The distractor-sequences task could also be compared with the box task of Moritz, Göritz, et al. (2017) in which participants were presented with 12 boxes on a computer

screen. With each click of a button, participants were shown an additional coloured ball in one of the boxes. Participants were instructed to determine which of two colours was more prevalent. The task was expected to be conceptually easier to understand and therefore less prone to miscomprehension, but otherwise similar to the beads task in measuring data-gathering. Additionally, as mentioned above, it may have the potential to reduce the influence of working memory as a confound. Caution may be required in using the box task to validate the distractor-sequences beads task however, as it remains unclear what the box task is measuring. Moritz, Göritz, et al. (2017) found a medium positive correlation between DTD on the box and beads tasks as expected, but Balzan et al. (2017), using 25 or 49 boxes, found no positive correlation, instead finding one small negative correlation that just failed to reach significance.

Finally, the distractor-sequences task could be compared with the decision-making tasks of Ziegler et al. (2008). They assessed information-gathering via a word task in which hints for a particular term were provided, a letter task in which letters and numbers were gradually resolved, and a task involving making relative comparisons of weights in the right and left hands. Unlike the box and beads tasks, these tasks are non-probabilistic, and hence would make an especially helpful contrast by removing any confounding effects of ability with probabilistic tasks. This is all the more important as odds literacy may be positively related to DTD, as found in Study 4.

Re-testing the Peters' delusions inventory – draws-to-decision relationship

As it was possible that the poor reliability of the standard beads task has contributed to heterogeneity and may have obscured the true nature of the PDI-DTD relationship in non-clinical samples, Studies 3 and 4 applied the more reliable distractor-sequences task to re-testing that relationship. In independent healthy samples, both studies found that PDI was positively related to DTD, that is, higher delusion-proneness was associated with *less* JTC.

This finding is in the opposite direction to what has been reported in the majority of clinical samples (including in the Study 1 meta-analysis), and in the meta-analysis of general-population samples reported by Ross et al. (2015). The unexpected finding of PDI being positively related to data gathering in non-clinical samples requires some explanation.

Heterogeneity

Firstly, given the heterogeneity in effects observed from other beads-task studies, it should be considered whether the findings of Studies 3 and 4 could simply fall within this expected range of variation. As discussed above, beads-task determinations of the PDI-DTD relationship may be susceptible to a range of study- and sample-specific factors. If so, perhaps the positive PDI-DTD relationship determined by the distractor-sequences task is a consequence not of better or more reliable measurement of a true positive relationship, but instead of study-difference-induced heterogeneity. This would best be tested by comparing the PDI-DTD relationships arising from the standard and distractor-sequences tasks in between-groups designs in which groups are drawn from the same pool of participants to eliminate sample differences, such as Study 2. While the PDI-DTD relationship was not the primary focus of Study 2, PDI data were collected, and a comparison of the PDI-DTD relationships arising from the two different beads tasks is possible. A Spearman's rho correlation revealed PDI and standard beads-task DTD were not related (rho = -.001), whereas PDI and the distractor-sequences beads-task DTD were significantly positively correlated (rho = .232, p =.014)[10], similar to the PDI-DTD relationships found in Studies 3 and 4. As these samples were drawn from the same online crowdsourcing pool with random allocation to groups, it is less likely that sample or study differences were responsible for the differing results. This lends credence to the possibility that the differences in PDI-DTD

[10] The Study 2 distractor-sequences group formed part of the Study 3 sample, hence this effect size is not independent to that of Study 3.

relationship found so far between the beads tasks (i.e., between Ross et al., 2015 and Studies 3 and 4) are due to the different beads tasks themselves, and not due to sample or other study differences. Further such direct comparisons would be helpful in confirming that the tasks do in fact produce different results under similar circumstances. In addition, while the positive PDI-DTD relationships duplicated in Studies 3 and 4 were small, they were consistent in size, and approximately twice the size of the small heterogeneous effect reported by Ross et al. (2015) using the standard beads task. Hence it is unlikely that these two positive PDI-DTD relationships result entirely from study-specific factors while not reflecting a real positive relationship.

Non-linearity

While study differences are unlikely to explain the findings of Studies 3 and 4, which diverged from Ross et al. (2015), Studies 3 and 4 could have found different results if they used samples with different PDI ranges than most, and the PDI-DTD relationship in general were non-linear (that is, the strength of the relationship varied with PDI). As previously noted, one study has found evidence for a non-linear relationship between delusions and JTC, and indicated that the likelihood of JTC increased non-linearly with the level of delusions (Van Dael et al., 2006). However, such non-linearity cannot account for a *reversal* in the direction of the PDI-DTD relationship from negative to positive. In addition, the PDI of the samples in Study 3 and Study 4 (*Mdn* = 38.0, IQR = [18.0, 63.0], and *Mdn* = 54.0, IQR = [35.0, 79.0] respectively) differed significantly ($U = 12438.0$, $Z = -4.41$, $p < .001$, $r = .27$), yet the PDI-DTD relationships were of the same sign and similar magnitude, failing to support the presence of strong sign-changing non-linearity. A meta-analysis of delusion-proneness and data-gathering which includes PDI level as a moderator may provide greater clarity on the sensitivity of the PDI-DTD relationship to sample PDI differences, but it is unlikely to account for the positive PDI-DTD relationship observed in Studies 3 and 4.

Habitual responding

Despite the improved psychometric properties of the distractor-sequences task used in Study 2, it is important to consider whether the repeated trials could have introduced other problems with reliability or validity, and might account for the positive PDI-DTD relationship observed in Study 3 and 4. In contrast to the standard task, mean DTD responses to the distractor-sequence task were quite stable over multiple trials, and MSE increased over trials only very slowly. Such results are consistent with sound psychometrics. However, while the stability could reflect participants' consideration of each trial relatively independently of the others, as suggested earlier, it could also reflect habitual responding – that is, responses which are no longer sensitive to stimuli but made out of habit. Counting against this however, it is unlikely participants would respond habitually to the target sequence each time it was presented, due to the intervening distractor sequences, which present different sequences of beads. It could also be argued that participants on the standard beads task in Study 2 had as much reason to respond habitually, but did not. While they faced fewer sequences (10 rather than 40), each sequence they did observe was the same, increasing the likelihood of responding habitually. Yet, their changing average DTD scores and high MSE both indicated that participants in this group did not respond habitually, instead changing their responses over time. Hence there are arguments against the likelihood for habitual responding to the distractor-sequences task. Nevertheless, if participants did respond habitually after a sufficient number of trials on the distractor-sequences task, it is possible that the DTD recorded would no longer reflect information-gathering, and that measurements of the PDI-DTD relationship would be invalid.

Fatigue

Perhaps of greater concern is if participants completing the distractor-sequences task become fatigued or disinterested, and begin to change their responses as a result. The

distractor-sequences group chose fewer beads on average than the standard beads-task group, which could indicate a degree of fatigue if fewer beads were chosen in reaction to the significantly greater number of sequences with which they were faced. However, this group did not significantly decrease DTD over trials as might indicate fatigue, rather, DTD remained consistent over trials.

Odds literacy

Neither normal heterogeneity due to study differences, differences in sample PDI, habitual responding, nor fatigue appear to explain the disparity between the positive PDI-DTD relationship observed in Study 3 and 4 and the generally weaker and negative relationships reported elsewhere. Rather, it appears more likely that it could be differences in the beads tasks themselves, and what they are measuring that have produced disparate results. Hence, if the distractor-sequences beads task does tap features of the data-gathering construct (which requires further evidence from convergent validity studies amongst other evidence, as above), the question remains why the distractor-sequences task has found a positive PDI-DTD relationship in non-clinical samples, at least in the two studies completed so far.

One potential mechanism for this positive relationship, the ability to understand and use odds or likelihood information ("odds literacy"), was investigated in Study 4. Higher odds literacy was suggested as a driver of reduced DTD, as, in a costless, unincentivized beads task, choosing fewer beads than the average is justifiable in statistical terms (Fear & Healy, 1997). Concurrently, it was suggested that, as delusional ideas involve accepting content that is unlikely to be true, those higher on odds literacy might be less delusion-prone. However, Study 4's results did not support this idea because odds literacy was positively rather than negatively related to both DTD and PDI. It was unclear why this might be.

Risk avoidance

Instead, it was noted in Study 4 that anxiety was positively correlated to distractor-sequence DTD and with PDI, leading to the suggestion that higher anxiety, which could be associated with delusion-proneness, may in turn be associated with risk-avoidance and an increased desire to choose the "correct" jar in beads-task studies, leading to higher DTD. Evidence from the literature that increased anxiety is associated with delusion-proneness is tentative at best however. There is some evidence that anxiety is related to delusions in clinical samples (Dudley et al., 2011; So, Freeman, & Garety, 2008) and to delusion-proneness in a socially-anxious sample (Johnstone, Chen, & Balzan, 2017), and as noted above, anxiety was related to PDI in Study 4. There is more evidence that anxiety is associated with risk-avoidance (Maner et al., 2007; Maner & Schmidt, 2006; Raghunathan & Pham, 1999). That increased risk avoidance might then lead to higher DTD appears logical, but little evidence is available. One study found risk-aversion did not predict DTD (Van der Leer, Hartig, Goldmanis, & McKay, 2015), however the task was incentivised towards deciding as soon as reasonable. Some evidence is available from social-anxiety studies if the fear of negative evaluation is accepted as possibly reflecting a degree of risk avoidance, but even so the results are mixed. Johnstone et al. (2017) found no relationship between fear of negative evaluation and DTD. On the other hand, Schlier, Helbig-Lang, and Lincoln (2016) found that socially-anxious participants did choose more beads than healthy controls, and ascribed this difference to the fear of negative evaluation, though this was not measured. The findings of studies which consider the relationship between anxiety and DTD directly (which, according to this suggestion, should be positive) are also mixed. So et al. (2008) found no impact of an anxiety induction on DTD or the number or participants showing JTC, both for clinical and control groups, and Johnstone et al. (2017) found no relationship between anxiety and DTD in a large non-clinical sample. Lincoln, Lange, Burau, Exner, and Moritz (2009)

found that an anxiety-inducing manipulation instead increased rates of JTC in a healthy sample – although induced anxiety did not decrease DTD, and may be associated with paranoia rather than more general non-psychotic factors in any case (Moritz, Van Quaquebeke, & Lincoln, 2012). That studies using the standard beads task have not reliably found a relationship between anxiety and DTD does not rule out the possibility that the distractor-sequences task might find such a relationship however. The greater length of the task might allow participants' sense of anxiety and performance-related risk-avoidance to grow, while the extremely brief standard beads task might not. A future study could investigate this potential mechanism, including measuring the key "risk-avoidance" aspect of the hypothesis which was not measured in Study 4.

