Evaluation of the 'Jumping to conclusions' bias in different subgroups of the at-risk mental state: from cognitive basic symptoms to UHR criteria

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Background. Patients with psychosis display the so-called 'Jumping to Conclusions' bias (JTC) – a tendency for hasty decision-making in probabilistic reasoning tasks. So far, only a few studies have evaluated the JTC bias in 'at-risk mental state' (ARMS) patients, specifically in ARMS samples fulfilling 'ultra-high risk' (UHR) criteria, thus not allowing for comparisons between different ARMS subgroups.

Method. In the framework of the PREVENT (secondary prevention of schizophrenia) study, a JTC task was applied to 188 patients either fulfilling UHR criteria or presenting with cognitive basic symptoms (BS). Similar data were available for 30 healthy control participants matched for age, gender, education and premorbid verbal intelligence. ARMS patients were identified by the Structured Interview for Prodromal Symptoms (SIPS) and the Schizophrenia Proneness Instrument – Adult Version (SPI-A).

Results. The mean number of draws to decision (DTD) significantly differed between ARM -subgroups: UHR patients made significantly less draws to make a decision than ARMS patients with only cognitive BS. Furthermore, UHR patients tended to fulfil behavioural criteria for JTC more often than BS patients. In a secondary analysis, ARMS patients were much hastier in their decision-making than controls. In patients, DTD was moderately associated with positive and negative symptoms as well as disorganization and excitement.

Conclusions. Our data indicate an enhanced JTC bias in the UHR group compared to ARMS patients with only cognitive BS. This underscores the importance of reasoning deficits within cognitive theories of the developing psychosis. Interactions with the liability to psychotic transitions and therapeutic interventions should be unravelled in longitudinal studies.

Introduction

Patients with schizophrenia spectrum disorders display cognitive biases. They present a decreased competence to control their own cognition ('thinking about one's thinking'). Typically, impairments affect the abilities to appraise and weigh information effectively, to select appropriate responses including decisions based on perceptions, to cope with cognitive limitations and to build up mental states (Lysaker *et al.* 2008, 2013). One major cognitive bias pertains to decision-making, the executive part of meta-cognition comprising meta-cognitive monitoring and self-regulation (Flavell *et al.* 1993). In marked contrast to self-report data indicating that schizophrenia patients consider themselves as rather hesitant and insecure (Freeman *et al.* 2006), they display an objective

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'Jumping to Conclusions' bias (JTC) – a tendency to hasty decision-making during probabilistic reasoning. The JTC bias in schizophrenia patients was initially described by Hemsley & Garety (1986). Patients display a premature acceptance of beliefs as true, even when there is limited supporting evidence (Garety & Freeman, 1999; Fine *et al.* 2007; Ziegler *et al.* 2008; Lincoln *et al.* 2010). JTC is commonly assessed by the 'beads task' (BT; Huq *et al.* 1988) or slightly modified versions using other stimuli (e.g. fish; Moritz *et al.* 2013). The task requests a decision after a variable amount of stimuli. Incorporating only one (or two) stimuli to come to a decision is defined as JTC (Garety *et al.* 1991; Moritz & Woodward, 2005; Van Dael *et al.* 2006; Speechley *et al.* 2010*b*). Furthermore, in their review that included more than 200 studies Garety and Freeman found JTC to be confirmed as a characteristic of individuals with delusions (Garety & Freeman, 2013).

Currently, several concepts try to link the JTC bias with general cognitive theories in schizophrenia. For example, JTC and altered salience attribution are supposed to be based on a common cognitive bias (Kapur, 2003; Rubio *et al.* 2011; Esslinger *et al.* 2013): A complex dopaminergic dysfunction (Fusar-Poli & Meyer-Lindenberg, 2012*a*, *b*; Howes *et al.* 2012) is considered to lead to the attribution of aberrant salience to stimuli, which could explain why patients are prone to assuming their hypothesis as confirmed by current evidence and making hasty decisions (Hemsley, 2005; Speechley *et al.* 2010*b*). Other authors suggest JTC to be linked to disturbed reward anticipation and learning (Heinz & Schlagenhauf, 2010; Murray, 2011; Juckel *et al.* 2012) as well as to altered prediction error signalling assuming a disturbed error-dependent updating of inferences and beliefs about the world (Hemsley & Garety, 1986; Bentall *et al.* 2009; Fletcher & Frith, 2009; Speechley *et al.* 2010*b*; Murray, 2011; So *et al.* 2012).

