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A fine-grained analysis of the jumping-to-conclusions bias in schizophrenia: Data-gathering, response confidence, and information integration

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Abstract

Impaired decision behavior has been repeatedly observed in schizophrenia patients. We investigated several cognitive mechanisms that might contribute to the jumping-to-conclusions bias (JTC) seen in schizophrenia patients: biases in information-gathering, information weighting and integration, and overconfidence, using the process tracing paradigm Mouselab. Mouselab allows for an in-depth exploration of various decision-making processes in a structured information environment. A total of 37 schizophrenia patients and 30 healthy controls participated in the experiment. Although showing less focused and systematic information search, schizophrenia patients practically considered all pieces of information and showed no JTC in the sense of collecting less pieces of evidence. Choices of patients and controls both approximated a rational solution quite well, but patients showed more extreme confidence ratings. Both groups mainly used weighted additive decision strategies for information integration and only a small proportion relied on simple heuristics. Under high stress induced by affective valence plus time pressure, however, schizophrenia patients switched to equal weighting strategies: less valid cues and more valid ones were weighted equally.

Keywords: decision making, schizophrenia, jumping to conclusions, heuristics.

1 Introduction

Hasty decision-making is a hallmark feature of presently deluded schizophrenia patients. A look of a stranger, sounds in the telephone line and certain initials on number plates are mistaken as proof of a conspiracy or surveillance. Cognitive studies have asserted that this so-called jumping-to-conclusions bias (JTC) in paranoid schizophrenia is not confined to idiosyncratic and delusions-related scenarios but extends to neutral situations (Garety, Hemsley, & Wessely, 1991; Huq, Garety, & Hemsley, 1988; Moritz & Woodward, 2005; Moritz, Woodward, & Lambert, 2007). While JTC is somewhat aggravated among schizophrenia (Moritz & Woodward, 2005; Startup, Freeman, & Garety, 2008; Van Dael et al., 2006) and sometimes also non-schizophrenia patients with acute persecutory delusions (Corcoran et al., 2008), other studies have found this bias also in remitted paranoid schizophrenia patients (Moritz, Woodward, & Hausmann, 2006; Peters & Garety, 2006). Recently, JTC has been found to correlate with delusion conviction (Garety et al., 2005). A number of researchers ascribe JTC a fundamental role in the pathogenesis of delusions, that is, fixed false beliefs (for reviews see Bell, Halligan, & Ellis, 2006; van der Gaag, 2006).

Traditionally, JTC has been investigated with the beads or probabilistic reasoning task: The subject is consecutively presented a sequence of beads drawn either from a jar that predominantly contains beads, for example in green, or a jar that predominantly contains beads in red (Huq et al., 1988). The chain of events usually strongly favours one of the jars. Compared to both healthy and psychiatric controls, schizophrenia patients make early, premature and incautious decisions in 40–70% of the cases (i.e., they decide after only one bead has been drawn). When presented with the entire available information all at once, group differences are abolished. In addition, probability ratings are usually not discrepant, indicating that patients have a data-gathering bias rather than deficits with probabilistic reasoning. (For an older but still relevant review on this topic, see Garety & Freeman, 1999.)

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Our group has confirmed this bias, ruling out deficits in memory and poor motivation as confounding factors (Moritz & Woodward, 2005). Others have found that this bias is not a result of impulsivity (Dudley, John, Young, & Over, 1997). Using an experimental variant of the “Who wants to be a millionaire” quiz, patients with schizophrenia, irrespective of current delusional ideation, displayed a lowered decision-threshold, that is, they over-interpreted the available amount of evidence (Moritz, Woodward, & Hausmann, 2006). The precise nature of JTC is not entirely understood and under some circumstances (enhanced ambiguity and multiple response options) the bias may even be diminished or abolished (Moritz, Woodward, & Lambert, 2007).

JTC can be conceptualized in different ways. The core contribution of this paper is to investigate JTC as a data-gathering bias (less information is taken into account for decision-making relative to controls) and/or over-confidence (the predictive value of information is over-interpreted relative to controls) and/or suboptimal information weighting and integration (the validity of cues is not considered appropriately or heuristics are more strongly preferred relative to controls). Our group has recently investigated the second aspect, and we have repeatedly found that patients with schizophrenia are over-confident in erroneous decisions (for a review see Moritz & Woodward, 2006), which so far has been mainly investigated in the context of memory tasks (for independent replications see Kircher, Koch, Stottmeister, & Durst, 2007; Laws & Bhatt, 2005). We have also found that patients tend to reach more incautious decisions when asked to deduce the correct title of classical paintings, especially under stress (Moritz et al., 2009) which conforms other studies assigning stress and arousal an aggravating role for cognitive biases in the disorder (Lincoln, Lange, Burau, Exner, & Moritz, in press).

For the present study, we used a task that assesses the data-gathering, confidence, and the information integration aspect of JTC in a single paradigm. We were especially interested to investigate cue selection in patients, since a striking feature of schizophrenia is patients’ reliance on unreliable sources of information (e.g., Internet fora for conspiracy theories). JTC may not be a problem if it is rested on the most valid pieces of information, and indeed cognitive research has found that a subgroup of healthy subjects adopt a so-called *take the best* heuristic (Ayal & Hochman, 2009; Bröder, 2000; Bröder & Schiffer, 2003; Gigerenzer & Goldstein, 1999; see also Hilbig, 2008a; Hilbig, 2008b; Newell, Weston, & Shanks, 2003) and that the application of this heuristic in some environments leads to good decisions (Czerlinski, Gigerenzer, & Goldstein, 1999). Although the beads task remains the gold standard to capture JTC, it does not shed light on this aspect of decision-making, as the sequence of events is pre-determined. Moreover, the beads task estimates JTC on the basis of a single item, reducing its reliability.