The Peters' delusions inventory – draws-to-decision relationship in clinical samples

As noted above, a key next step in understanding what the distractor-sequences beads task measures is to test the task in clinical samples, with replication. However, once a pattern of responses is established, it may be possible to make inferences. The inferences arising from positive and negative PDI-DTD relationships would be significantly different.

Implications of a negative relationship

If the distractor-sequences task produced a negative relationship between PDI and DTD in clinical samples, this would be consistent with the relatively robust findings of numerous studies using the standard beads task (Dudley et al., 2016; So et al., 2016). The measurement of DTD and the DTD-delusions relationship can be expected to be less equivocal over the robust clinical-to-nonclinical comparison than in general-population samples. Hence such a finding would support the possibility that the distractor-sequences task measures information-gathering, as the standard task is assumed to (imperfectly) do.

However, if a negative relationship is found in clinical samples, the question arises as to why the distractor-sequences task found a positive relationship in two non-clinical

samples. After all, the PDI has been used to demonstrate that delusions occur on a continuum, not only in clinically ill patients with psychosis, but in healthy non-clinical samples as well (Peters, Joseph, Day, & Garety, 2004). The continuum nature of delusions might imply that the direction, if not the strength of the PDI-DTD relationship should remain consistent between clinical and non-clinical samples.

While purely speculative, such a change in the PDI-DTD relationship between non-clinical and clinical samples could perhaps be explained if the process driving JTC only operates at clinical levels of delusions. The continuum nature of delusions suggested by the PDI does not rule out such a possibility, as it is apparent that clinical samples, with a diagnosis of a psychotic illness, are very different to non-clinical samples. The inadequacy of the PDI to capture such differences is also demonstrated by the extreme overlap of PDI values between clinical and non-clinical samples (Peters et al., 2004). Hence perhaps clinical or non-clinical status could act as a moderator of the PDI-DTD relationship.

The process operating at clinical levels of delusions (i.e., for people with psychosis), may well be the liberal acceptance account discussed earlier (Moritz, Pfuhl, et al., 2017; Moritz & Woodward, 2004). According to this account, people with psychosis have a tendency to make decisions at a lower level of confidence, and based on less information. This can lead to the formation of delusional ideas, as ideas which would otherwise be rejected on the basis of implausibility and insufficient evidence may be accepted. Correspondingly, in the beads task, liberal acceptance may lead people with psychosis to decide on a jar earlier, on the basis of fewer beads, than healthy people, resulting in JTC.

In this situation, then, the most likely explanation for the unexpected finding of a small positive relationship in the two non-clinical samples of Studies 3 and 4 is that no strong PDI-JTC relationship exists in non-clinical samples, and that limitations of the beads task or random factors such as sampling have led to two false positive relationships in these studies.

It must be noted that both effect sizes were small, lending credence to this possibility. This possibility is all the more likely as the relationship between delusions and JTC may be non-linear and disproportionately weaker at lower levels of delusion-proneness (Van Dael et al., 2006). Alternatively, or in addition, it may be that the beads task itself, whether the standard or distractor-sequences version, is a poor or noisy measure of information-gathering – and that even a negative PDI-DTD relationship in general-population samples is difficult to observe.

Speculatively, however, and if the small positive relationship found so far using the distractor task in non-clinical samples proves robust, it is also possible that at non-clinical levels of delusion-proneness another process operates to generate a perhaps-weaker positive PDI-DTD relationship. This could be the proposed anxiety / risk-avoidance mechanism discussed above, which might be overwhelmed by the liberal acceptance process at higher levels of delusions.

Implications of a positive relationship

If on the other hand the distractor-sequences task produced a positive relationship between PDI and DTD in clinical samples, or repeatedly failed to find any relationship at all, this would be inconsistent with the relatively robust findings from the standard beads task in clinical samples (Dudley et al., 2016; So et al., 2016, and Study 1). As mentioned previously, the measurement of DTD and the DTD-delusions relationship can be expected to be quite robust over the clinical-to-nonclinical comparison. Hence such a finding would support the possibility that the distractor-sequences task is a poor measure of information-gathering. If this were the case, it is unclear why the distractor-sequences task would not measure data-gathering while the standard task presumably does. A number of possibilities, such as habituated responding and fatigue, have been discussed above however.

Another possible weakness of this measure (and indeed the standard beads task also) that could affect results is that the task is not incentivised. Each individual has their own set of experiences, assumptions, beliefs, interests, and concerns, and delusions form within these self-relevant contexts. Hence, the experience of strange events, the first consideration of a bizarre explanation, the grappling with the possible interpretation, and the final acceptance of a delusional idea are undoubtedly emotionally-charged experiences. The acceptance of a delusional idea, then, must have palpable consequences and importance, and is subject to motivational pressures.

The motivation experienced by individuals with psychosis may in part be the need for closure, in which individuals find it preferable to accept any explanation, even a bizarre one, for unexplained perceptual stimuli, rather than remaining uncertain or confused (Colbert & Peters, 2002). Need for closure has been associated with delusion-proneness in the general population (Colbert & Peters, 2002), and in clinical samples (Bentall & Swarbrick, 2003; Colbert, Peters, & Garety, 2006). Counter-evidence is available however, one clinical study found only a weak link between need for closure and psychosis symptoms that was fully explained by affect (Freeman et al., 2006), and another found that need for closure, while associated with persecutory delusions, was not associated with JTC (McKay, Langdon, & Coltheart, 2007). If need for closure does partly motivate the drawing of delusional conclusions, it may be associated with JTC (Fine, Gardner, Craigie, & Gold, 2007).

The beads task, on the other hand, is usually presented purely as a somewhat-statistical game, with no explicit cost for deferring a decision (i.e., requesting more beads). It is unclear what internal motivation, if any, participants bring to the task. It may be, then, that the beads task fails to capture a central aspect of delusion-related JTC – that of motivation. Early attempts have been made to introduce a motivational element to the beads task, in one instance by instituting a monetary cost to draw additional beads (Esslinger et al., 2013; Van

der Leer et al., 2015), but perhaps motivation could also be provided by time pressure, as has been done in the beads task (Moritz, Göritz, et al., 2017) and an alternative JTC task (Glöckner & Moritz, 2008), or by other means.

Hence, as well as testing the distractor-sequences task in clinical samples, and perhaps especially if a positive or null relationship is found, it may be fruitful to test incentivizing the task. If incentivisation of the beads task proves important to achieving valid results, it is possible that the non-clinical results of Studies 3 and 4 have failed to capture the relationship of information-gathering to delusion-proneness after all, but rather reflect elevated risk-aversion in the delusion-prone as suggested above. Then, perhaps, with incentivization if required, the distractor-sequences beads task may provide both a valid and more reliable measure of DTD and JTC for delusions research.

Conclusion

This thesis sought to clarify the nature of the relationship between cognitive biases and delusions, in clinical and non-clinical groups. Cognitive therapies have a role to play in the alleviation of delusional symptoms, and ideally, our theoretical understanding of biases and delusions would keep pace and guide these developments.

The most significant contributions to new knowledge of this thesis are as follows. First, JTC is associated with delusions across diagnoses, and along with BADE, BACE, and LA, covaries with delusions. This finding increases confidence that JTC is associated with delusions, and not just with schizophrenia. This finding is also consistent with the possibility these four biases together contribute to delusion formation and maintenance, and indicates they may be conceptually related, perhaps under the liberal acceptance account of delusion formation. Second, the finding that the standard beads task has limited reliability and repeatability is a call for caution in its use, certainly over repeated measures such as treatment and intervention studies, but also in single-trial studies, and this thesis clearly demonstrates

that as a minimum a practice trial should be provided. Third, this thesis has provided a potentially useful alternative beads task which, while requiring further testing, appears to overcome much of the limitations of the standard task. Fourth and finally, this thesis found that the PDI-DTD relationship in non-clinical samples according to the new task was positive, in contrast to the small negative relationship reflected in the literature. This finding admittedly raises more questions than it answers at present, but may open the door to a much fuller understanding of the relationship between information-gathering and delusions and delusion-proneness, across the spectrum from healthy to clinical populations.

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Appendix: Supplementary material to Chapter 2

The appendix comprises the supplementary material referred to in

McLean, B. F., Mattiske, J. K., & Balzan, R. P. (2017). Association of the Jumping to Conclusions and evidence integration biases with delusions in psychosis: A detailed meta-analysis. *Schizophrenia Bulletin, 43*(2), 344-354. doi:10.1093/schbul/sbw056

and available online at http://schizophreniabulletin.oxfordjournals.org

The supplementary material contains forest plots of the meta-analyses of

- the Jumping to Conclusions bias (JTC)
- the Bias Against Disconfirmatory Evidence (BADE)
- the Bias Against Confirmatory Evidence (BACE), and
- the Liberal Acceptance bias (LA),

and the associated references.