So far, several functional magnetic resonance imaging (fMRI) studies have defined neural correlates underlying probabilistic reasoning in healthy volunteers and schizophrenia patients, predominantly involving a fronto-striatal-thalamic network (Blackwood *et al.* 2004; Grinband *et al.* 2006; Weickert *et al.* 2009; Furl & Averbeck, 2011; Koch *et al.* 2011; Bach & Dolan, 2012; Morris *et al.* 2012).

Recently, a hypo-activation in the ventral tegmental area (VTA) and the right ventral striatum (VS) during the point of decision-making was found in schizophrenia patients compared with healthy controls, while a broad cortical activation pattern became apparent during the entire process of probabilistic reasoning (Rausch *et al.* 2014). A comparably reduced activation pattern within the right VS was also revealed in

patients with an 'at-risk mental state' (ARMS; Rausch *et al.* 2015), which illustrates that underlying neurobiological alterations are already present in the ARMS population. Pathogenetic studies in schizophrenia are limited by illness- and treatment-related confounds, which is why comprehensive investigations of ARMS patients are an extraordinarily useful tool to gain insight into the development of pathology over time.

ARMS patients are commonly identified using cognitive basic symptoms (BS) or 'ultra-high-risk' (UHR) criteria. Patients fulfilling UHR criteria present with attenuated psychotic symptoms (APS) and/or brief limited intermittent psychotic symptoms (BLIPS) or display a genetic risk and a deterioration syndrome (Fusar-Poli *et al.* 2013).On average, about 22% of ARMS patients convert to psychosis later on (McGorry *et al.* 2009; Ruhrmann *et al.* 2010; Fusar-Poli *et al.* 2012).

So far, the associations between JTC and neurocognitive properties have been studied in patients with schizophrenia spectrum disorder (Bentall *et al.* 2009; Garety *et al.* 2014), in patients with first-episode psychosis (Falcone *et al.* 2014), in patients with current and remitted delusions (Dudley *et al.* 1997; Colbert *et al.* 2010), in delusion-prone individuals (Colbert & Peters, 2002; White & Mansell, 2009) and in ARMS patients (Broome *et al.* 2007). As meta-cognitive impairments are associated with the development of delusions (Fletcher & Frith, 2009; Speechley *et al.* 2010*a*; Moritz *et al.* 2014; Ross *et al.* 2015), it seems reasonable that the majority of studies assessed JTC in ARMS samples with upcoming psychotic positive symptoms according to the UHR criteria. However, the ARMS sample can be comprehensively characterized if cognitive BS as well as UHR criteria are assessed using sensitive instruments, such as the Early Recognition Inventory based on IRAOS (ERIraos; Häfner *et al.* 2012; Rausch *et al.* 2013; Maurer *et al.* 2015), or the Schizophrenia Proneness Instrument – Adult Version (SPI-A; Schultze-Lutter *et al.* 2007) combined with the Structured Interview for Prodromal Symptoms (SIPS; Miller *et al.* 2003), or the Comprehensive Assessment of At-Risk Mental States (CAARMS; Yung *et al.* 2005). So far, no data are available on JTC in ARMS stages presenting with cognitive BS only and potential differences compared to ARMS stages fulfilling UHR criteria.

Therefore, we evaluated the baseline data of the secondary prevention of schizophrenia study (PREVENT; Bechdolf *et al.* 2011). Within this study, several ARMS subgroups were comprehensively characterized for cognitive BS and UHR criteria, and the JTC bias was assessed. We hypothesized we would find a more pronounced JTC bias in ARMS patients fulfilling UHR criteria (ARMS-UHR) in contrast to ARMS patients only

presenting with cognitive BS (ARMS-BS). Secondary endpoints were the comparison of the ARMS group and a group of healthy control participants that were assessed in a parallel study, as well as correlations of the JTC severity with psychometric data.

Method and materials

The protocol of the clinical multi-centre PREVENT study (registry identifier: ISRCTN: 02658871) was approved by the respective institutional ethical committees of the trial sites. All participants were provided with detailed information about the study, and written informed consent was obtained prior to study entry. Detailed descriptions of design and setting have been published separately (Bechdolf *et al.* 2011), but the most important characteristics are summarized below.