A final aim was to investigate the impact of stress exerted by time-pressure and emotionally framed scenarios within-subjects. On the basis of the available literature we expected that patients with schizophrenia (Szs) collect less (H1) and particularly less valid (H2) information, show a less systematic information search inspecting less valid information first (H3), are over-confident in their judgments (H4), and that these biases might be more pronounced under conditions of stress induced by time-pressure or affective framing of the task (H5) compared to controls (CPs). Following an exploratory account, we investigated whether there are differences in choice accuracy, whether subjects particularly rely on a take the best strategy and if there is a relation between schizophrenia severity measures (i.e., PANSS; see below) and the different aspects of JTC biases.

1.1 Methodological preliminaries

The aforementioned hypotheses for decision-making in schizophrenia were investigated using emotional and neutral probabilistic inference tasks that have been repeatedly investigated in recent research on heuristics, that is, simple short-cut decision strategies (Bröder & Gaissmaier, 2007; Bröder & Schiffer, 2006; Gigerenzer & Goldstein, 1996; Glöckner, 2006; Newell et al., 2003).[1] We used the standard process tracing paradigm of behavioral decision research: Mouselab (Payne, Bettman, & Johnson, 1988).[2] In Mouselab, different cues (i.e., predictors) and their varying validity (i.e., predictive accuracy) are presented in a two-dimensional matrix (Figure 1). Information is (usually) hidden behind information cards and can be investigated by mouse click. Besides choices, decision times and confidence ratings, Mouselab allows recording and analyzing the amount, distribution and order of information search to infer individuals’ decision strategies (for a discussion of the limitations of Mouselab, see Glöckner & Betsch, 2008c).

2 Method

2.1 Subjects

Overall, 67 subjects took part in the experiment. They belonged to a clinical condition of schizophrenic patients (Szs) or were healthy persons (CPs). The sample consisted of 37 Szs and 30 CPs. Patients were inpatients re-

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[1] In contrast to preference decisions (e.g., which car do you prefer), probabilistic inference tasks have an objectively correct solution.

[2] For an early study using classic cognitive tasks to investigate the processes underlying formal thought disorders see also Persons and Baron (1985).

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cruited at the Department of Psychiatry and Psychotherapy of the University Medical Center Hamburg Eppendorf. Healthy subjects were recruited via a subject pool, advertisement and word-of-mouth. No monetary or other incentive was provided for any of the subjects. All patients gave written informed consent for participation. Diagnoses relied on DSM-IV criteria for schizophrenia which were determined by experienced clinicians using the neuropsychiatric MINI interview (Sheehan et al., 1998). Symptom severity was assessed by the same clinicians with the Positive and Negative Syndrome Scale (PANSS; Kay, Opler, & Lindenmayer, 1989) following a semi-structured interview. The PANSS has 30 items. The positive and negative syndrome scores were composed following the standard algorithm (sum of all seven positive and all seven negative items, respectively). In addition, we computed a core delusion score which was comprised of the items tapping delusions, suspiciousness and unusual thought content. In keeping with factor analytic studies which have reliably detected a syndrome called disorganization, we also computed a disorganization factor capturing formal thought disorder, posturing/mannerisms and disorientation.

None of the patients had substance dependency or neurological disorders. Healthy subjects were screened for absence of a psychiatric illness using the MINI interview. Additionally, the premorbid intelligence of all subjects was tested using a vocabulary test, the Multiple Choice Intelligence Task (MWT-B; Lehrl, 1995). The MWT-B requests the subject with 36 items each consisting of 5 words, of which only one is a correctly spelled noun. Neuroleptic dosage was converted in % maximal neuroleptic dosage following German prescription guidelines.

The groups were comparable in age (M_{Szs}= 31.8, SD_{Szs}=10.5 vs. M_{CPs}= 32.1, SD_{CPs}=12.0 years), IQ (both M=106, SD_{Szs}=12.8, SD_{CPs}=38.8) and duration of school education (M_{Szs}= 11.5, SD_{Szs}=1.6 vs. M_{CPs}= 11.9, SD_{CPs}=1.6 years). Szs were mainly male (28 male), whereas CPs were mainly female (20 female).[3] Szs received inpatient treatment on average 3.5 times (SD=3.7; including the current hospitalization).

2.2 Materials and design

All subjects completed a total of 108 probabilistic inference decisions between three options based on 3 cues which differed in validity (i.e., the percentage of correct predictions given a certain criterion value). The cues had a validity of .70, .80, and .60 (i.e., predictive validity of 70%, 80% and 60% accuracy). Subjects were explicitly informed about the validity of the cues which was equal in all decision tasks. Half of the decisions used neutral materials (i.e., chose the better out of three brands of oranges; Figure 1, left), the other used more affective material (i.e., chose one out of three persons who more likely committed a crime; Figure 1, right) constituting the factor Affective Valence.[4] This factor was fully crossed with the factor Presentation Format/Time Pressure. A third of the decisions were presented in the classic Mouselab format with hidden information boxes and without time pressure, another third was presented in the same paradigm but with explicit time pressure induction using a time-bar (Figure 1, left). In the remaining decision tasks, information was instantly available and subjects were instructed to decide as quickly as possible (Figure 1, right). Subjects completed 18 decisions for the six combinations of conditions each, constituting the factor Decisions. Decision tasks were similar to the ones used in previous studies (Glöckner & Betsch, 2008c). Hence, we used a 2 (Szs vs. CPs) x 2 (Affective Valence) x 3 (Presentation Format/Time Pressure) x 18 (Decisions) design with all factors except of the first one being manipulated within subjects. Subjects were assigned to one out of four balancing conditions in which order of the relevant conditions was varied (neutral vs. affective first; hidden vs. open information first).[5]

2.3 Procedure

Subjects first completed a mouse-ability pre-test in which they opened the nine boxes of the information matrix by mouse-click as quickly as possible. This test was later used to adapt trial duration to the subjects' individual speeds. This procedure was repeated five times to determine the average time for information search. Subjects were introduced to the decision task using the neutral material (i.e., select the best orange based on testers). The three presentation formats of Presentation Format/Time Pressure were introduced (i.e., hidden information Mouselab, hidden information Mouselab + time

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[3] To control for gender effects, we also ran the core analyses correcting for gender effects using gender as covariate. Although we observed some gender effects, the results concerning our hypotheses were similar to the results without covariate. In the following, only the simpler analyses without the covariate are reported.