Forest plots, Jumping to Conclusions bias

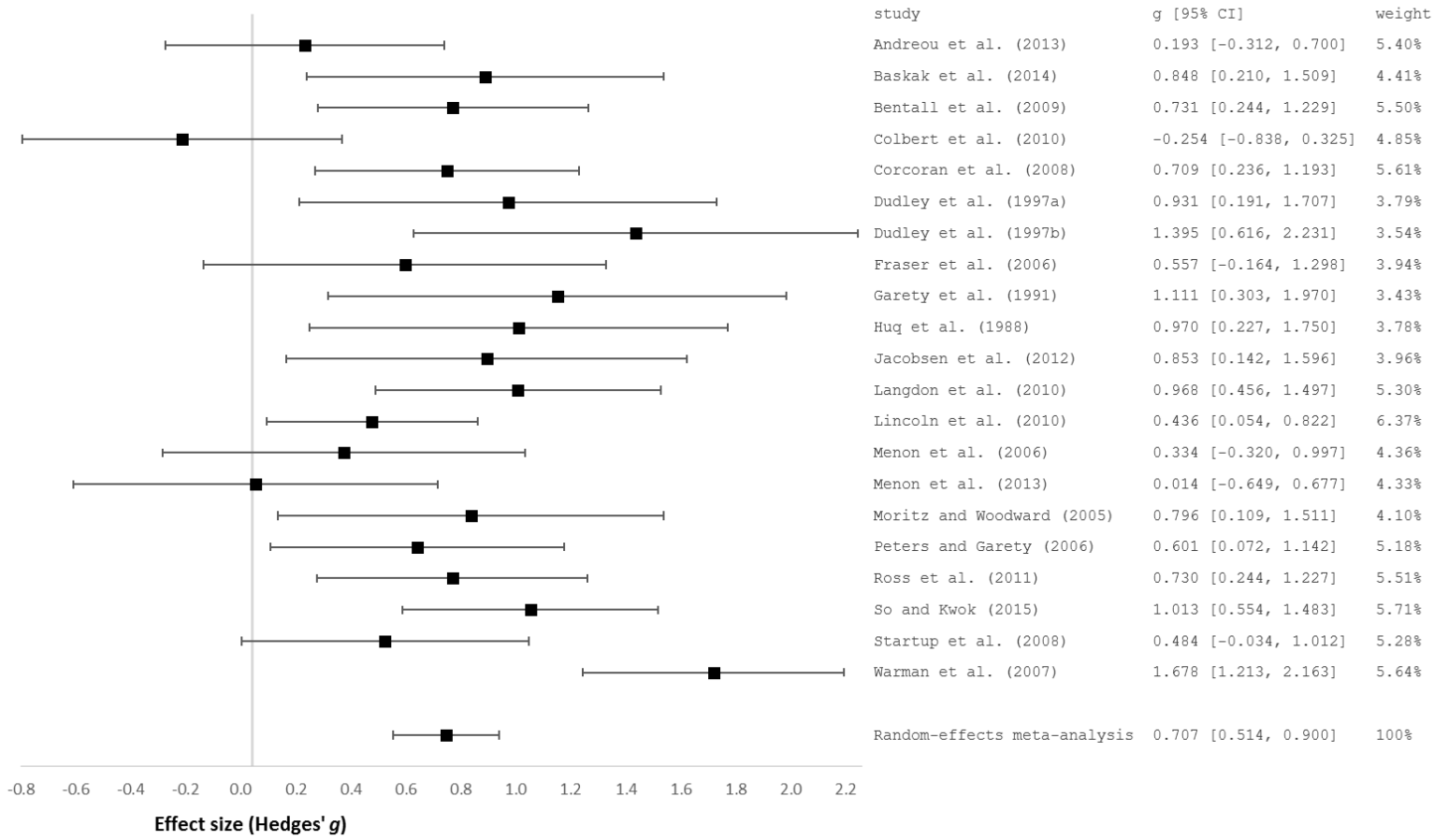

Figure A1. Forest plot of random-effects meta-analysis showing Hedges' g effect sizes, 95% CI's, and study weights for the difference in JTC between groups with schizophrenia currently experiencing delusions and healthy control groups.

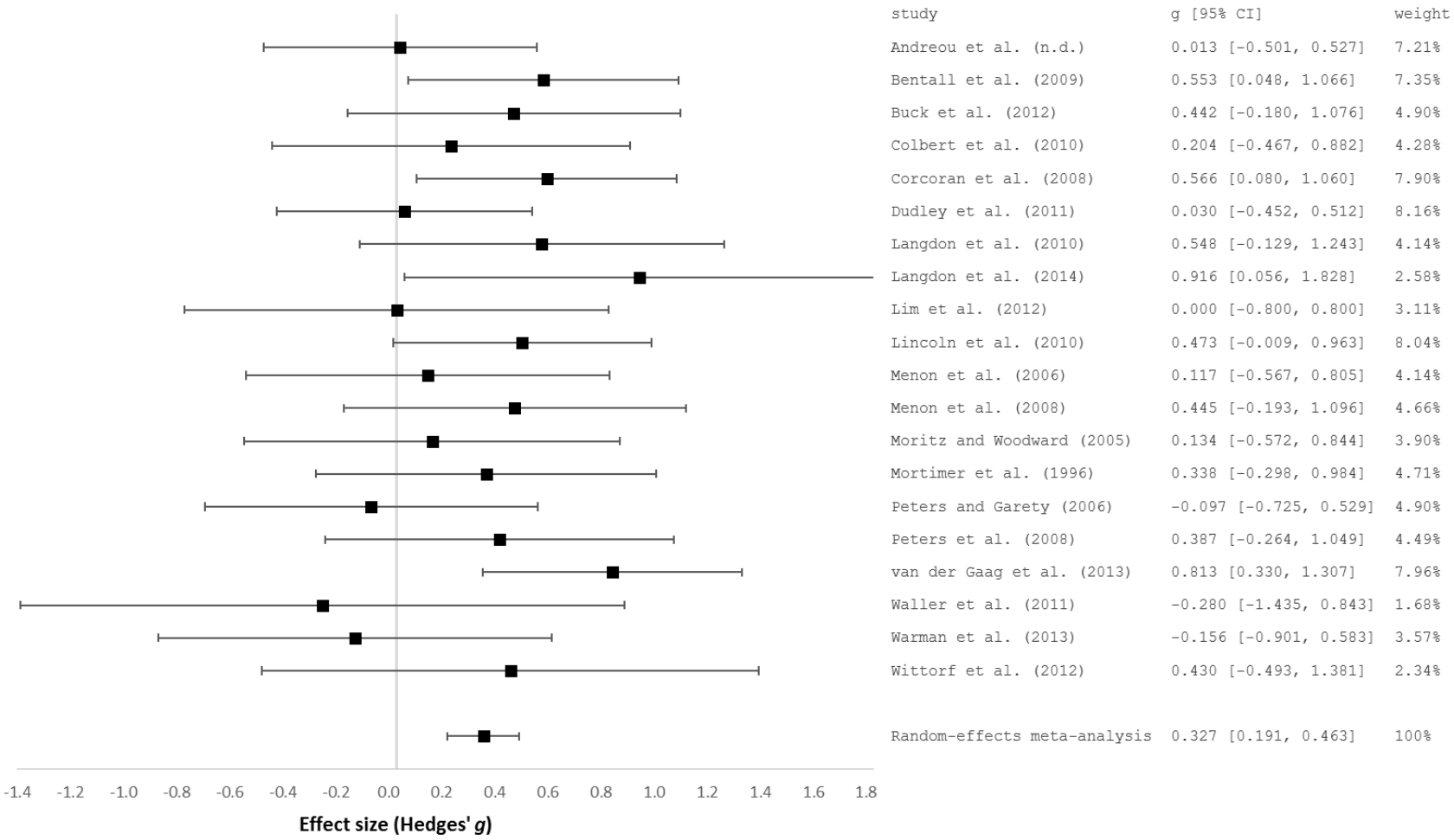

Figure A2. Forest plot of random-effects meta-analysis showing Hedges' g effect sizes, 95% CI's, and study weights for the difference in JTC between groups with schizophrenia currently experiencing delusions and groups with schizophrenia not currently experiencing delusions.

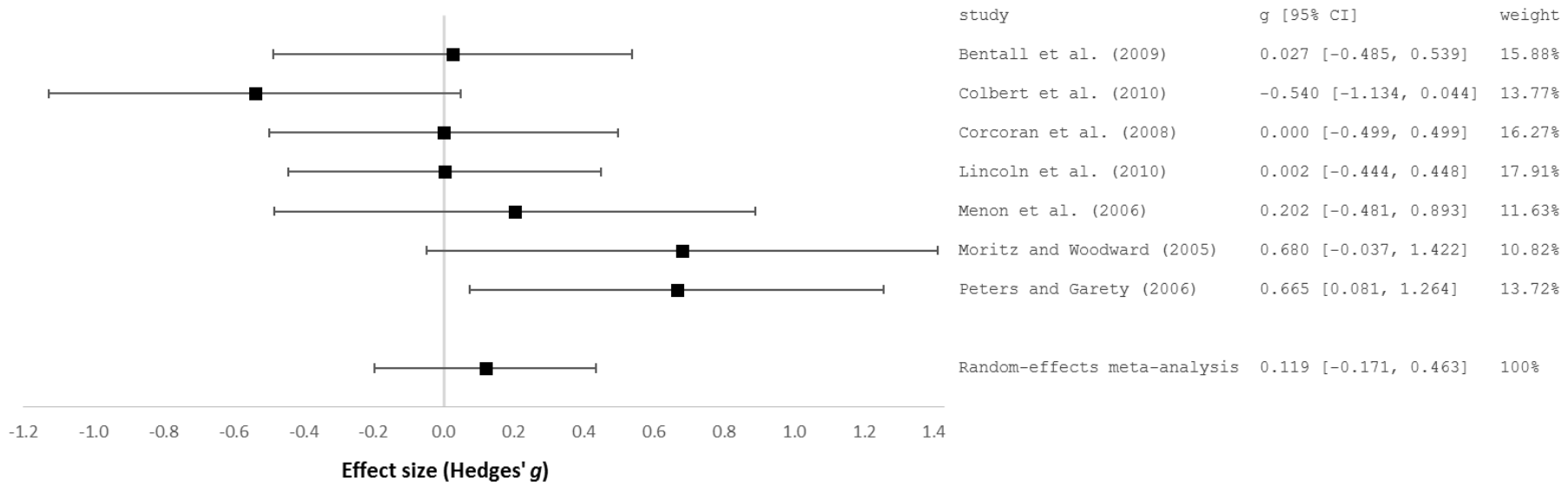

Figure A3. Forest plot of random-effects meta-analysis showing Hedges' g effect sizes, 95% CI's, and study weights for the difference in JTC between groups with schizophrenia not currently experiencing delusions and healthy control groups.