Setting and subjects

The ongoing interventional trial PREVENT was conducted at 12 German Early Intervention Centres (Aachen, Berlin, Bochum, Bonn, Cologne, Dresden, Düsseldorf, Göttingen, Hamburg, Heidelberg, Mannheim, Munich). First, subjects were screened by an Inclusion Criteria Checklist (ICC). For the detailed assessment of UHR criteria, the SIPS including the Scale of Prodromal Symptoms (SOPS) was applied (Miller *et al.* 2003). Additionally, cognitive BS were assessed by the SPI-A (Schultze-Lutter *et al.* 2007).

Inclusion criteria for the ARMS group. Age between 18 and 49 years and attribution to one of the following groups: (A) attenuated positive symptoms – presence of at least one of the following symptoms (SOPS scores 3–5): unusual thought content/delusional ideas, suspiciousness/persecutory ideas, grandiosity, perceptual abnormalities/hallucinations, disorganized communication. (B) Brief limited intermittent psychotic symptoms – presence of at least one of the following symptoms: ⩽7 days resolving spontaneously (SOPS score = 6): hallucinations, delusions, formal thought disorder. (C) Predictive basic symptoms – presence of at least two of the following nine symptoms (SPI-A ⩾3) at least three times a week during the last 3 months: inability to divide attention, thought interferences, thought pressure, thought blockages, disturbance of receptive speech, disturbance of expressive speech, disturbance in abstract thinking, unstable ideas of reference, captivation of attention by details of the visual field. (D) Family risk plus reduced functioning: any DSM-IV psychotic disorder in first-degree relatives or DSM-IV schizotypal personality disorder of the index person plus impaired global functioning [a 30% drop in the Global Assessment of Functioning Scale (GAF) compared to the premorbid level or a score of ⩽50 during the last 12 months].

Exclusion criteria for the ARMS group. (A) Prior or present antipsychotic treatment for >1 week, (B) prior psychotic episode for >1 week, (C) present suicidality or self-harming behaviour, (D) alcohol or substance dependence, (E) presence of an organic brain disease, (F) intelligence quotient (IQ) <70, (G) contemporary or planned pregnancy, breastfeeding or missing reliable method of contraception in case of sexual activity.

Healthy control participants. Thirty healthy control participants were recruited in parallel in the Mannheim study centre. Control subjects were matched for age, gender, level of education and premorbid verbal intelligence. Prior to study entry, all of the participants were comprehensively evaluated to exclude any positive family history of schizophrenia, bipolar disorder or suicide in first-degree relatives, any previous or current psychiatric disorders according to the Mini-International Neuropsychiatric Interview (M.I.N.I.) and any former or present psychopharmacological treatment.

Methods of cross-sectional assessments

Socio-demographic parameters such as age, gender, educational level and estimated level of premorbid verbal intelligence [Multiple-Choice Vocabulary Intelligence Test, version B (MWT-B)] were assessed. For psychometric ratings, the SIPS, the SPI-A, the Positive and Negative Syndrome Scale (PANSS), the Montgomery–Asberg Depression Scale (MADRS), the Social and Occupational Functioning Assessment Scale (SOFAS), and the Clinical Global Impression Scale (CGI) were applied. Furthermore, to assess lifetime diagnoses of co-morbid disorders, the Structured Clinical Interviews for DSM-IV, SCID-I and SCID-II were performed at baseline. Additionally, several neurocognitive and metacognitive tests including a JTC task to assess a tendency towards hasty decision-making during probabilistic reasoning were applied. The JTC task was conducted on a PC screen and requested a probabilistic decision after a variable amount of stimuli. Participants successively viewed a total of ten fish in two different colours being fished out of a lake and had to decide which of two possible lakes they were coming from. Colour ratios in the lakes were 80/20% or 20/80%, respectively. The coloured fish were presented in a predefined fashion (1–1–1–2–1–1–1–1–2–1). After each fish, subjects were asked to estimate the probability of the fish being taken from lake A or lake B. Afterwards they were asked if this probability was already sufficient for them to decide for one of the

two lakes. This task was not repeated, but consisted of a single run (Moritz *et al.* 2013). It has been developed based on the classical BT (Huq *et al.* 1988), where subjects viewed beads of two colours being drawn out of a jar and had to decide which of two jars they were drawn from. Further instructions are identical. The ARMS patients underwent the fish task within the PREVENT study whereas the healthy control participants who allowed secondary analyses completed the classical BT and preponderantly also a modified JTC fish task within fMRI scanning, which was part of another study (also see limitations section). Both tasks are detailed described elsewhere (Esslinger *et al.* 2013; Rausch *et al.* 2015).