[4] The effectivity of the manipulation of affective valence was shown in a comprehensive pre-study (N=122; student population) using essentially the same material and procedure. Subjects (among other measures) indicated in how far they were emotionally affected by the different types of decisions. A repeated measurement ANOVA with valence as within subjects factor indicated a strong and significant effect on the ratings, F (1, 121) = 64.8, $p < .001$, $\eta^2 = .35$. Subjects were much more emotionally affected by the criminal case decision tasks as compared to the orange decision tasks.

[5] For pragmatic reasons, hidden information presentation under time pressure always followed after hidden information presentation without time pressure. Due to some error in the randomization procedure, subjects were not exactly equally distributed over the counterbalancing conditions.

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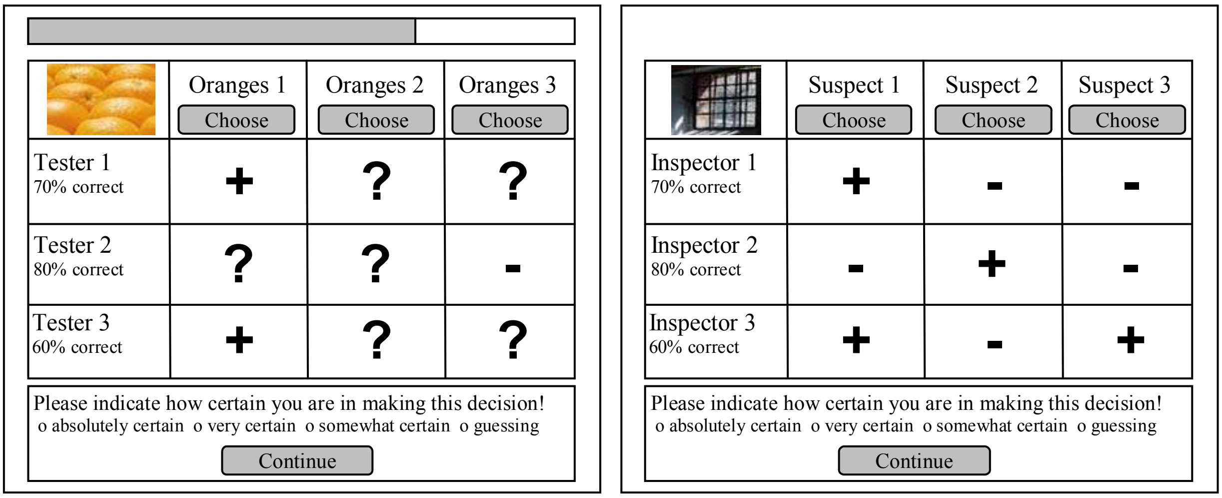

	Oranges 1 Choose	Oranges 2 Choose	Oranges 3 Choose
Tester 1 70% correct	+	?	?
Tester 2 80% correct	?	?	-
Tester 3 60% correct	+	?	?

Please indicate how certain you are in making this decision!
o absolutely certain o very certain o somewhat certain o guessing

	Suspect 1 Choose	Suspect 2 Choose	Suspect 3 Choose
Inspector 1 70% correct	+	-	-
Inspector 2 80% correct	-	+	-
Inspector 3 60% correct	+	-	+

Please indicate how certain you are in making this decision!
o absolutely certain o very certain o somewhat certain o guessing

Figure 1: Decision screens for neutral orange decisions (left) and affective criminal case decisions (right). The left picture shows an example for a Mouselab with time-pressure condition, the right picture shows an example for open information presentation (cf. factor Presentation Format/Time Pressure).

pressure, open information Mouselab) and subjects completed a test decision for each of them. Complete instruction can be found in the appendix. Each decision trial started with the presentation of the information matrix with open or hidden information cards. In the two hidden-information conditions, information cards could be opened with the mouse and remained open for the rest of the decision. Decision time was recorded from stimulus onset (open information), or from the inspection of the first information card (hidden information). In the explicit time pressure condition, only a limited time was available for information search. The time was individually determined from the average time for information search (see above) in the mouse-ability pre-test plus 2 seconds. Hence, there was just sufficient time for inspecting all information and applying a simple decision strategy. A down-counting time-bar was used to induce time pressure (see Figure 1, left). Options were selected by mouse-click. Afterwards individuals rated the confidence in their decision on the following 4-point scale: *absolutely certain* (1), *very certain* (2), *somewhat certain* (3), *guessing* (4).[6] Finally, subjects were informed that the next decision was about other oranges or other accused persons, and the next trial was started by mouse-click. Decision tasks were presented using a block design of six blocks (2 Affective Valence x 3 Presentation Format/Time Pressure) with randomized order of decisions within each block. After each block, a short break and a new instruction for the following block was included.

The aspects of JTC were tapped via the following variables:

1. Biased gathering of information
    - Amount of inspected information.
    - Validity of inspected information.
    - Order of information search (i.e., is more valid information inspected first).
2. Overconfidence
    - Number of confidence ratings “absolutely certain”. Given that even the best cue had a validity of no more than 80%, any absolutely certain response was deemed incautious.
3. Suboptimal weighting and information integration
    - Percentage of normatively correct answers according to Bayes’ theorem.
    - Individuals’ decision strategies. The percentage of subjects that take into account all information and weight them by their validity (weighted additive strategy users), was compared with the proportion of subjects that ignore less valid information (take the best users), and the ones that ignore cue weights (equal weight users).

3 Results

Checks for mouse handling. Overall, Szs and CPs were both well able to handle the pre-test as well as the main experiment. There were no drop outs during the

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[6] The corresponding scale labels in German language were: “völlig sicher”, “sehr sicher”, “wenig sicher”, and “geraten”. The original question was: “Schätzen Sie bitte ein, wie sicher Sie sich bei dieser Entscheidung sind!”