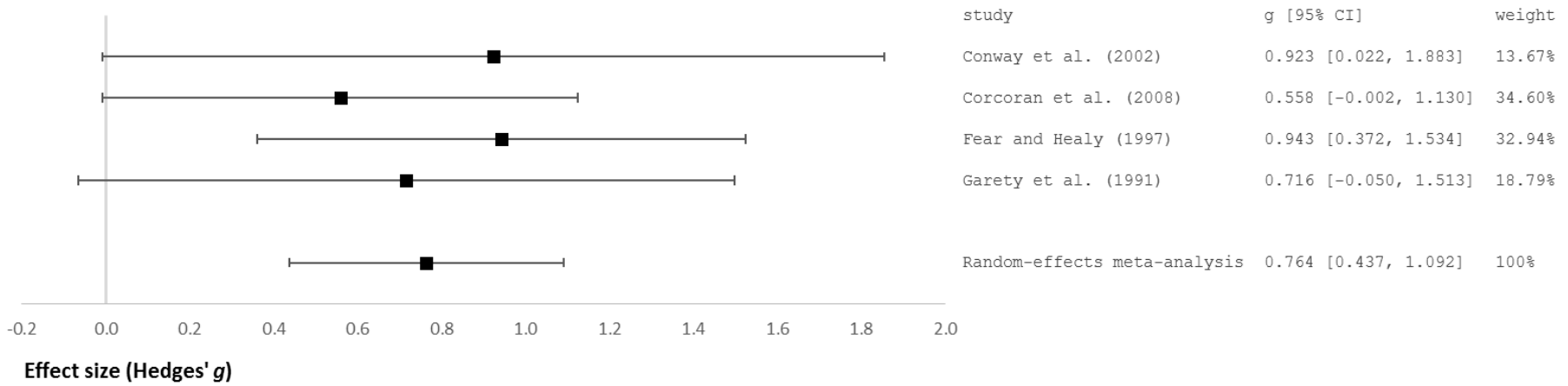

Figure A4. Forest plot of random-effects meta-analysis showing Hedges' g effect sizes, 95% CI's, and study weights for the difference in JTC between groups with non-schizophrenia-spectrum illnesses currently experiencing delusions and healthy control groups.

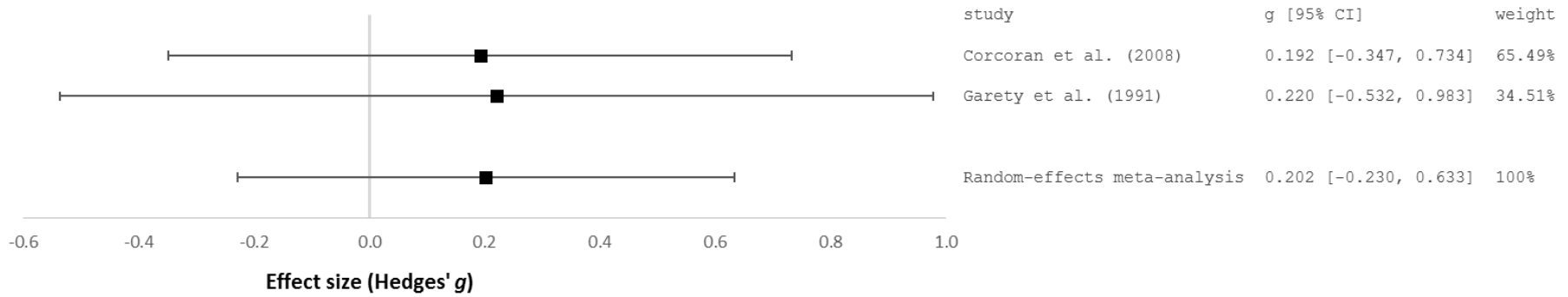

Figure A5. Forest plot of random-effects meta-analysis showing Hedges' g effect sizes, 95% CI's, and study weights for the difference in JTC between groups with schizophrenia currently experiencing delusions and groups with non-schizophrenia-spectrum illnesses currently experiencing delusions.

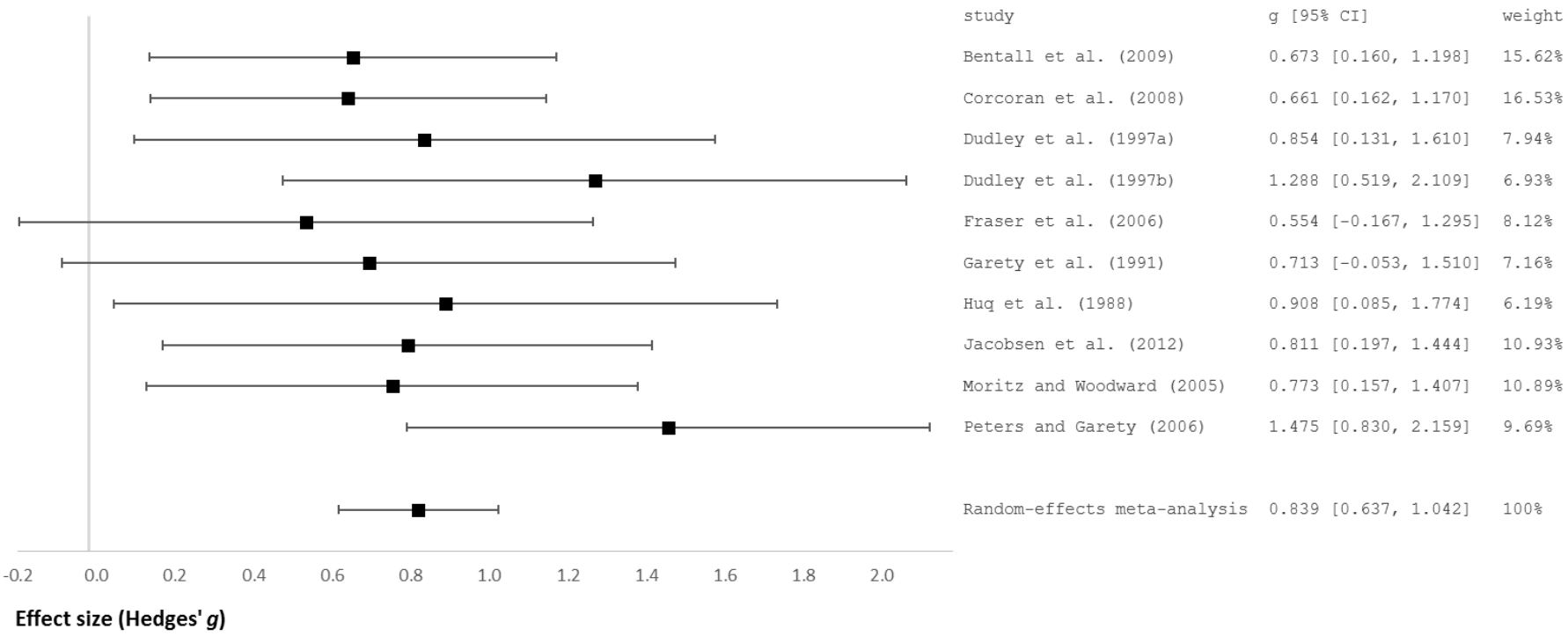

Figure A6. Forest plot of random-effects meta-analysis showing Hedges' g effect sizes, 95% CI's, and study weights for the difference in JTC between groups with schizophrenia currently experiencing delusions and groups with other psychiatric illnesses not associated with delusions.

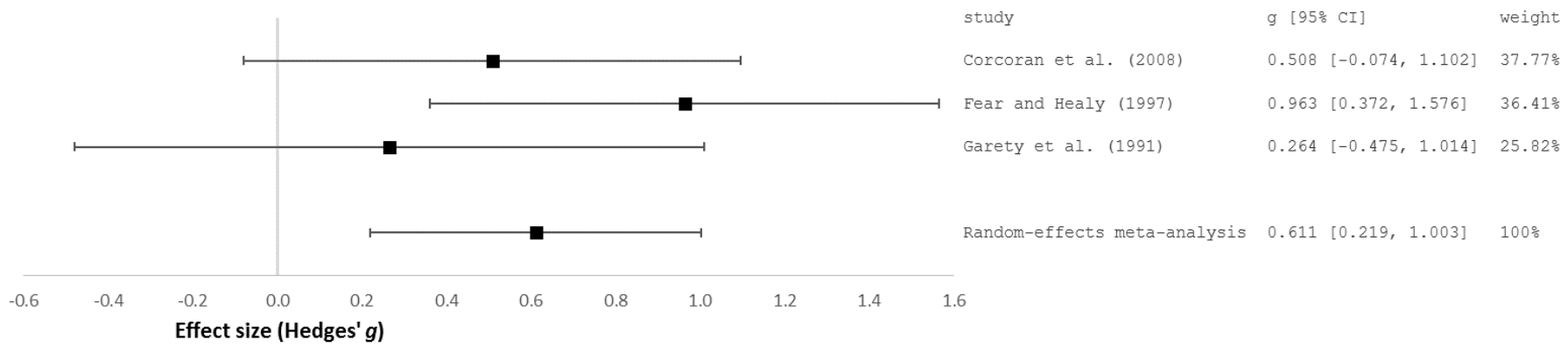

Figure A7. Forest plot of random-effects meta-analysis showing Hedges' g effect sizes, 95% CI's, and study weights for the difference in JTC between groups with non-schizophrenia-spectrum illnesses currently experiencing delusions and groups with other psychiatric illnesses not associated with delusions.

