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Auditory discrimination in female adolescents varying in schizotypal features: Preliminary findings

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Abstract Earlier experiments have suggested impaired auditory perception in patients with schizophrenia. The purpose of the present study was to investigate auditory discrimination in young adults varying in schizotypal features. Three hundred and forty-nine female adolescent subjects were rated with the Schizotypal Personality Questionnaire (SPQ) and the Perceptual Aberration Scale (PAS) and with questions from the Chinese Health Questionnaire (CHQ) that address non-psychotic, psychological status of the subjects. Sixty-one subjects were selected to participate in an auditory detection and discrimination task, with 20 subjects each with low and high, and 21 subjects with intermediate, SPQ scores. The sensitivity in auditory discrimination and the response bias were computed, using signal detection theory. The results show that the ratings of the subjects in the three questionnaires correlate with one another and that subjects with higher SPQ scores appear to perform worse in auditory discrimination. The impaired performance occurs for most of the signal-to-noise ratios. Taken together, these preliminary findings are consistent with earlier studies demonstrating impaired auditory processing in schizophrenia patients. In contrast, the significant correlation between both the SPQ and PAS scores and the CHQ score suggests that further studies are required to rule out the effect of non-psychotic factors such as anxiety on the current results. Second, the three groups of subjects did not differ in the response bias. This latter finding provides evidence at odds with the 'self-monitoring' model of auditory hallucination.

Key words auditory perception, hallucination, response bias, schizophrenia, schizotypy, 'self-monitoring', signal detection theory.

INTRODUCTION

Schizophrenia patients are impaired in perceptual as well as in cognitive functions. Many studies have demonstrated a deficit in auditory perception[1–3] and in auditory attention[2,4–7] consistent with the findings of structural pathology in the temporal association cortex in patients with schizophrenia.[8–11] It has also been shown that, compared to normal subjects, people with schizotypal traits are impaired in a variety of attention tasks[12–19] and in auditory information processing.[20–22] For instance, using a Continuous Performance Test (CPT), Chen *et al.* found that a poor CPT performance was associated with schizotypy measured by Perceptual Aberration Scale (PAS) and the Schizotypal Personality Questionnaire (SPQ) in the general population.[12] While these studies explore attention and auditory information processing as independent functional modules, a psychophysical model based on theories of signal detection provides a unified perspective where the two functions can be examined together.[23,24] Indeed, a more recent study shows that patients with schizophrenia have shallower psychometric functions in auditory detection and discrimination, which in turn

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can result from a deficit in auditory attention.[25] Following up on this earlier experiment, the present study investigates whether adolescents varying in schizotypal features differ in their performance in auditory discrimination. and furthermore, if a difference does exist, whether it exhibits a similar pattern as has been observed between schizophrenia patients and normal subjects. In particular, we examine whether subjects with higher schizotypy would demonstrate an altered psychometric function that would implicate a deficit in perceptual attention.

A concurrent objective of the present study is to address whether subjects differing in schizotypal features would also display different response bias in this perceptual task. This result can be relevant to the 'self-monitoring' model of auditory hallucination, which postulates that a defective mechanism in integrating corollary discharge and self-generated signals (as involved in subvocal speech or auditory imagery) lead to this aberrant perceptual experience.[26,27] Support for the model based on psychophysical studies examining response bias of schizophrenia patients in perceptual signal detection has been mixed.[25,28–36] Employing signal detection theory and methodology, the current experiment allows us to compute not only auditory discrimination sensitivity but also the response bias. Therefore, we are able to examine whether adolescents differing in schizotypal features also vary in their response propensity in detecting an auditory signal.

METHODS

Subjects

Three hundred and forty-nine female adolescents from the Chang Gung Institute of Nursing, ages 16–18 years, participated in the initial screening for schizotypal features with a Chinese version of SPQ and PAS.[12,37,38] In this questionnaire, 74 questions from the SPQ and 35 questions from the PAS are intermixed with 12 questions (Chinese Health Questionnaire, CHQ) about non-psychotic status of the subjects.[12] The 12 questions essentially serve as a negative control, while the SPQ and PAS questions measure various features of schizotypy. Twenty or 21 subjects each of the highest, middle and lowest SPQ scores were paid to further participate in the auditory test. None of these 61 subjects had a history of neurological insult or of use of illicit substance. None of them had history of hearing difficulties, nor did they report any hearing problems at the time of experiments. We obtained informed, written consent from all of the subjects before the experiment was conducted.