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Table 1: Means of log-transformed decision times with *SE*s in parentheses. MOUS, MOUS+TP, OPEN refer to the presentation formats mouselab, mouselab with time pressure, and open mouselab. Szs are schizophrenic patients, CPs are controls.

	Neutral			Affective		
	MOUS	MOUS+TP	OPEN	MOUS	MOUS+TP	OPEN
Szs	3.82 (0.04)	3.69 (0.04)	3.58 (0.03)	3.84 (0.04)	3.73 (0.03)	3.58 (0.03)
CPs	3.84 (0.05)	3.67 (0.04)	3.52 (0.04)	3.84 (0.04)	3.68 (0.03)	3.54 (0.04)

experiment. Since the program was computer directed, no missing values occurred for our main dependent variables. To analyze whether the Szs differ from CPs in their mouse-handling skills, a *t*-test was conducted using mean reaction time in the mouse pre-test as dependent variable. The test revealed a marginally significant difference, $t(61.7) = 1.70$, $p = .09$. As expected, reaction time was higher for the Szs (M=7.1 sec) compared to the CPs (M=6.1 sec) indicating lower mouse-handling skills of the former. As outlined above, slowed subjects were automatically allowed more time for the time-pressure tasks.

Decision times. Decision times were log-transformed to base 10 before conducting the analysis to correct for deviations from normal distribution and to reduce the influence of outliers. A 2 (Szs vs. CPs) x 2 (Affective Valence) x 3 (Presentation Format/Time Pressure) x 18 (Decisions) mixed model analysis of variance (ANOVA) was computed to analyse log-transformed decision times. There was a highly significant main effect for Presentation Format/Time Pressure, F (1.4, 92.4) = 95.5, $p <$ .001, $\eta^2 = .60$ (as in all following analyses Greenhouse-Geisser correction was used if the assumption of sphericity was violated). The log-mean decision times for the conditions hidden information Mouselab, hidden information Mouselab with time pressure, and open information Mouselab were 6.8 sec, 4.9 sec, and 3.6 sec. Thus, the time pressure manipulation worked, in that decision times decreased if a time limit was enforced in Mouselab. Note, however, that decision time in the open Mouselab paradigm was even way below the decision time in the time pressure Mouselab condition. The main effect for clinical condition and all interactions did not reach conventional significance levels (all $Fs < 1.4$; Table 1). Thus, decision time did not differ between Szs and CPs. Hence, although Szs were slower in simple mouse-handling, they did not show longer decision times overall.

Information search. To test the hypotheses that Szs look up less information (H1) and concentrate more on less valid information (H2) than CPs, we calculated information inspection scores, which measure the percentage of opened information boxes per cue for each of the 2 (Affective Valence) x 2 (Presentation Format/Time Pressure: hidden information Mouselab with vs. without time pressure) blocks of decision tasks. Descriptive statistics are summarized in Table 2. A 2 (Szs vs. CPs) x 2 (Affective Valence) x 2 (Presentation format/Time Pressure: hidden information Mouselab with vs. without time pressure) x 3 (Cue) mixed model ANOVA was calculated using information inspection scores as dependent variable. There was no main effect of clinical condition, F (1, 65) = .57, $p = .45$, $\eta^2 = .009$. In the structured information environment Mouselab, Szs inspected 91% and CPs 88% of the information. Hence, there was no reduced information search of Szs and H1 was not supported by the data. There was a main effect for Cue, indicating that subjects focused more on more valid cues, F (1.2, 77.9) = 23.2, $p < .001$, $\eta^2 = .26$. For cue 2 (80% validity), 97% of the information was inspected, whereas for the cues 1 (70% validity) and 3 (60% validity) only 89% and 83% were investigated. Descriptively, Szs focused less strongly on this most valid cue and more on the less valid cues compared to CPs, indicating a less systematic information search. The respective interaction effect, however, did not reach conventional significance levels in a two-sided test, F (1.2, 77.9) = 1.86, $p = .17$, $\eta^2 = .03$.

To explore H2 (less valid information) directly, we compared information search differences of Szs and CPs for cue 2 (80%; most valid cue) and cue 3 (60%; least valid cue) using planned deviation contrasts. The interactions between cue 2 (cue 3) vs. the grand mean and Szs vs. CPs both turned out to be marginally significant, F (1, 65) = 1.93, $p = .08$, $\eta^2 = .03$ (F (1, 65) = 2.15, $p =$ .07, $\eta^2 = .03$; both one-sided).[7] This provides support that SPs, indeed, look up the most valid cue less often than CPs and in contrast investigate the least valid cue more often. To test the robustness of these marginally significant results, we rerun the analysis using a multilevel regression with random effects for subjects (Nezlek, Schröder-Abe, & Schütz, 2006) and a clustered regres-

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[7] Due to the fact that we had a directed hypothesis, we used one-sided tests.

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Table 2: Mean information inspection rate with *SE*s in parentheses by cue. MOUS, MOUS+TP, OPEN refer to the presentation formats mouselab, mouselab with time pressure, and open mouselab. Szs are schizophrenic patients, CPs are controls.

	Neutral		Affective		Overall
	MOUS	MOUS+TP	MOUS	MOUS+TP	
Cue 1 (70% correct)					
Szs	0.88 (0.03)	0.90 (0.04)	0.94 (0.02)	0.92 (0.03)	0.91 (0.02)
CPs	0.88 (0.04)	0.85 (0.04)	0.90 (0.03)	0.88 (0.04)	0.88 (0.02)
Cue 2 (80% correct)					
Szs	0.95 (0.02)	0.95 (0.02)	0.96 (0.02)	0.98 (0.01)	0.96 (0.01)
CPs	0.97 (0.03)	0.98 (0.03)	0.98 (0.02)	0.98 (0.01)	0.98 (0.01)
Cue 3 (60% correct)					
Szs	0.84 (0.05)	0.87 (0.05)	0.88 (0.04)	0.85 (0.05)	0.86 (0.02)
CPs	0.80 (0.05)	0.76 (0.05)	0.82 (0.04)	0.80 (0.05)	0.80 (0.02)

sion (Rogers, 1993) using robust standard errors (Hayes & Cai, 2007). In the former, both effects reached the conventional significance level (both $p < .05$; one-sided), in the latter the cue2-interaction-effect was marginally significant ($p < .10$) whereas the cue 3-interaction-effect was significant ($p < .05$). Hence, results seem to be robust and we conclude that there is support for H2 in that patients are less guided by valid information.