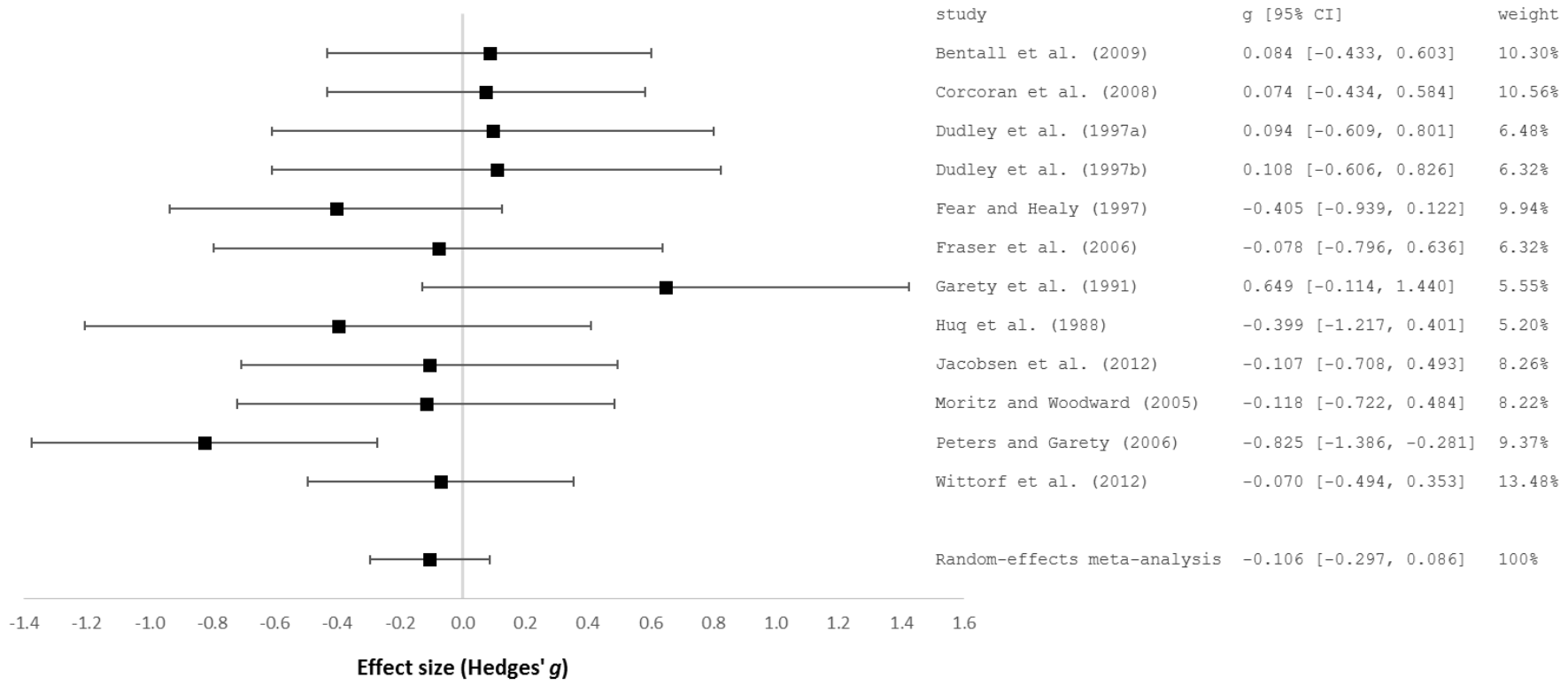

Figure A8. Forest plot of random-effects meta-analysis showing Hedges' g effect sizes, 95% CI's, and study weights for the difference in JTC between groups with other psychiatric illnesses not associated with delusions and healthy control groups.

Forest plots, Bias Against Disconfirmatory Evidence

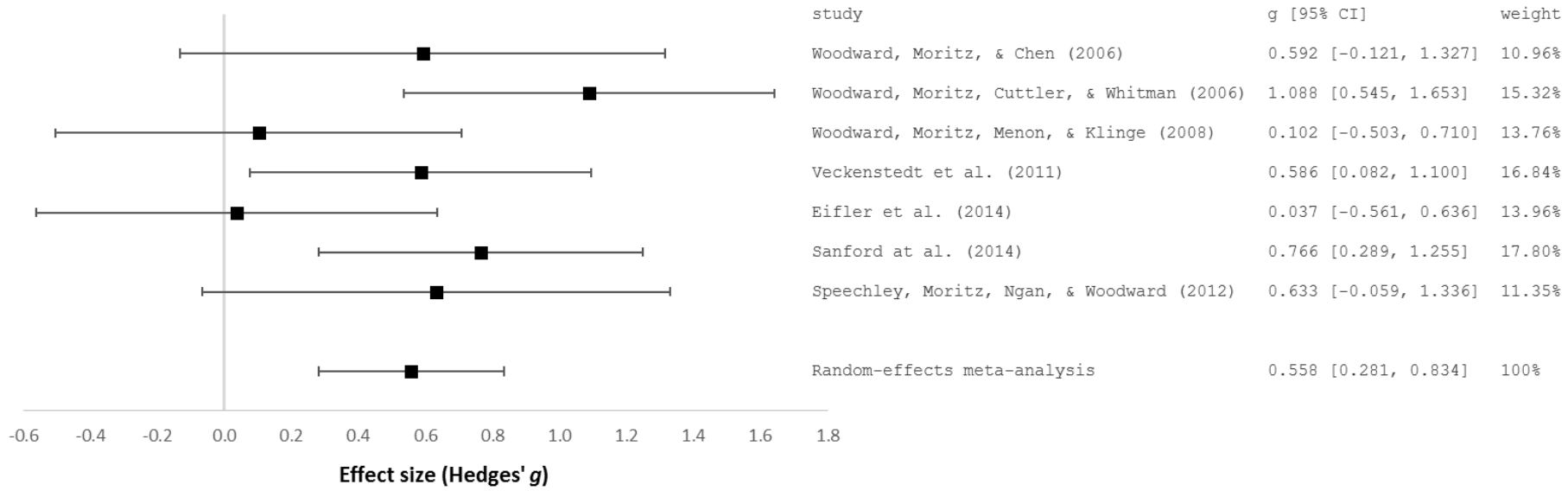

Figure A9. Forest plot of random-effects meta-analysis showing Hedges' g effect sizes, 95% CI's, and study weights for the difference in BADE between groups with schizophrenia currently experiencing delusions and healthy control groups.

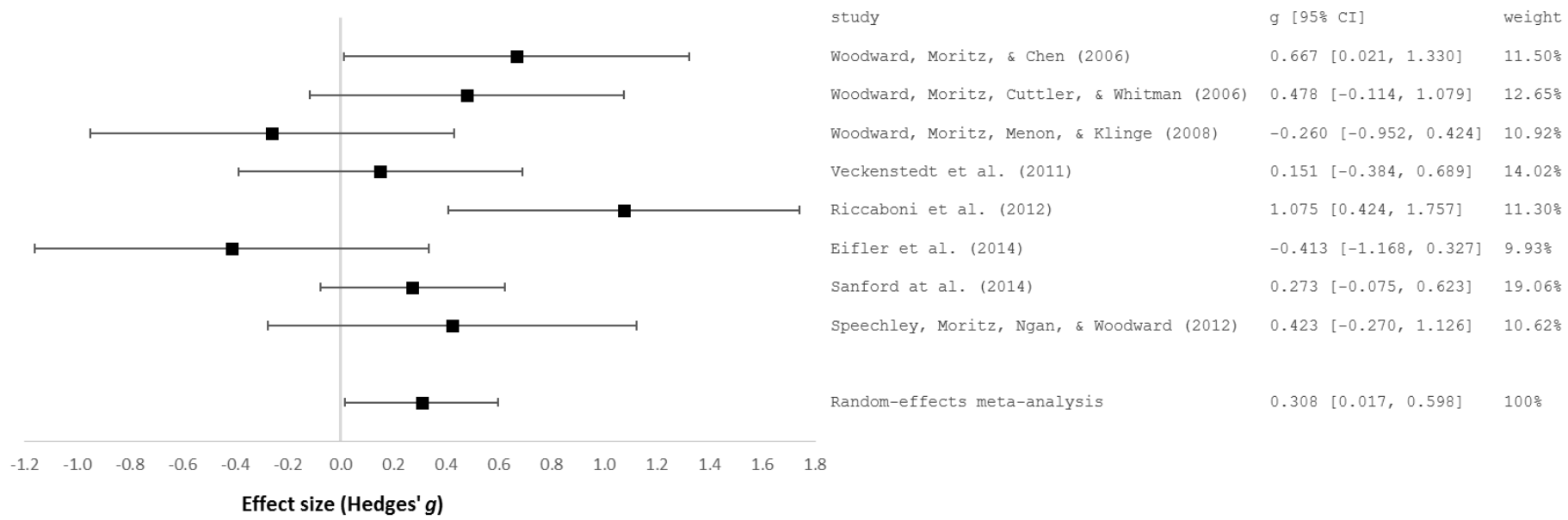

Figure A10. Forest plot of random-effects meta-analysis showing Hedges' g effect sizes, 95% CI's, and study weights for the difference in BADE between groups with schizophrenia currently experiencing delusions and groups with schizophrenia not currently experiencing delusions.