Experimental setups and procedures

The experiments were carried out on a PowerBook computer (Apple). Auditory signals were created with SOUNDEDIT 16, version 2 (Macromedia), and experimental procedures were automated by a program. In the experiment, the subjects listened through a headset to a 'sound strip', 1.8 s in duration (Fig. 1). In a 'signal' trial, this consisted of 0.6 s of white noise (approximately 65 dB, sound pressure level), a second 0.6 s of a signal ('*nee-hao*' or '*hao-ma*', of variable intensity) superimposed on the white noise, and a third 0.6 s of white noise. '*Nee-hao*' and '*hao-ma*' means 'How are you?' and 'Is it all-right?', respectively, in Mandarin. We used these short phrases rather than some pure tones in this perceptual task in order to capture some aspect of semantics in auditory perception.[25] A 'noise' trial consists of 1.8 s of white noise. At the end of the presentation the subjects had to judge the presence or absence of a signal over the middle 0.6 s. They also rated their confidence level about the judgment, and, if a signal was detected, further decided whether it was a '*nee-hao*' or '*hao-ma*.' All subjects were allowed their own pace on the task, although they were often quick with their decisions. Each experiment consisted of 800 trials, half of which contained only noise inputs. Of the 400 trials containing a signal, the signal-to-noise (SNR; amplitude) ratio varied from 3% to 30% at intervals of 3% with 40 trials repeated for each SNR. All trials were pseudo-randomized in presentation.

The subjects were given a demonstration of the two signals prior to the experiment. Each subject was then led through a trial and was instructed how to rate his or her confidence: 'If you are absolutely or very sure that there is a signal in the middle third of the sound strip, choose level 3; if you are mostly but not absolutely sure, pick level 2; finally, if you think there might be a signal in the sound strip, but not without doubt, pick level 1'. Instructions as to confidence ratings for a 'no' judgment went vice versa. The subjects were then given a test run of 30 trials, half of which contained a signal, and were asked if they had questions regarding the task before they proceeded to the experiment proper. Feedback was given for the test run but not during the experiment. A 1-min break was imposed every 100 trials. All of the subjects completed the 800-trial task in one session, which lasted approximately 90 min.

RESULTS

The SPQ score ranged from 7 to 61 with a mean of 31.9 ± 11.5, the PAS score ranged from 0 to 28 with a mean of 8.1 ± 5.9, and the CHQ score ranged from 1 to