To analyze H3 (that Szs use a less focused and more unsystematic information search), we analyzed the amount of information search that focused on the most important cue (i.e., cue 2) for the first three information acquisitions in each decision. Assuming that all pieces of information are looked up, this represents the first third of information inspections.[8] In all three cases, CPs focused much more strongly on the most valid cue than Szs (total proportion of acquisitions on the most valid cue in 1st: 47% vs. 24%; 2nd: 65% vs. 40%; 3rd acquisition: 47% vs. 21%). We calculated initial-focus scores indicating the average frequency of inspections of the most valid cue in the first three acquisitions per person. The score was significantly higher for CPs ($M = 1.06$, $SE = 0.13$) as compared to Szs ($M = 0.56$, $SE = 0.10$) according to an independent *t*-test, $t(65) = 3.04$, $p < .01$. Hence, there is support for H3 that Szs show a less systematic information search.

Confidence ratings. It has been shown that overconfidence of Szs does not always result in a generally increased confidence level, but in more frequent extreme ratings (i.e., feelings of absolute confidence; Moritz & Woodward, 2006). Therefore, in line with previous research (Moritz, Woodward, & Rodriguez-Raecke, 2006; see also Moritz, Woodward, Whitman, & Cuttler, 2005) we tested H4 by investigating the frequency of the rating "absolutely certain". In the probabilistic inference task used in the study, one could never be absolutely certain that a chosen outcome would be realized, because posterior probabilities were all below 1. Hence, "absolutely certain" ratings are deemed incautious. An extreme rating score (i.e., frequency of absolutely certain ratings) was analyzed using an independent *t*-test. In line with earlier findings, we observed a significantly higher number of extreme ratings from Szs ($M = 28.7$) as compared to CPs ($M = 9.3$), $t(52.2) = 2.8$, $p = .007$, supporting H4.

We additionally conducted a 2 (Szs vs. CPs) x 2 (Affective Valence) x 3 (Presentation Format/Time Pressure) x 18 (Decisions) mixed model ANOVA to analyse mean confidence ratings. There was also a tendency that Szs ($M = 2.17$) were more confident in their decisions than CPs ($M = 2.40$) (low scores indicate high confidence), which, however, did not reach conventional significance levels, $F(1, 65) = 2.15$, $p = .15$, $\eta^2 = .03$. There were main effects for affective valence, $F(1, 65) = 8.3$, $p = .005$, $\eta^2 = .11$ and Presentation Format/Time Pressure, $F(2.0, 129.8) = 4.8$, $p = .01$, $\eta^2 = .07$. Subjects were more confident in the neutral ($M = 2.22$) as compared to the emotional ($M = 2.34$) decisions. There was, however, no interaction with the clinical condition. Subjects under time pressure were less confident than in the two other conditions. Nevertheless, these results should be interpreted cautiously because it is not entirely clear whether our measure for confidence ratings is interval-scaled.

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[8] Due to the fact that information boxes remain open after being inspected, this effect was naturally reversed for the remaining two-thirds of information inspections.

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Table 3: Mean confidence scores with *SE*s in parentheses. MOUS, MOUS+TP, OPEN refer to the presentation formats mouselab, mouselab with time pressure, and open mouselab. Szs are schizophrenic patients, CPs are controls. Confidence scale ranged from 1 (*absolutely certain*) to 4 (*guessing*).

	Neutral			Affective		
	MOUS	MOUS+TP	OPEN	MOUS	MOUS+TP	OPEN
Szs	2.06 (0.11)	2.19 (0.11)	2.15 (0.11)	2.24 (0.11)	2.27 (0.11)	2.12 (0.10)
CPs	2.31 (0.13)	2.33 (0.12)	2.31 (0.13)	2.41 (0.13)	2.55 (0.12)	2.47 (0.11)

To investigate the effect further, we examined the number of extreme ratings separately for correct and wrong decisions according to Bayes' Theorem (see also below). We determined for each decision whether people did or did not chose the option with the highest posterior probabilities for being of good quality from the set of available options.[9] Interestingly, the effect was driven by more extreme ratings in the cases in which subjects made correct decisions and the difference between CPs and Szs was not significant for the wrong decisions. Hence, in the structured environment Mouselab, Szs used more extreme ratings, but mainly in cases in which they made normatively correct decisions. Thus, in line with the previous results, Szs seem to show more extreme confidence ratings, but often these occur in cases in which their decisions are normatively correct.

Quality of choices. To analyze the quality of choices we calculated whether choices were in line with the optimal solution according to Bayes' Theorem. In both conditions, a high proportion of correct choices was observed. Szs showed 75% correct choices, CPs showed 77%. There was no significant difference concerning quality of choices between Szs and CPs (see logistic regression in additional analyses below). In a structured information environment which provided information about cue validities and allowed information search in a limited space, Szs decided with similar accuracy to CPs.