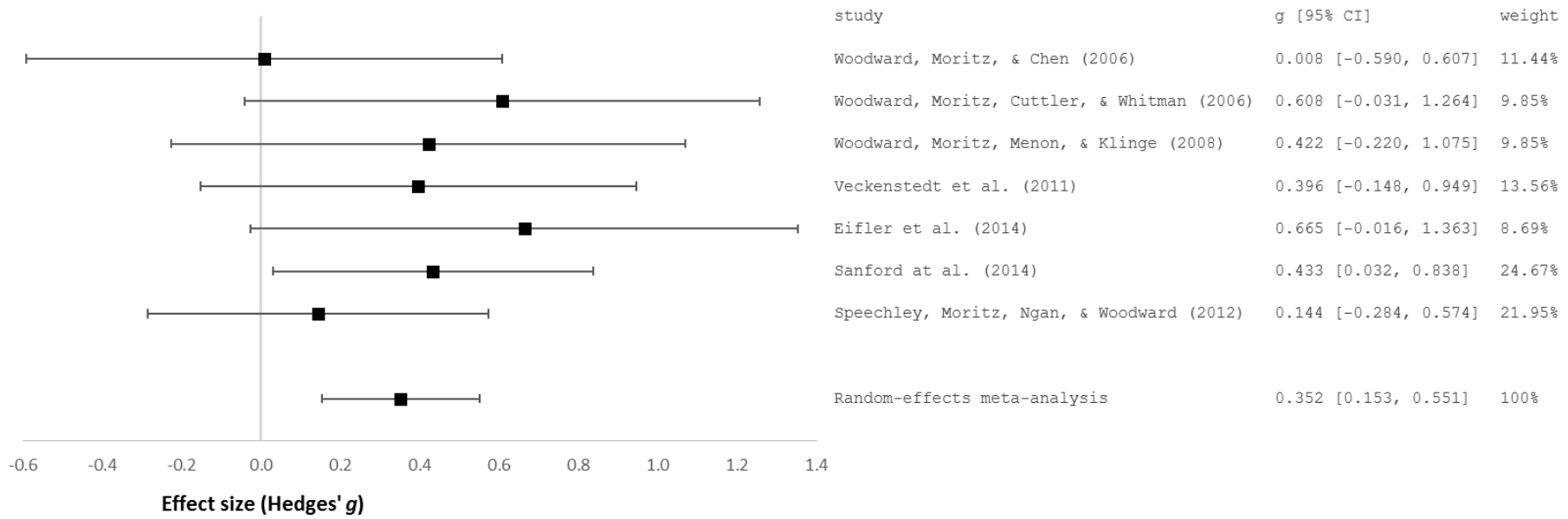

Figure A11. Forest plot of random-effects meta-analysis showing Hedges' g effect sizes, 95% CI's, and study weights for the difference in BADE between groups with schizophrenia not currently experiencing delusions and healthy control groups.

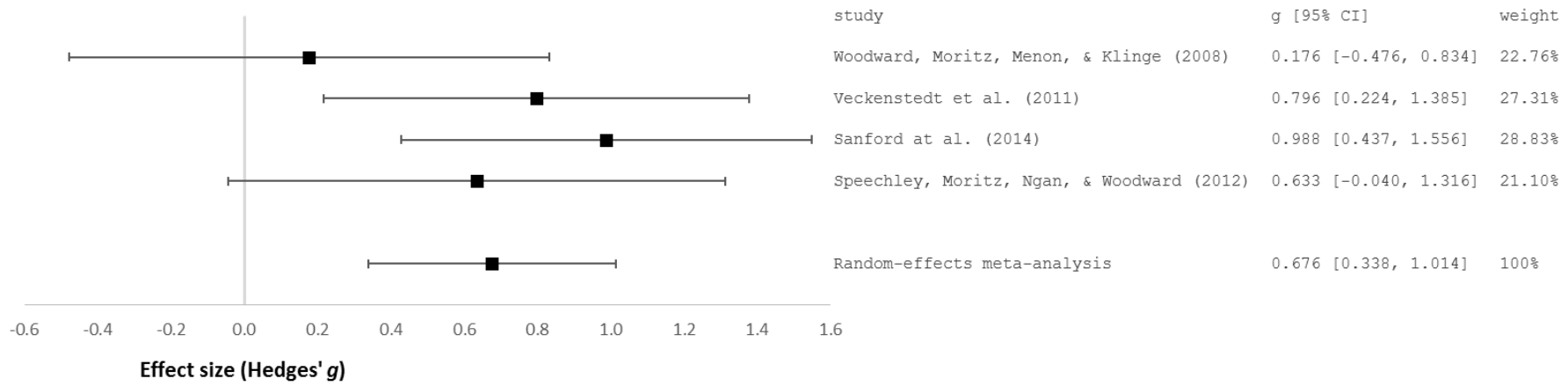

Figure A12. Forest plot of random-effects meta-analysis showing Hedges' g effect sizes, 95% CI's, and study weights for the difference in BADE between groups with schizophrenia currently experiencing delusions and groups with other psychiatric illnesses not associated with delusions.

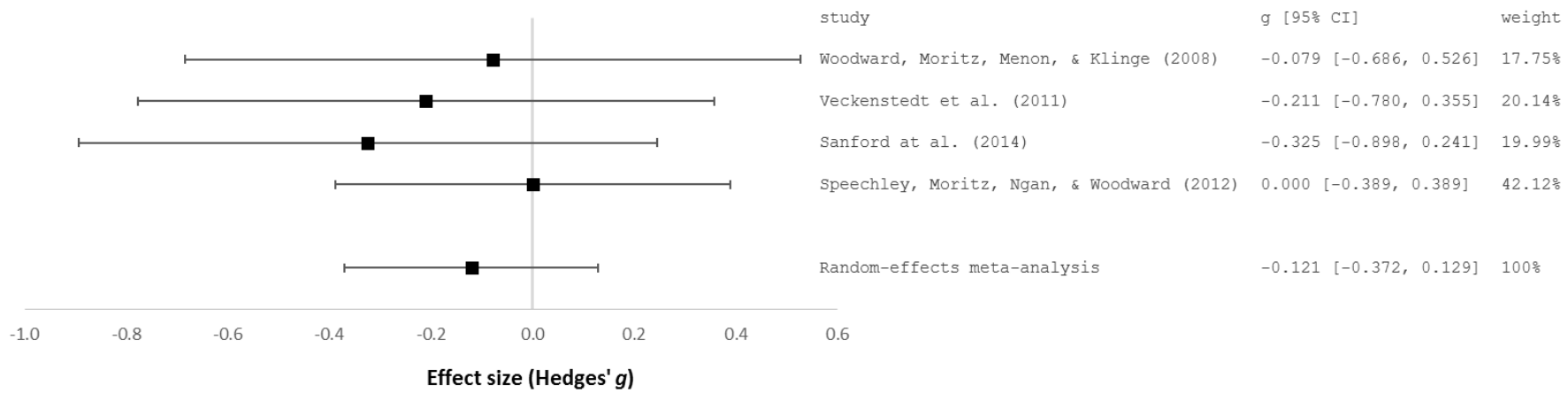

Figure A13. Forest plot of random-effects meta-analysis showing Hedges' g effect sizes, 95% CI's, and study weights for the difference in BADE between groups with other psychiatric illnesses not associated with delusions and healthy control groups.

Forest plots, Bias Against Confirmatory Evidence

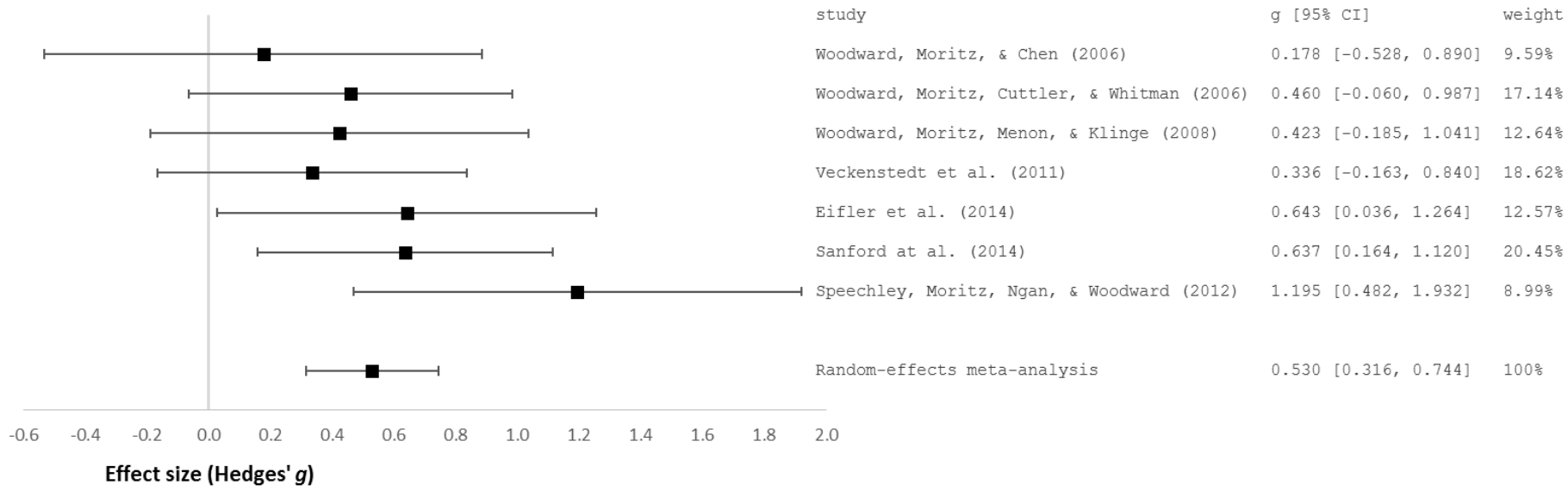

Figure A14. Forest plot of random-effects meta-analysis showing Hedges' g effect sizes, 95% CI's, and study weights for the difference in BACE between groups with schizophrenia currently experiencing delusions and healthy control groups.