Primary outcome

The primary endpoint of this cross-sectional investigation was the comparison of the 'draws to decision' (DTD; number of fish needed for a decision) between the different ARMS subgroups either presenting cognitive BS or fulfilling UHR criteria. The UHR group contains a subgroup presenting with attenuated psychotic symptoms (ARMS-APS) and a subgroup presenting with brief limited intermittent psychotic symptoms (ARMS-BLIPS) (solely or additionally to APS). We hypothesized we would find significantly less DTD in the UHR group. Additionally, we compared the number of subjects showing JTC (defined as one or two draws) expecting to find more JTC in the UHR group.

Within the PREVENT study, patients with genetic risk for psychosis in parallel to reduced functioning were classified as 'vulnerability group' and separated from the ARMS subgroups either presenting cognitive BS or fulfilling UHR criteria. We therefore excluded them from our primary analysis, but not from secondary evaluations.

Secondary outcomes

In order to examine the occurrence of the JTC bias in our ARMS sample *per se* we compared the total ARMS group with a group of healthy control participants who had been investigated in a parallel project in the Mannheim study centre regarding DTD, as a secondary outcome (Rausch *et al.* 2015). Again, we evaluated the number of subjects showing JTC in the different groups.

For exploratory reasons, we further stratified the ARMS group for vulnerability, cognitive BS, APS and BLIPS to evaluate group differences. Moreover, we evaluated possible correlations of DTD with clinical characteristics.

Statistics

Statistical analyses were performed using the SPSS software (IBM SPSS v. 21.0, IBM Corp., USA). Socio-demographic characteristics as well as the primary endpoint were assessed using Student's t tests. Secondary endpoints were evaluated using analysis of variance (ANOVA), two-sided Student's t test and Fisher's exact test to investigate group-specific differences. Correlations were expressed by Pearson's correlation coefficient.

Results

In the framework of the PREVENT study, 234 ARMS patients were recruited and 188 subjects could be included in the final data analysis. In parallel, a sample of 30 healthy control participants was characterized and could be included in the final data analysis. ARMS patients were identified using SIPS and SPI-A. The mean SIPS sum score was 29.2, the mean SPI-A sum score was 60.54. A total of 42 patients were allocated to ARMS-BS and 132 patients were attributed to ARMS-UHR, presenting APS and/or BLIPS (Table 1). Furthermore, 14 subjects were attributed to the vulnerability group (see Method section, inclusion criteria, group D). There were no significant differences regarding age, gender, education and premorbid verbal intelligence between ARMS-BS and ARMS-UHR (Table 1).

Comparison of the ARMS subgroups (ARMS-BS v. ARMS-UHR)

As related to the primary endpoint of this study, the DTD significantly differed between ARMS-BS (3.66 ± 2.35) and ARMS-UHR (2.62 ± 2.25) as UHR patients needed fewer fish to make a decision ($T = 2.30$, df = 172, $p = 0.023$, $d = 0.41$; see Fig. 1). The mean level of certainty (%) at the point of decision did not differ between the ARMS subgroups (ARMS-BS: 84.77 ± 16.62; ARMS-UHR: 84.10 ± 13.39; $T = 0.26$, df = 152, $p = 0.799$, $d = 0.05$).

Furthermore, ARMS-UHR tended to fulfil behavioural criteria for JTC (43.2%) more often than ARMS-BS (26.2%) (Fisher's exact test, $p = 0.069$, $d = 0.28$).