Decision strategy analysis. Individuals' decision strategies were analyzed by within-subjects comparisons of the distribution of choices using χ^2-tests (for detailed description of the method see Glöckner & Betsch, 2008c).[10] The method allowed to determine if individuals used a take the best heuristic (TTB, i.e., ignore less valid information and based their decision on the most important information only), an equal weight heuristic (EQW, i.e., ignore the validity of cues and chose the option which has more positive predictions), or a weighted additive strategy (WADD, i.e., choose the option with the higher weighted sum of cue values and cue validities) (Payne et al., 1988). The results indicate that there was no increased usage of TTB for Szs (Table 4).[11]

In line with recent findings, Szs and CPs both mainly used a WADD strategy (cf. Bröder, 2003) that might be based on automatic processing (Glöckner, 2008; Glöckner & Betsch, 2008a, 2008b, 2008c; Glöckner & Herbold, in press; Glöckner & Hodges, 2009; Glöckner & Witteman, in press). Interestingly, this is not the case for Szs who have to make (affective) criminal decisions under time pressure. Under this very specific condition Szs show an increased usage of EQW. This result indicates that Szs ignore cue weights in high stress conditions in which time pressure and high affective valence coincide. According to rational standards of probability theory, this can be considered a bias because the predictions of the cues differ in their validity, which should be taken into

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[9] The optimal solution to the problem is to choose the option with the highest posterior probability being of good quality given the base-rate and all cue values. The cue validities provided in this experiment can be interpreted as prior probabilities [$p(\text{cue}_{+}|\text{O}_{+}) = 1 - p(\text{cue}_{-}|\text{O}_{+})$; with O indicating options (A, B or C) and subscripts +/- indicating positive/negative criterion values or cue values, respectively]. Hence, under the assumption that the cues make independent predictions the posterior probability for good quality of, for instance, option A, $p(\text{A} \mid \text{cues, base-rate})$, according to Bayes' theorem can be determined using the base rate, the cue values and the prior probabilities of the cues according to:

$$\frac{p(A|p_A, p_{C1}, p_{C2}, p_{C3})}{1-p(A|p_A, p_{C1}, p_{C2}, p_{C3})} = \frac{p_A}{1-p_A}\frac{p_{C1}}{1-p_{C1}}\frac{p_{C2}}{1-p_{C2}}\frac{p_{C3}}{1-p_{C3}}$$

p_A is the base-rate for good quality of option A. Because each decision is made between new options no informative base-rate information is available (we set p_A=.50 which can be ignored in calculations). p_{C1}, p_{C2}, and p_{C3} are the prior probabilities of the respective cue value given the option has good quality (i.e., for positive cue values: .70, .80, .60; for negative cue values: .30, .20, .40). The option with the highest posterior probability for good quality should be chosen.

[10] Per subject two χ^2-tests were conducted, which tested against the null hypotheses that individuals ignored less valid cues (i.e., used TTB) and that they did not take into account cue weights (i.e., used EQW). Only if both hypotheses could be rejected, individuals were classified as WADD users. In the case that the error rate for the classified strategy was above .50, individuals' decision strategy was not classified (but see Glöckner, 2009, for an improved methodological approach).

[11] Because of a programming error, decision strategies could be reliably determined only for the Presentation Format/Time Pressure conditions hidden information Mouselab with time pressure and open information Mouselab.

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Table 4: Proportion of subjects using the respective decision strategy by condition. TTB (take the best) strategy indicates ignorance of less valid cues, EQW (equal weight) strategy indicates inappropriate equal weighting of cue information, WADD (weighted additive) strategy indicates an integration of cue information according to its validity. For the clinical condition, Szs stands for schizophrenia patients, CPs for controls.

	Decision strategy classification (in %)			
Clinical condition	TTB	EQW	WADD	not class.
Time pressure Mouselab neutral (oranges)				
Szs	0.16	0.16	0.59	0.08
CPs	0.2	0.2	0.57	0.03
Open Mouselab neutral (oranges)				
Szs	0.14	0	0.78	0.08
CPs	0.2	0.13	0.67	0
Time pressure Mouselab affective (criminal case)				
Szs	0.19	0.35	0.38	0.08
CPs	0.17	0.23	0.57	0.03
Open Mouselab affective (criminal case)				
Szs	0.14	0.08	0.73	0.05
CPs	0.17	0.1	0.7	0.03

account. To test this result statistically, we conducted a logistic regression with usage of WADD (0=no, 1=yes) as categorical dependent variable, and clinical condition (Sz=1 vs. CP=0), and a contrast comparing the high stress conditions (i.e., Mouselab with time pressure and affective content; coded 1) against the remaining conditions (coded $-1/3$) as well as their interaction as predictors.[12] The interaction between clinical condition and the contrast for high versus low stress condition turned out significant, *Odds-ratio* = .33, $z = -2.19$, $p = 0.029$ indicating that (after correcting for the main effects) the probability for usage of WADD was reduced in the stress condition to one third as compared to the other conditions.

Differential influence of time pressure and affective valence on Szs vs. CPs. As indicated by the previous analyses, there was a main effect of time pressure on decision time and a main effect of affective valence and time pressure on confidence. We did not, however, find significant interactions of these factors with clinical condition, indicating that there are no differential effects of stress induced by time pressure and affective valence on Szs as compared to CPs concerning decision time, confidence and information search. As reported in the last section, we found a shift in decision strategies specifically for Szs under high stress induced by time pressure and affective valence. Under this condition, many Szs used EQW which means that they seemed to ignore the validity of cues. Hence, H5 that biases of Szs should be more pronounced under stress was supported by the data for information integration strategies, but not for confidence and information search.

Correlations between schizophrenia measures and dependent variables. The observed mean PANSS sum-score largely corresponds to a "mildly ill" clinical state according to the criteria adopted by Leucht et al. (2005). For Szs, the PANSS sum-score and the subscales of the PANSS (positive, negative, disorganization, delusions) were correlated with the total amount of information search, and the number of absolutely certain ratings (Table 5). The amount of information search correlated marginally significantly and negatively with the PANSS sum-score. The effect was mainly driven by correlations with the PANSS positive and PANSS delusion subscale and it did also hold in a regression when simultaneously controlling for intelligence and gender differences (at $p <$ .05). This indicates that the amount of information search decreases with the severity of schizophrenia symptoms. There were, however, no significant correlations between the amount of absolute certain ratings and the schizophrenia measures. Due to the relatively small power in the analysis (power = .45; two-tailed test assuming a medium effect r = .30; Faul, Erdfelder, Lang, & Buchner, 2007), further research must determine whether this null result replicates (but see also the general discussion for similar findings in previous studies).