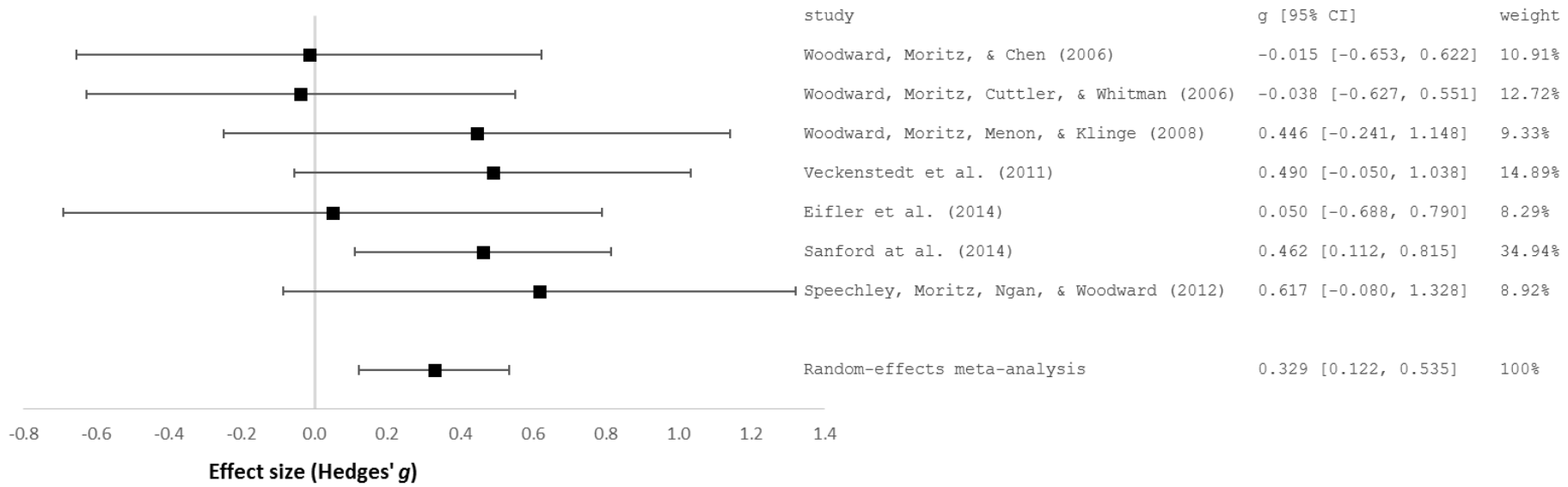

Figure A15. Forest plot of random-effects meta-analysis showing Hedges' g effect sizes, 95% CI's, and study weights for the difference in BACE between groups with schizophrenia currently experiencing delusions and groups with schizophrenia not currently experiencing delusions.

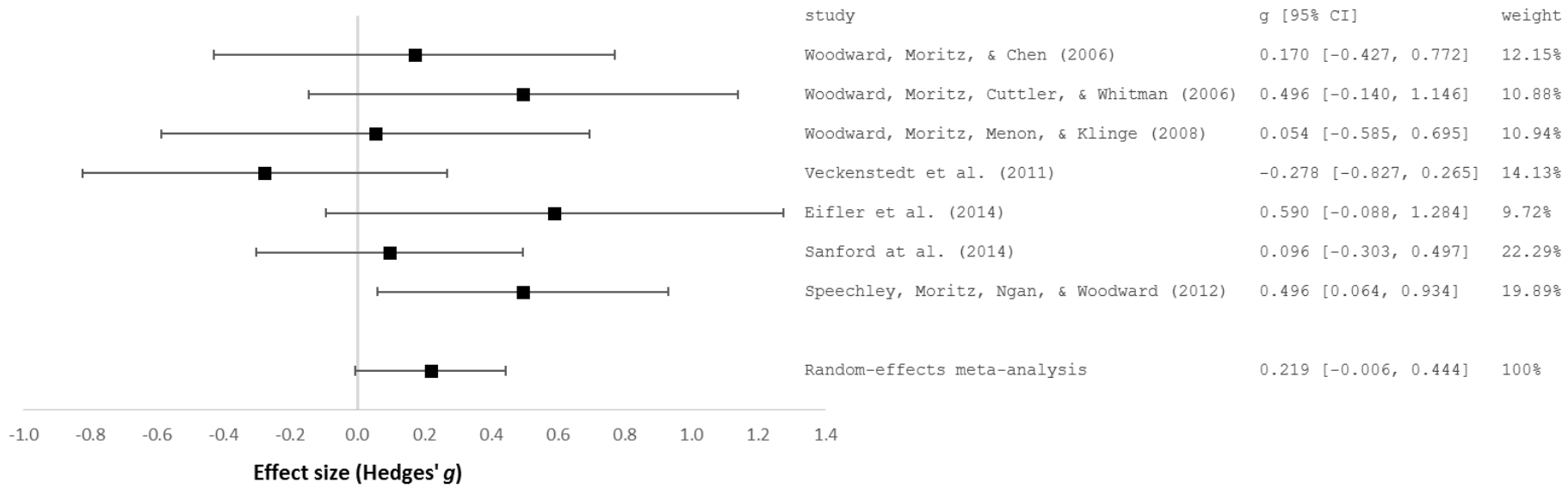

Figure A16. Forest plot of random-effects meta-analysis showing Hedges' g effect sizes, 95% CI's, and study weights for the difference in BACE between groups with schizophrenia not currently experiencing delusions and healthy control groups.

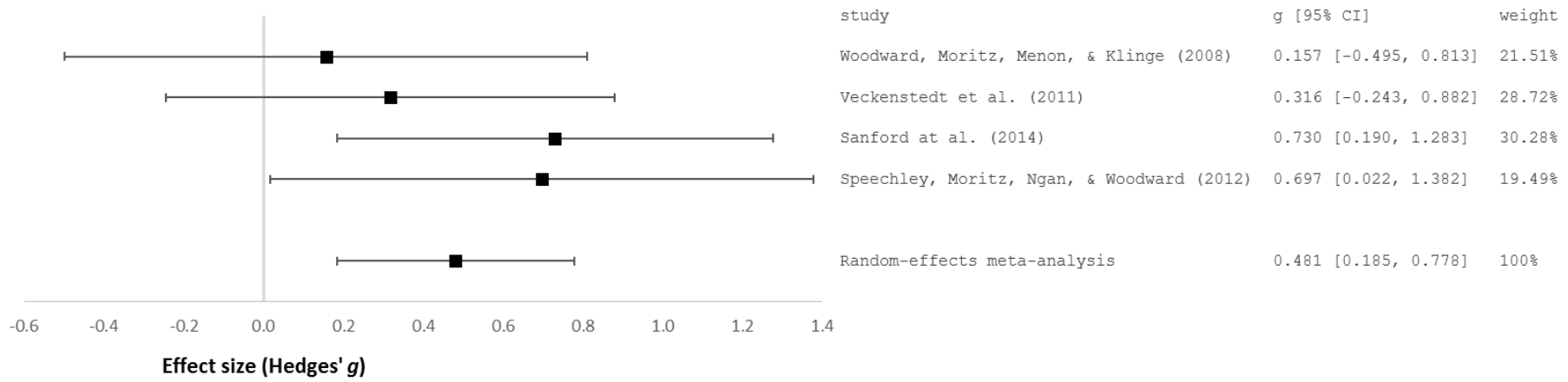

Figure A17. Forest plot of random-effects meta-analysis showing Hedges' g effect sizes, 95% CI's, and study weights for the difference in BACE between groups with schizophrenia currently experiencing delusions and groups with other psychiatric illnesses not associated with delusions.

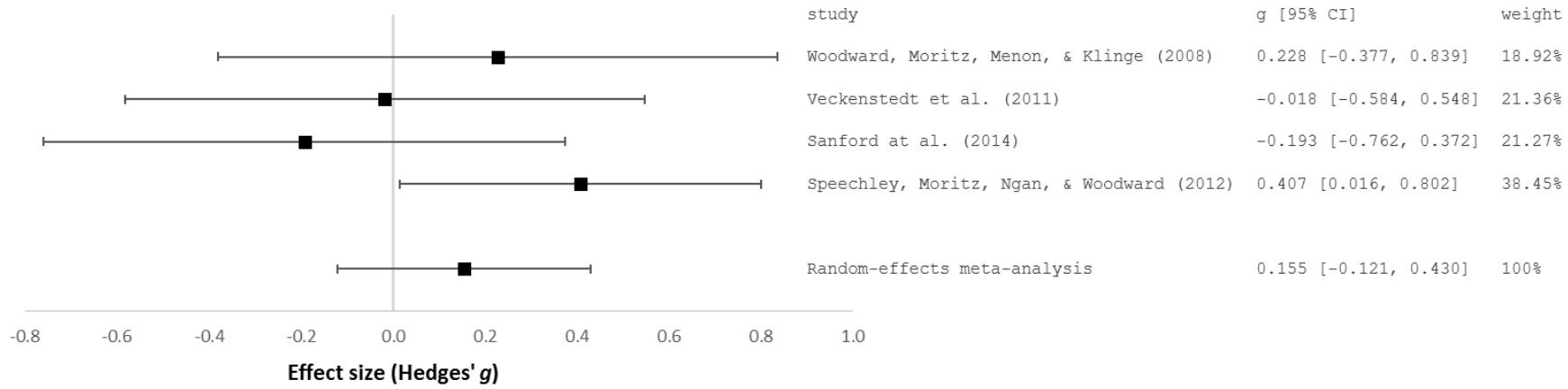

Figure A18. Forest plot of random-effects meta-analysis showing Hedges' g effect sizes, 95% CI's, and study weights for the difference in BACE between groups with other psychiatric illnesses not associated with delusions and healthy control groups.

Forest plots, Liberal Acceptance bias

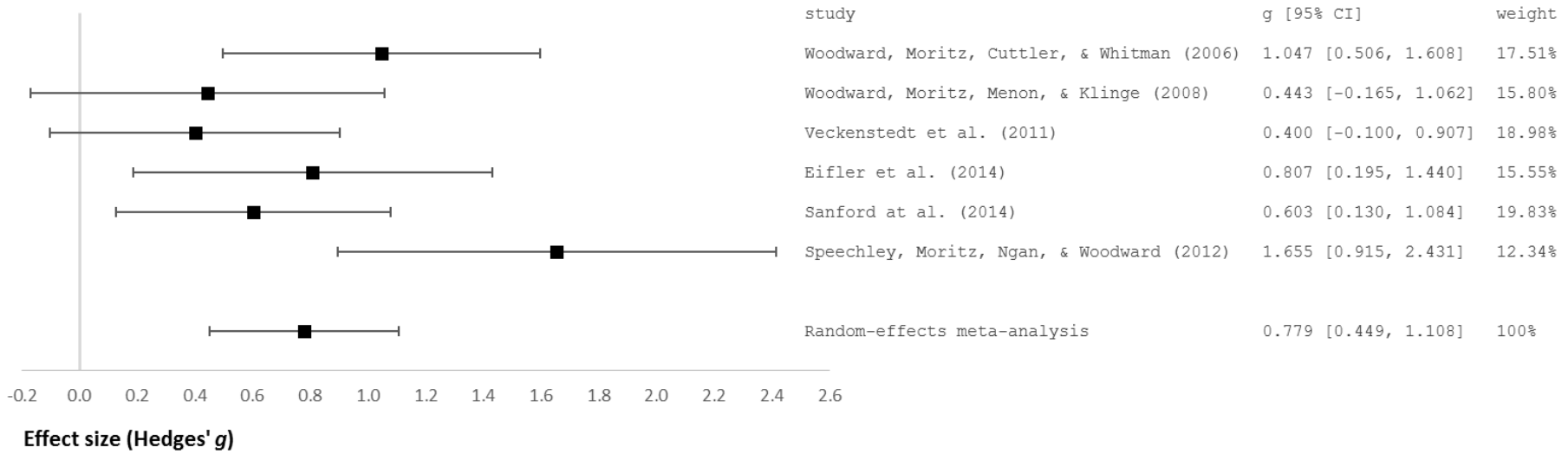

Figure A19. Forest plot of random-effects meta-analysis showing Hedges' g effect sizes, 95% CI's, and study weights for the difference in LA between groups with schizophrenia currently experiencing delusions and healthy control groups.