Comparison with healthy control participants

The PREVENT sample of 188 ARMS patients was compared within a secondary analysis with healthy control subjects ($N = 30$) who did not differ significantly regarding age ($p = 0.429$), gender ($p = 0.313$), education as measured by the number of school years ($p = 0.232$) and estimated premorbid verbal intelligence

Table 1. *Socio-demographic and psychopathological characteristics of ARMS-BS and ARMS-UHR subgroups*

	ARMS-BS (N = 42)	ARMS-UHR (N = 132)	Comparison
Socio-demographics, age, years	24.10 ± 3.92	24.77 ± 5.72	p = 0.389
Gender (female/male)	14/28	48/84	Fisher: p = 0.854
School years	11.24 ± 1.98	11.21 ± 2.20	p = 0.942
Multiple choice word test version B (MWT-B)	27.02 ± 4.79	27.14 ± 5.05	p = 0.896
Estimated verbal IQ	102.64 ± 12.58	103.60 ± 13.18	p = 0.681
SIPS	29.53 ± 11.92	29.90 ± 12.50	p = 0.872
SPI-A	67.18 ± 32.12	60.91 ± 35.34	p = 0.335
PANSS			
Total score	47.50 ± 10.78	48.26 ± 12.00	p = 0.731
Positive symptoms	9.58 ± 2.14	11.12 ± 2.99	p = 0.004*
Negative symptoms	11.37 ± 4.74	10.95 ± 4.48	p = 0.622
Global psychopathology	26.55 ± 6.57	26.19 ± 6.62	p = 0.773
Additional scales			
MADRS	21.64 ± 7.81	19.07 ± 8.24	p = 0.076
SOFAS	50.48 ± 13.93	53.71 ± 13.45	p = 0.180
CGI-S	4.11 ± 0.98	4.24 ± 1.01	p = 0.479

Data is reported as mean ± standard deviation (s.d.).

ARMS, At-risk mental state; BS, basic symptoms; CGI-S, Clinical Global Impression – Severity subscore; MADRS, Montgomery–Asberg Depression Scale; PANSS, Positive and Negative Syndrome Scale; SIPS, Structured Interview for Prodromal Symptoms; SOFAS, Social and Occupational Functioning Assessment Scale; SPI-A, Schizophrenia Proneness Instrument – Adult Version; UHR, ultra-high risk;
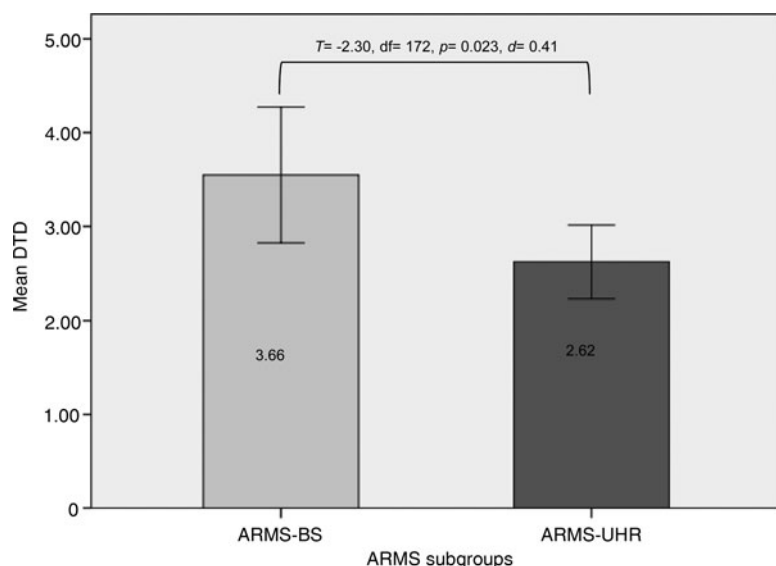
* Significant.

Fig. 1. Displays the mean DTD in the ARMS subgroups. ARMS, At-risk mental state; BS, basic symptoms; DTD, draws to decision; UHR, ultra-high risk.

(MWT-B; p = 0.336). A between-group comparison regarding DTD revealed significant differences, as ARMS patients (2.90 ± 2.32) needed less stimuli than controls (4.20 ± 2.44) to make a decision (T = 2.83, df = 216, p = 0.005, d = 0.56; see Fig. 2). The mean level of certainty (%) at the point of decision differed significantly between groups, as controls were more secure with their decision (ARMS: 84.64 ± 13.90; controls: 89.67 ± 8.09; T = 2.76, df = 64.5, p = 0.008, d = 0.43).