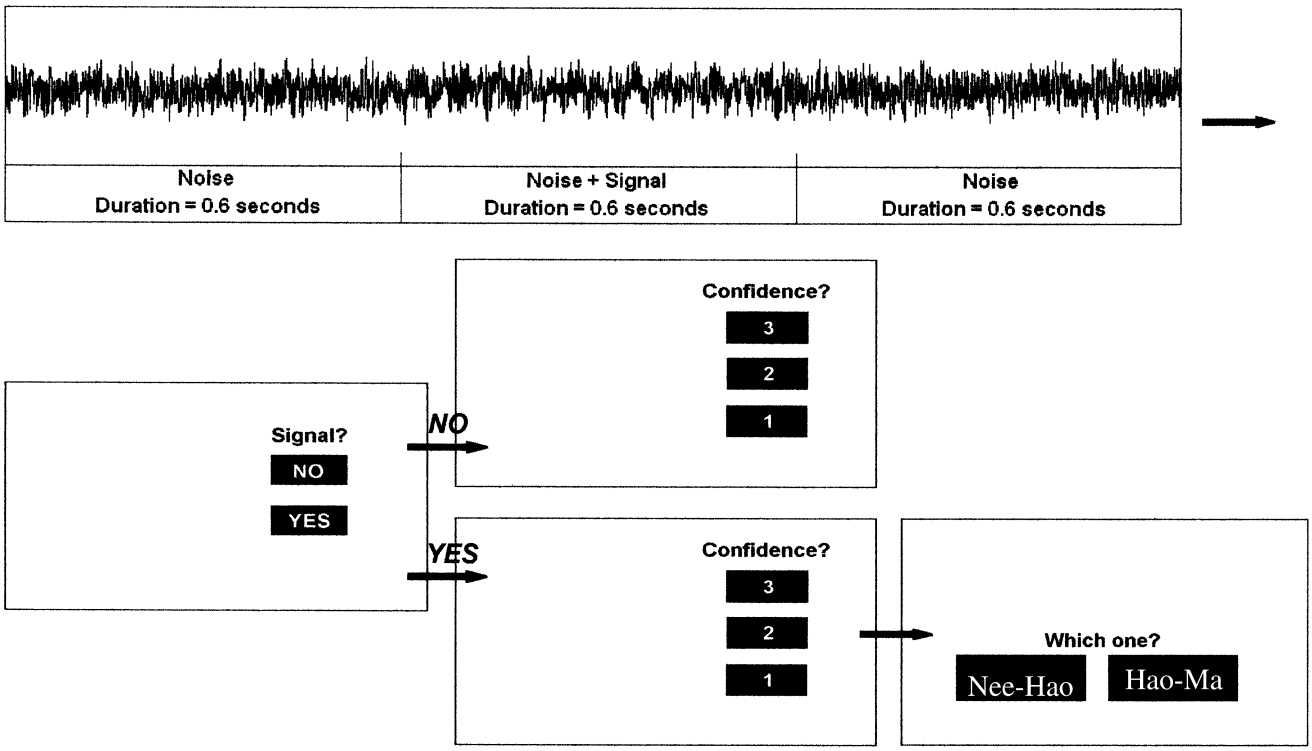

Figure 1. Auditory discrimination task. Each trial consisted of three segments, each lasting 0.6 s. In half of the trials, the middle segment contained a signal, as shown here. The signal-to-noise ratio (SNR) varied from trial to trial. The subject first made a detection judgment and then rated their confidence in the judgment. When a signal was detected, the subject further decided whether a '*nee-hao*' or a '*hao-ma*' was present.

11 with a mean of 5.3 ± 2.1, across the entire sample. Figure 2 shows a linear regression of the SPQ and PAS scores for all 349 subjects. The two scores are significantly correlated ($r^2 = 0.289$, $P = 0.000$). In contrast, the SPQ and CHQ ($r^2 = 0.272$, $P = 0.000$) and the PAS and CHQ ($r^2 = 0.241$, $P = 0.000$) scores are both significantly correlated, although the strength of correlation is slightly less than that between SPQ and PAS. Sixty-one subjects were selected on the basis of their SPQ scores to participate in the auditory task. The 'low' group ($n = 20$) had a mean SPQ score of 10.6 ± 1.8 (7–13), a mean PAS score of 2.8 ± 2.1 (0–8) and a mean CHQ score of 3.9 ± 1.7. The 'middle' group ($n = 21$) had a mean SPQ score of 32.0 ± 0.7 (31–33), a mean PAS score of 8.4 ± 6.1 (3–20) and a mean CHQ score of 5.3 ± 1.6. The 'high' group ($n = 20$) had a mean SPQ score of 54.6 ± 2.9 (51–61), a mean PAS score of 15.1 ± 7.9 (3–28) and a mean CHQ score of 7.7 ± 2.0. The three groups differed in all of the three scores ($P < 0.001$, one-way ANOVA), with the difference going in the same direction: the higher any of the three scores was, the higher the other two scores were.

The discrimination sensitivity and detection response bias were computed based on signal detec-

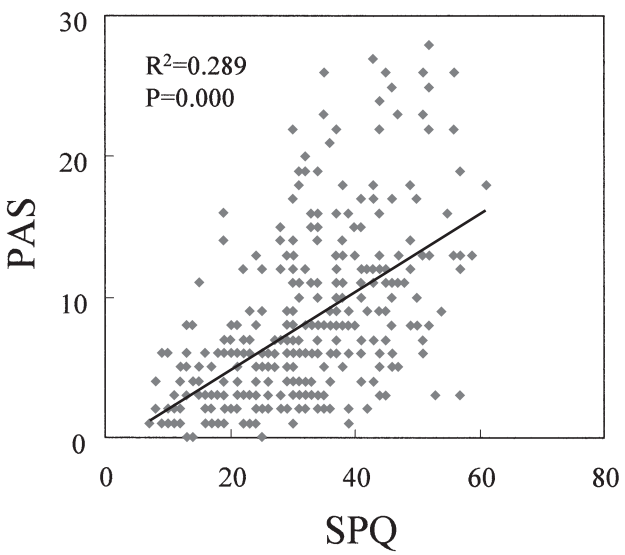

Figure 2. Correlation of Schizotypal Personality Questionnaire (SPQ) and Perceptual Aberration Scale (PAS) scores across the entire sample of subjects. Each data point represents an individual.