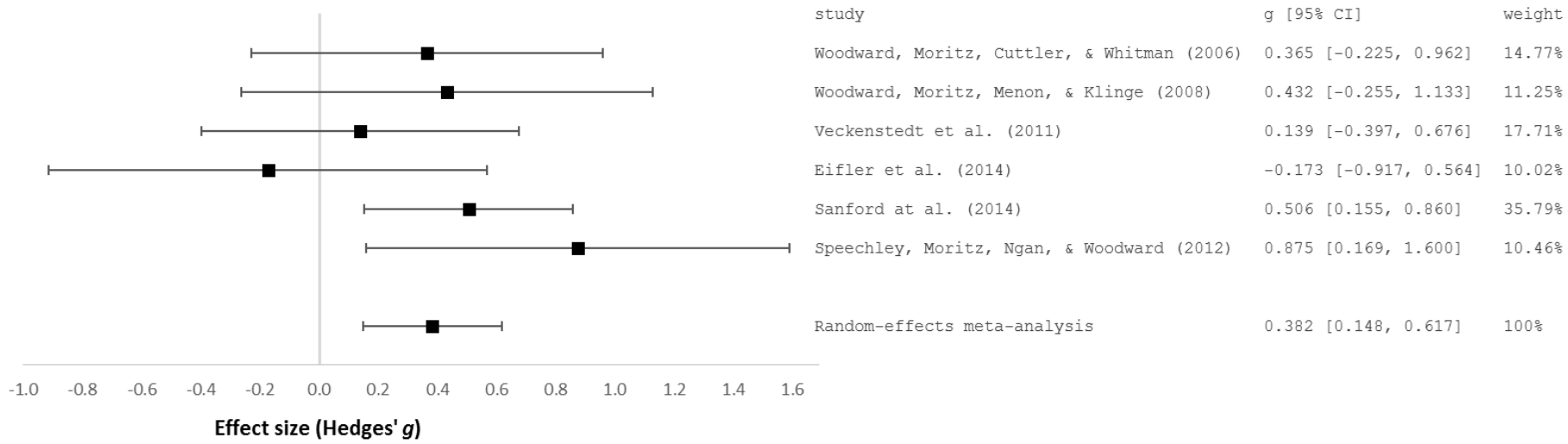

Figure A20. Forest plot of random-effects meta-analysis showing Hedges' g effect sizes, 95% CI's, and study weights for the difference in LA between groups with schizophrenia currently experiencing delusions and groups with schizophrenia not currently experiencing delusions.

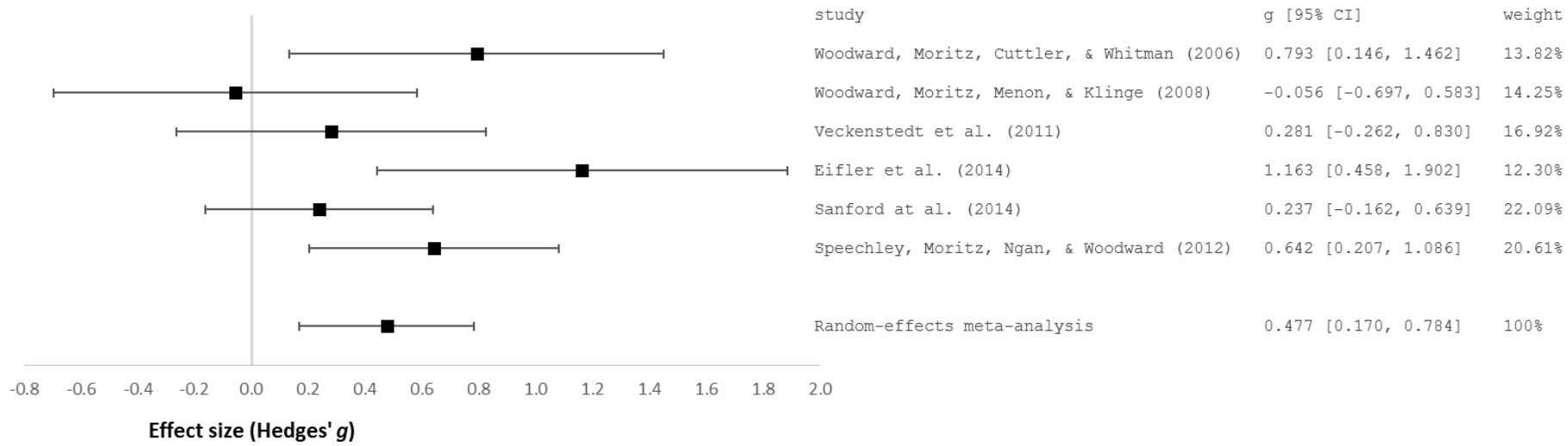

Figure A21. Forest plot of random-effects meta-analysis showing Hedges' g effect sizes, 95% CI's, and study weights for the difference in LA between groups with schizophrenia not currently experiencing delusions and healthy control groups.

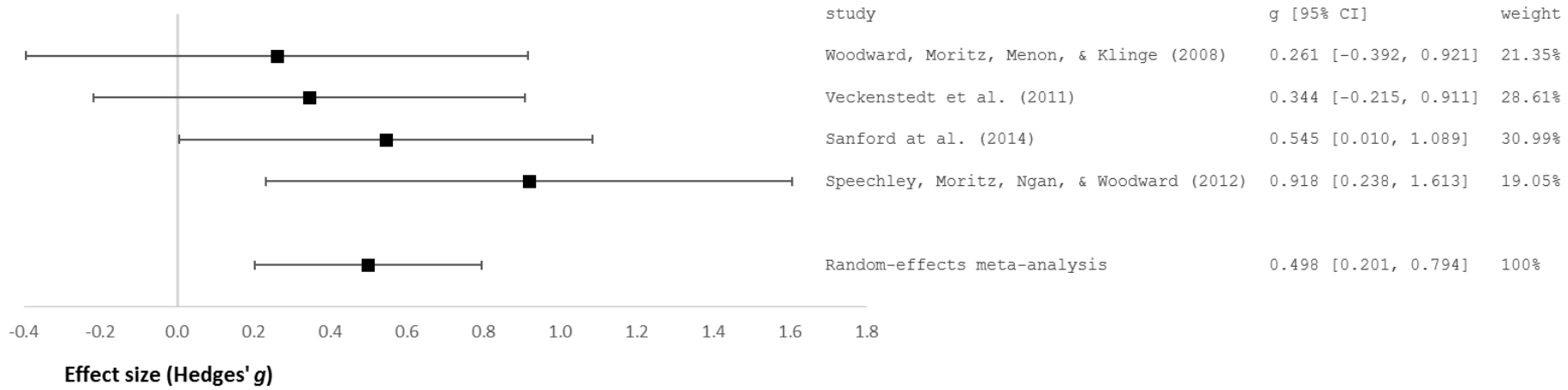

Figure A22. Forest plot of random-effects meta-analysis showing Hedges' g effect sizes, 95% CI's, and study weights for the difference in LA between groups with schizophrenia currently experiencing delusions and groups with other psychiatric illnesses not associated with delusions.

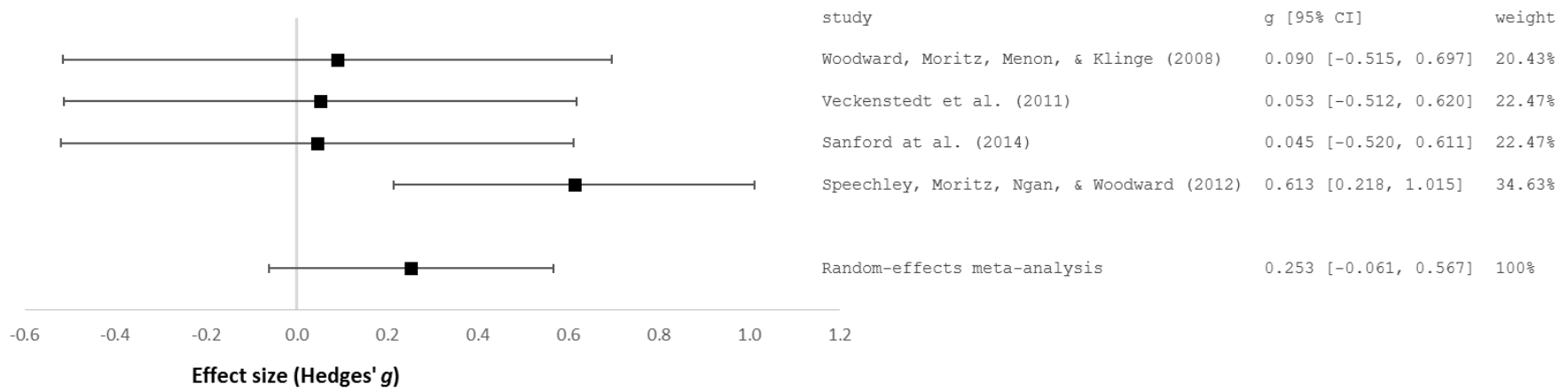

Figure A23. Forest plot of random-effects meta-analysis showing Hedges' g effect sizes, 95% CI's, and study weights for the difference in LA between groups with other psychiatric illnesses not associated with delusions and healthy control groups.

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