Moreover, the ARMS group tended to show more JTC (38.8%) compared to the control group (20.0%) (Fisher's exact test, p = 0.064, d = 0.25).
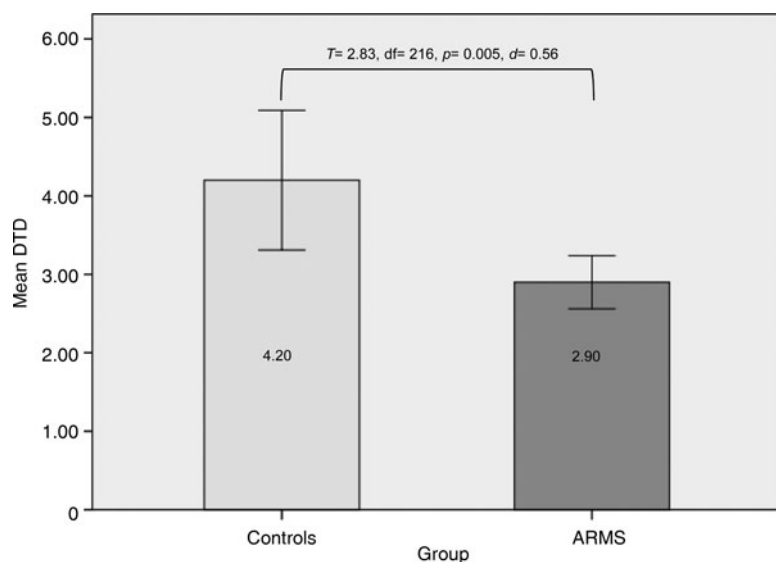
Fig. 2. Displays the mean DTD of ARMS patients and healthy control participants. ARMS, At-risk mental state; DTD, draws to decision.
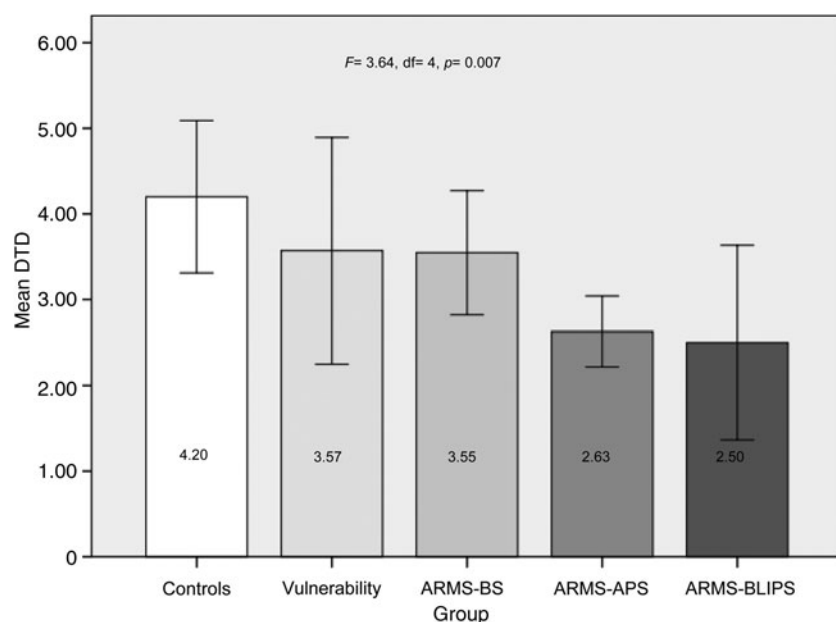

Fig. 3. Displays the mean DTD in the different symptom groups and the healthy control participants. APS, Attenuated psychotic symptoms; ARMS, at-risk mental state; BLIPS, brief limited intermittent psychotic symptoms; BS, basic symptoms; DTD, draws to decision.

Exploratory analysis

The between-group comparison of the entire model including the vulnerability group, ARMS-BS, ARMS-UHR-APS, ARMS-UHR-BLIPS and healthy controls using a one-way ANOVA revealed a significant difference ($F = 3.64$, df = 4, $p = 0.007$, $d = 0.56$). Fig. 3 displays the group means of DTD for all subgroups.