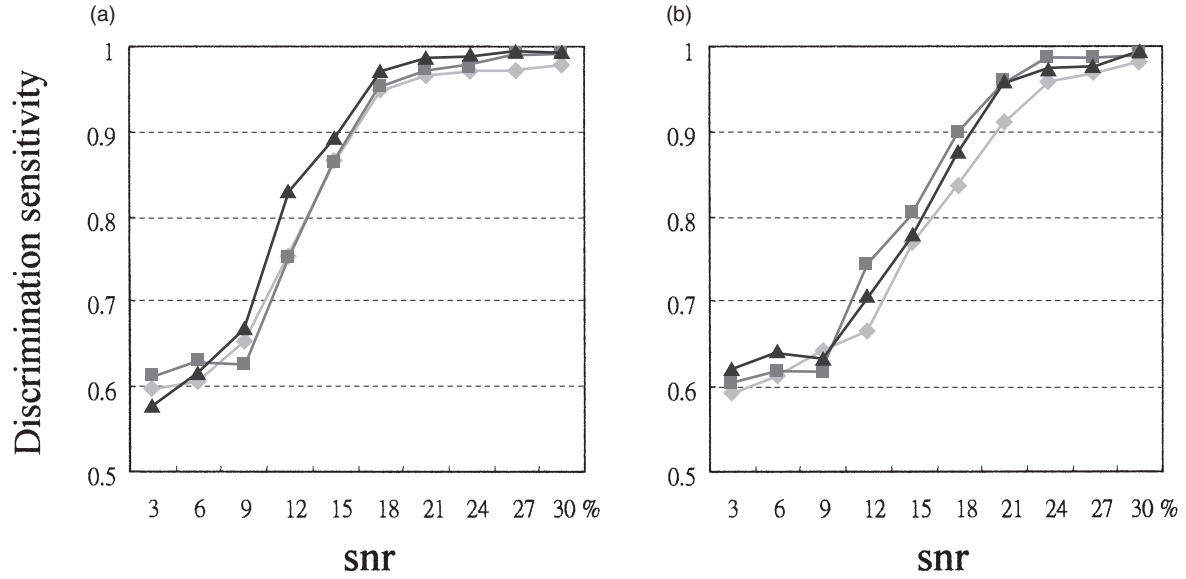

Figure 3. Psychometric functions of the discrimination sensitivity for (a) '*hao-ma*' and (b) '*nee-hao*' for subjects with low (■), middle (▲) and high (✦) Schizotypal Personality Questionnaire (SPQ) scores. See text for further explanation and statistics.

tion theory.[39,40] Repeated measures ANOVA using generalized linear models with the two signals and the SNR as the within-subject variables and the group as the between-subject variable was performed to examine for a difference in discrimination sensitivity in the three groups of subjects. The results show that there is a significant difference between the SNR ($P=0.000$) and between the two signals ($P=0.000$), with the discrimination sensitivity for '*hao-ma*' being higher than that for '*nee-hao*'. Moreover, there is a significant interaction between the two within-subject variables ($P=0.000$), which is largely reflected in the steeper slope in the psychometric function for '*hao-ma*' than for '*nee-hao*'. In contrast, there is no difference in discrimination sensitivity between the three groups ($P=0.130$). Figure 3 plots discrimination sensitivity of the two signals against SNR for the three groups of subjects, respectively.

Because the auditory discrimination appeared to differ between the two signals, we separated the results for the two signals and performed the repeated measures ANOVA with SNR as the within-subject variable and the group as the between-subject variable, for each of two signals. The results showed that, for '*hao-ma*', there is no difference in discrimination sensitivity between the three groups ($P=0.367$), nor was there any significant group and SNR interaction ($P=0.465$). For '*nee-hao*', the difference in discrimination sensitivity between the three groups was close to significance ($P=0.060$), but there was no significant group and SNR interaction ($P=0.455$). Those subjects with high SPQ scores performed worse than those with middle and low scores.