Maximal neuroleptic dosage following German prescription guidelines (in percent) did not differ between users of different strategies and did not correlate significantly with information search, and confidence. The average dosage was $M = 61\%$ ($SD = 44\%$).

Additional analyses. We observed training effects over the 108 choices in the main experiment. Subjects decided more quicly over time. We regressed decision time (in milliseconds) on order (1 to 108), clinical condition (Sz=1, CP=0), and their interaction and found a significant order effect, $b = -25.62$, $t = -4.72$, $p < 0.001$, but no interaction with clinical condition, $b = -9.80$, $t = -1.19$, $p = 0.24$. Hence, training effects were not significantly different for Szs and CPs. Furthermore, we investigated

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[12] As in all following regressions we corrected for clusters in the data due to repeated measurement (Rogers, 1993) and used robust standard errors (Hayes & Cai, 2007) relying on STATA standard commands "cluster" and "robust" (Gould, Pitblado, & Sribney, 2006).

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Table 5: Descriptive statistics for schizophrenia measures and correlation with decision parameters (amount of information search, amount of absolute certain ratings for confidence). $^{+}p < .10$; $^{*}p < .05$.

Schizophrenia measures	*M* (*S.D.*)	Info search	Amount absolute certain
PANSS Sum-Score	52.1 (13.8)	$-.30^{+}$	$-.01$
PANSS positive (positive items 1-7, conventional algorithm)	11.6 (6.4)	$-.38^{*}$	$-.05$
PANSS negative (negative items 1-7, conventional algorithm)	11.3 (3.9)	$-.27$	.03
PANSS desorg (positive item 2, global items 5 and 10)	3.4 (0.9)	$-.01$	$-.17$
PANSS core delusional items (positive items 1 and 6, global item 9)	7.5 (4.3)	$-.40^{*}$	$-.10$

whether the correctness of choices according to the normative Bayes' standard changed over time by conducting a logistic regression with correct scores (1=correct, 0=wrong) as dependent variable and order (1 to 108), clinical condition (Sz=1, CP=0), and their interaction as predictors. None of these effects turned out significant (clinical condition: *Odds−ratio*=.97, $z = -0.12, p = 0.91$; order: *Odds-ratio*=.997, $z = -1.25$, $p = 0.211$; interaction: *Odds-ratio*=.998, $z = -0.36$, $p= 0.72$). Hence, also for performance there were no differential learning effects for Szs as compared to CPs.

4 Discussion

In the current study, we used Mouselab to investigate different aspects of jumping to conclusions (JTC) in schizophrenia versus healthy subjects: information gathering, overconfidence and information integration in probabilistic inference decisions. Overall, we observed group differences on all three dependent variables but the magnitude of these differences was smaller than we expected, perhaps owing the rather mild psychopathological status. We found that Szs show a less systematic information search compared to CPs. In line with the clinical observation that patients give undue weight to less relevant and sometimes random aspects, schizophrenia subjects focused more strongly on less valid information and, in particular, started the information search with less valid information. In a structured information environment, however, they do not inspect fewer pieces of information than CPs. This finding reflects recent evidence that JTC, in the sense of a data-gathering bias, is not found with all paradigms (Ziegler, Rief, Werner, Mehl, & Lincoln, 2008) and may under some conditions also be abolished in the beads task (Moritz, Woodward, & Lambert, 2007).

4.1 Confidence Ratings

We further observed that Szs tend to be overconfident, in that they use the extreme and inappropriate rating "absolutely certain" more often than controls, which accords with findings using memory paradigms (Moritz, Woodward, & Hausmann, 2006; Moritz, Woodward, Jelinek, & Klinge, 2008). Interestingly, extreme ratings seem to be more sensitive to capture group differences than simple means, on which we did not find differences. Our findings do not indicate a general overconfidence but only an increased number of extreme ratings, which we view as a specific kind of overconfidence (see also Moritz & Woodward, 2006). "Overconfidence" implies that "absolutely certain" ratings are considered irrational. We think that this is justified by the fact that all Bayes-posterior probabilities were below 1 and hence ratings for absolute certainty are incautious. Of course, some subjects might have misinterpreted the scale and could have used the rating as an indicator for some high level of certainty. There is, however, no good reason to assume that this should appear more often for Szs compared to CPs. However, considering the fact that the increased number of extreme ratings in Szs was mainly found for correct choices we cannot completely rule out that this increase might also be partially due to better discrimination.

4.2 Decision strategies and decision quality

Szs and CPs mainly used complex WADD strategies to make decisions (i.e., they took into account all pieces of information according to their importance of validity). Under most conditions, there was no tendency for Szs to rely more on simple heuristics such as Take the Best (TTB) or Equal Weighting (EQW). Only under high stress induced by affective valence and time pressure did Szs rely more on EQW strategies, which, according to probability theory, implies a less appropriate weighting of information (i.e., all pieces of information are weighted equally although they differ in validity). One might, however, argue that applying EQW under time pressure is adaptive (or even rational) if only minor effects on accuracy can be expected, because, with less cognitive effort, EQW often leads to rather accu-

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rate choices (Dawes & Corrigan, 1974). Note, however, that this classic adaptive-strategy-selection explanation cannot account for the observations a) that the effect is not found for the time pressure condition without affective stimuli, and b) that the effect is found only for Szs but not for CPs of similar intelligence. Hence, it seems more likely that the effect is caused by a specific reaction of Szs to stress induced by time pressure and affect. Considering recent findings, it might even be questioned whether WADD strategies that are based on automatic-intuitive processes are indeed cognitively more effortful than deliberate EQW strategies (Glöckner & Betsch, 2008a, 2008c; Glöckner & Herbold, in press; Hilbig & Pohl, 2009; see also Horstmann, Ahlgrimm, & Glöckner, 2009).

Interestingly, in spite of these differences concerning aspects of decision making, we did not observe an overall difference in the quality of the choices compared with the normative standard provided by Bayes' theorem between Szs and CPs. In Mouselab, the effects of JTC biases on decision quality seem to be low.