Additionally, a prognostic score allowing for an individualized estimation of the transition risk was recently proposed by Ruhrmann et al. (2010) and Müller et al. (unpublished data). The prognostic score was calculated as $(1.571 \times$ SIPS-positive score > 16) + (0.865 × SCID-II score for schizotypal personality disorder = 3) + (0.793 × bizarre thinking score > 2) + (1.037 × sleep

disturbance score > 2) + [((100 – highest SOFAS in the past year) – 34.64) × 0.033] + [(years of education recoded – 12.52) × 0.250]. Stratifying the ARMS group for the corresponding risk classes revealed a decrease of mean DTDs in parallel to an assumed increase of the risk for transition, with DTD = 3.15 in risk class 1, 2.79 in risk class 2, 2.73 in risk class 3 and 2.00 in risk class 4. The between-group comparison including the four risk classes and the healthy control group using a one-way ANOVA revealed a significant difference ($F = 2.59$, df = 4, $p = 0.038$, $d = 0.57$).

Furthermore, we evaluated possible associations of DTD with the early recognition scales SIPS and SPI-A and their subscales, but no significant correlations became apparent. However, in the entire ARMS group the correlation of DTD with clinical characteristics revealed significant correlations with the PANSS total score ($r = -0.248$, $p = 0.001$) and all scores of the PANSS five-factor model (Van der Gaag et al. 2006) except Emotional Distress that displayed a trend (Positive: $r = -0.228$, $p = 0.003$; Negative: $r = -0.178$, $p = 0.023$; Disorganization: $r = -0.223$, $p = 0.004$; Excitement: $r = -0.199$, $p = 0.011$; Emotional Distress: $r = -0.147$, $p = 0.061$; all two-sided). Stratifying the ARMS group for ARMS-UHR and ARMS-BS, similar correlations became apparent in ARMS-UHR, but in ARMS-BS no significant correlations between DTD and PANSS scores were revealed. Regarding MADRS, SOFAS and CGI, no correlations became evident.

Furthermore, in patients the mean level of certainty (%) at the point of decision significantly correlated with DTD ($r = 0.360$, $p \leqslant 0.001$), as subjects were more secure when they evaluated more stimuli before making a decision. However, no correlations with clinical characteristics were observed.

As DTD might be affected by the premorbid verbal intelligence (MWT-B) we tested for possible associations in the total sample, but no significant correlations became apparent ($r = 0.021$, $p = 0.763$).

Due to the exploratory character of the correlation study, the levels of statistical significance were reported without correction for multiple testing.

Discussion

Our findings indicate that ARMS patients fulfilling UHR criteria, in contrast to patients only presenting with cognitive BS, display an increased behavioural propensity to hasty decision-making. Furthermore, the comparison of ARMS patients and healthy control participants revealed that ARMS patients needed fewer stimuli than controls to reach a decision, confirming previous findings (Broome et al. 2007; Rausch et al. 2015).

In comparison with healthy controls, the ARMS patients were more insecure about their decision. This pattern of findings suggests that ARMS patients tend to decide after fewer stimuli and on the basis of less certainty, which corresponds to findings of Moritz and colleagues, pointing to hasty decision-making based on low subjective certainty (Moritz et al. 2006) and suggesting a liberal acceptance bias to be responsible for decision-making biases in schizophrenia (Moritz et al. 2007, 2008). Moderating effects of the entire amount of information on the subjective certainty seem possible, as suggested be the observed correlation of DTD and certainty.

To our knowledge, so far there is no study comparing different ARMS subgroups (ARMS-BS and ARMS-UHR) regarding JTC. Our data correspond to the results of studies exclusively assessing UHR samples (Broome et al. 2007). Furthermore, our findings add to data on schizophrenia patients that suggest JTC as a 'state' associated with psychotic symptoms as well as a maintaining factor for delusions (Jolley et al. 2014). On the other hand there are findings that support the theory of JTC as a trait phenomenon (Moritz & Woodward, 2005; Van Dael et al. 2006; Garety & Freeman, 2013; Falcone et al. 2014).

However, the JTC bias seems to be an early cognitive marker of the emerging psychotic state. In a recent fMRI investigation, ARMS patients defined according to the ERIraos (Häfner et al. 2012; Rausch et al. 2013; Maurer et al. unpublished data) also presented with JTC and showed reduced activation of the right VS during probabilistic decision-making (Rausch et al. 2015). Our results support associations of JTC with general delusion development, as the ARMS-BLIPS group in average needed the fewest fish to come to a decision. This might indicate a mechanism for the development of BLIPS and disturbed cognition during prodromal states. Taking into account the correlation of DTD with Positive, Negative, Disorganization and Excitement subscores of the PANSS, the JTC bias might be a hint towards general and underlying cognitive alterations that induce the development of psychotic symptoms in general, not only positive symptoms.