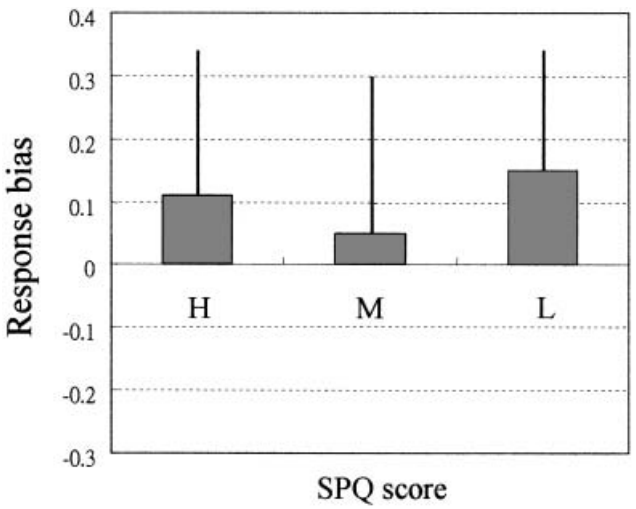

Figure 4. Average response biases (with standard deviations) in the detection task for the three subject groups. Data were collapsed across all signal-to-noise ratios (SNR) for each subject. A more negative value indicates a higher bias in the auditory perceptual decision.

A response bias in terms of the root mean square (RMS) standard deviation of the noise distribution was computed for each individual subject.[39] Figure 4 plots the group means. A one-way analysis of variance with group as the factor showed that there was no difference

between the three groups with different SPQ scores ($P = 0.396$).

DISCUSSION

Schizotypy and auditory discrimination

The significant correlation between SPQ and PAS scores in our subject sample reflects some success in the screening for schizotypy in this population. The result validates varying degrees of schizotypy in our subject sample. The preliminary results from the analysis of variance suggest that the subjects with higher schizotypy are impaired in auditory discrimination, when compared to those with lower schizotypy. The fact that a negative finding was observed for the signal '*hao-ma*' is hard to explain. The mechanics of this sound signal in the current set-up probably has such an effect on its discriminability that it limits the differentiability in the subjects' performance. To the extent that the difference between groups in the discrimination of the '*nee-hao*' signal is close to statistical significance, this preliminary result is consistent with previous studies demonstrating deficits in auditory detection[41–43] and phonemic discrimination[1,44] in patients with schizophrenia. This finding suggests that the SPQ and PAS scores indeed capture some dimensions of psychopathology intrinsic to the schizophrenic disorders.

In contrast, the significant correlation between both the SPQ and PAS scores and the CHQ score suggests that this result to a degree may be confounded by other non-psychotic, psychological factors. For instance, anxiety or excessive concern about one's health could be such a component. Interestingly enough, the psychometric functions of these 'schizotypal' subjects do not appear to have a flatter slope, as we have observed for patients in schizophrenia in a previous study.[25] Their auditory discrimination sensitivity appears to be worse than that of those with lower schizotypal scores at all except the lowest SNR. This result suggests that the impairment in auditory discrimination in subjects with schizotypal traits could involve a mechanism different from that implicated in schizophrenia – a mechanism that may not be directly related to perceptual attention, at least not as have been conceived by the theories of perceptual signal detection.[23,24] A recent study shows that the anxiety component of schizotypy, more than the perceptual disorganization component, accounts for the attentional dysfunction in high schizotypals, as measured by the magnitude of disruption in a latent inhibition task.[45] Although mostly speculative at this point, we are also tempted to propose that the impairment in auditory discrimination observed for the subjects with high SPQ (and PAS, as well as CHQ) score in the current study may to a certain extent be attributed to a non-psychotic factor such as anxiety. Further studies with a larger number of subjects are required to determine whether psychotic tendency or schizotypy contributes to perceptual attention dysfunction. An important question along the line is that, if it does, whether its effect is independent of non-psychotic factors such as anxiety. A sufficiently large sample of subjects perhaps might allow us to determine a cut-off on the schizotypal scores that can directly relate to an impairment in auditory perceptual functions. Additional experiments investigating auditory discrimination in patients with anxiety disorders with this behavioral task may also contribute to our understanding of this issue.

Schizotypy and response bias

The current results also showed that patients with varying degrees of schizotypy did not differ from each other with respect to response bias in the detection of auditory signals. This finding is in agreement with previous studies that demonstrated a similar response bias in perceptual signal detection in schizophrenics, as compared to healthy controls[25] and in community subjects with varying schizotypal features.[12] It extends the previous studies by showing that the same result can be obtained even when an auditory signal with some verbal import is used in the behavioral task. This finding does not support the self-monitoring model that perceptual hallucination results from a change in response bias in perceptual judgment.