4.3 Structured information presentation and decision quality of Szs

It should be noted that the Mouselab environment differs from real world decisions in that it provides a clearly structured and rather simple information environment with a finite number of data. All these pieces of information are available and can be nicely compared and integrated within short time. Decisions in the real world, in contrast, are often characterized by incomplete information, provided in an unstructured way and without easily comparable probability information. Perhaps, most importantly, the amount of available information is unknown, gathering of further information is associated with high (time) costs, and the number of available cues is uncertain. The present finding that patients, especially in the first phase of each trial, tend to use less valid cues might be more consequential in the real world, where the search process might not be prolonged. To summarize, the structured environment is likely to influence choice behavior (cf. Glöckner & Betsch, 2008c) and it therefore has to be tested whether our results generalize to other realistic situations. Against the backdrop of earlier findings concerning stronger JTC biases in other situations, the structured information presentation, however, seems to have a positive influence on choice behavior. Hence, structured information presentation in a matrix format including information on cue validities might be a means to enhance decision quality of Szs.

4.4 Severity of schizophrenia and decision behavior

For Szs, we observed a correlation between schizophrenia measures (particularly driven by PANSS positive and PANSS delusion scores) and the amount of information search. Subjects who scored higher on these measures gathered fewer pieces of information. We did not, however, find a respective effect for the amount of absolute confidence ratings, which might be partially due to the low power of the analysis. Note, however, that a null-effect for the latter relation has also been observed in prior studies (Moritz, Woodward, & Rodriguez-Raecke, 2006). Overall, there were no reliable differences in strategy use related with increasing schizophrenia scores.

4.5 Partial task specificity of findings

The present findings may seem at odds with data obtained with the beads task where stronger JTC in the sense of less gathered information has been quite consistently found (Fine, Gardner, Craigie, & Gold, 2007). A striking difference between our task and the beads task could be that the subject in our task was confronted with place holders for the other options, which could have fostered curiosity or encouraged a search through all information — especially since it was not associated with great time loss. In contrast, in the draws-to-decision condition of the beads task the subject knows that more fish can be drawn, usually no placeholders for other beads are presented, and after each draw the subject is asked whether or not to terminate data gathering, which could also prompt hasty decision-making. Therefore, we regard findings obtained from both tasks as complementary and they allow for the conclusion that patients rest too much confidence on scarce information.

In sum, our results qualify findings concerning JTC biases in structured information environments. Although we found JTC biases for specific aspects of information search (i.e., less focused, less ordered), confidence ratings (i.e., more extreme ratings) and information integration (i.e., inappropriate cue weighting under stress) other aspects (i.e., amount of information search, average confidence rating, integration strategy without stress, quality of decisions) were not influenced. This more differentiated view was made possible by a paradigm tapping different aspects of JTC in a single paradigm which could stimulate further research. Cognitive treatment programs such as the Metacognitive Training for Schizophrenia patients (MCT; Moritz & Woodward, 2007; Moritz, Woodward, & Group, 2007) have began to train patients to search both for more and especially valid pieces of information and to tone down confidence in case of inconsistent evidence or ambiguity.

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Appendix: Instructions

Welcome to the experiment! In the course of this experiment, you will make a number of decisions. In different situations and on the basis of given information, you will decide which of the several types of oranges is of the best quality, and which of several suspects is the most likely to have committed a crime. Please do your utmost to reach an optimal decision. In some cases, your decision time will be limited. You should by all means adhere to this time frame. Should you have any questions, please do not hesitate to ask the experimenter.

Neutral orange selection decisions

In the following, you should decide which of three types of orange is of the best quality. In order to do this, you will receive information from three people who have tested the oranges. These testers have assessed the quality of the oranges as good (+) or bad (-). [Example omitted] Testers are allowed to give several positive and negative evaluations. The testers' conclusions vary in reliability. From many years of experience, the following is known:

Tester 1: 70% of evaluations are correct (7 out of 10).
Tester 2: 80% of evaluations are correct (8 out of 10).
Tester 3: 60% of evaluations are correct (6 out of 10).

Please note that none of the testers produces completely reliable evaluations. Thus, even three positive evaluations can still mean there is an orange type of poor quality. Should you have any questions, please contact the experimenter now. If this is not the case, please click on "Continue" to start the decision phase!

Additional instruction for hidden information presentation and no time pressure

You are asked to choose the type of orange that is of the best quality. The information provided by the testers is initially hidden by question marks ("?"), but it can be revealed by using the mouse. You are under no time constraints when reaching your decision. Please try to decide as correctly as possible and in as short a space of time as possible.

Instruction after each decision

A new day at the market — new kinds of orange! Please make another decision! Please choose from three kinds of orange. Please try to decide as correctly as possible and in as short a space of time as possible.

Affective decisions concerning a criminal case

In the following, you should decide which of three suspects is most likely to have committed a crime. In order to do this, you will receive information from members of the criminal investigation department. Three chief inspectors have assessed whether a particular suspect is guilty (+) or not guilty (-). [Example omitted] Chief inspectors are allowed to consider several suspects guilty or not guilty. The inspectors' conclusions vary in reliability. From many years of experience, the following is known:

Inspector 1: 70% of evaluations are correct (7 out of 10).

Inspector 2: 80% of evaluations are correct (8 out of 10).

Inspector 3: 60% of evaluations are correct (6 out of 10).

Please note that none of the inspectors produces completely reliable evaluations. Thus, even three positive evaluations can still mean there is a suspect who is not guilty. Should you have any questions, please contact the experimenter now. If this is not the case, please click on "Continue" to start the decision phase!

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Additional instruction for open information presentation

You should now decide which of the suspects is most likely to have committed a crime. The inspectors' information is unconcealed. You are not under time constraints when reaching your decision. Please try to decide as correctly as possible and in as short a space of time as possible.

Instruction after each decision

A new criminal case — new suspects! Please make another decision! Please choose between three suspects. Please try to decide as correctly as possible and in as short a space of time as possible.

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