Our findings further underpin the proposals of disturbances related to reward anticipation (Heinz & Schlagenhauf, 2010; Murray, 2011; Juckel et al. 2012) and the ability to propagate prediction errors in a hierarchical Bayesian inference framework between lower- and higher-level systems in schizophrenia patients (Lee & Mumford, 2003; Fletcher & Frith, 2009; Friston, 2010; Dura-Bernal et al. 2012), extending them to the ARMS.

Furthermore, since our findings point to a successive increase of JTC during the course of the ARMS, this might suppose the late ARMS stage as a progress –

not only theoretically, but underpinning the patients' increasing cognitive impairment. This fact is reflected in the primary endpoint of the PREVENT trial, defining both transitions from the early to the late ARMS and to the psychotic state. Thus, JTC might display a measure of progressing functional alterations predominantly assigned to striatal brain regions that is accessible for scientific observation.

Besides JTC, several other measures are supposed to reflect the neurobiology in early psychotic states. For instance, Bodatsch *et al.* (2011) found a significant reduction in the duration mismatch-negativity in those ARMS patients who later converted to psychosis, compared to those without a transition. These results might contribute to an individualized prediction of the transition risk. The study of Frommann *et al.* (2011) revealed more pronounced neurocognitive impairments (e.g. in the domains of working memory, processing speed and memory) in an UHR sample compared to patients only presenting with cognitive BS. Similarly, Koutsouleris *et al.* (2012*b*) found executive functioning and verbal IQ deficits to be particular properties of the late ARMS stage. Moreover, they suggest MRI-based biomarkers, e.g. alterations in prefrontal perisylvian and subcortical brain structures, to depict a helpful tool for an improved estimation of the psychosis risk (Koutsouleris *et al.* 2012*a*).

However, it remains to be seen if a predictive value regarding transitions to psychosis can also be attributed to the JTC bias. Therefore, follow-up investigations within the PREVENT sample are mandatory.

Finally, our results underscore the importance of JTC and meta-cognitive deficits in general within cognitive theories of the developing psychosis as JTC is suggested as a state predominantly co-occurring with UHR stages. On the other hand, one could argue that subjects that are not liable to show JTC perhaps will not develop APS or BLIPS. Moreover, these findings highlight the need for complemented psychosis and ARMS treatments with bias modification programmes like meta-cognitive (Moritz *et al.* 2014) and reasoning (Ross *et al.* 2011) training. For instance, Andreou *et al.* (2014) observed a positive association between an improvement of the JTC bias and the vocational outcome in patients with schizophrenia, also underpinning the importance of interventions regarding meta-cognitive deficits.

Limitations

This study is limited by its cross-sectional design, thus prohibiting accounts on the inherent transition risk and on differences regarding the transition risk in several ARMS subgroups. Therefore, the analysis of the longitudinal data of the PREVENT study is crucial.

Furthermore, it must be re-emphasized that the healthy control participants were not recruited within PREVENT and underwent the classical BT instead of the fish task as described above. Regarding DTD, the instructions were identical, but outside this construct slight wording-differences were present. It might be discussed, whether the more salient fish paradigm might have enforced a tendency towards JTC behaviour (Dudley *et al.* 1997; Young & Bentall, 1997). However, we were able to control for this caveat: a comparison of DTD according to the classical BT (mean 4.20 ± 2.44) revealed no significant difference to DTD extracted from a JTC fish task that was applied to a subgroup ($n = 28$) of the healthy control participants during fMRI scanning (mean 4.14 ± 2.29). Therefore we propose that it is feasible to draw a robust measure like DTD out of this data, especially because the mean DTD in our control group matches to scores of control groups reported in other studies (Moritz & Woodward, 2005; White & Mansell, 2009; Colbert *et al.* 2010; Garety and Freeman, 2013; Ermakova *et al.* 2014; Rausch *et al.* 2014).

Conclusions

Data found in our study indicate an enhancement of hasty decision-making in patients fulfilling UHR criteria compared to patients presenting with cognitive BS only. Finally, interactions of JTC with the liability of psychotic transitions and therapeutic interventions should be unravelled during the longitudinal phase of PREVENT.

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Declaration of Interest

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