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REFERENCES

1. Bruder G, Kayser J, Tenke C *et al.* Left temporal lobe dysfunction in schizophrenia: Event-related potential and behavioral evidence from phonetic and tonal dichotic listening tasks. *Arch. Gen. Psychiatry* 1999; **56**: 267–276.
2. Hoffman RE, Rapaport J, Mazure CM, Quinlan DM. Selective speech perception alterations in schizophrenic patients reporting hallucinated 'voices'. *Am. J. Psychiatry* 1999; **156**: 393–399.
3. McKay CM, Headlam DM, Copolov DL. Central auditory processing in patients with auditory hallucinations. *Am. J. Psychiatry* 2000; **157**: 759–766.

4. Cullum CM, Harris JG, Waldo MC *et al.* Neurophysiological and neuropsychological evidence for attentional dysfunction in schizophrenia. *Schizophr. Res.* 1993; **10**: 131–141.
5. Pigache RM. Auditory sustained attention in schizophrenia: A comparison of the Continuous Performance Test and the Pigache Attention Task. *Psychiatry Res.* 1996; **60**: 155–165.
6. Spring B, Weinstein L, Freeman R, Thompson S. Selective attention in schizophrenia. In: Steinhaurer SR, Gruzelier JH, Zubin J (eds). *Handbook of Schizophrenia*. Elsevier, Amsterdam, 1991; 371–396.
7. Ward PB, Catts SV, Fox AM, Michie PT, McConaghy N. Auditory selective attention and event-related potentials in schizophrenia. *Br. J. Psychiatry* 1991; **158**: 534–539.
8. Barta PE, Pearlson GD, Brill LB *et al.* Planum temporale asymmetry reversal in schizophrenia: Replication and relationship to gray matter abnormalities. *Am. J. Psychiatry* 1997; **154**: 661–667.
9. Kwon JS, McCarley RW, Hirayasu Y *et al.* Left planum temporale volume reduction in schizophrenia. *Arch. Gen. Psychiatry* 1999; **56**: 142–148.
10. Levitan C, Ward PB, Catts SV. Superior temporal gyral volumes and laterality correlates of auditory hallucinations in schizophrenia. *Biol. Psychiatry* 1999; **46**: 955–962.
11. Marsh L, Harris D, Lim KO *et al.* Structural magnetic resonance imaging abnormalities in men with severe chronic schizophrenia and an earlier age at clinical onset. *Arch. Gen. Psychiatry* 1997; **54**: 1104–1112.
12. Chen WJ, Hsiao CK, Hsiao L-L, Hwu H-G. Performance of the Continuous Performance Test among community samples. *Schizophr. Bull.* 1998; **24**: 163–174.
13. Keefe RS, Arnold MC, Bayen UJ, Harvey PD. Source monitoring deficits in patients with schizophrenia; a multinomial modeling analysis. *Psychol. Med.* 1999; **29**: 903–914.
14. Larrison AL, Ferrante CF, Briand KA, Sereno AB. Schizotypal traits, attention and eye movements. *Prog. Neuropsychopharmacol. Biol. Psychiatry* 2000; **24**: 357–732.
15. Laurent A, Biloa-Tang M, Bougerol T *et al.* Executive/attentional performance and measures of schizotypy in patients with schizophrenia and in their nonpsychotic first-degree relatives. *Schizophr. Res.* 2000; **46**: 269–283.
16. Lenzenweger MF. Reaction time slowing during high-load, sustained-attention task performance in relation to psychometrically identified schizotypy. *J. Abnorm. Psychol.* 2001; **110**: 290–296.
17. Mannan MR, Hiramatsu KI, Hokama H, Ohta H. Abnormalities of auditory event-related potentials in students with schizotypal personality disorder. *Psychiatry Clin. Neurosci.* 2001; **55**: 451–457.
18. Moran MJ, Thaker GK, Laporte DJ, Cassady SL, Ross DE. Covert visual attention in schizophrenia spectrum personality disordered subjects: Visuospatial cueing and alerting effects. *J. Psychiatr. Res.* 1996; **30**: 261–275.
19. Nuechterlein KH, Asarnow RF, Subotnik KL *et al.* The structure of schizotypy: Relationships between neurocognitive and personality disorder features in relatives of schizophrenic patients in the UCLA Family Study. *Schizophr. Res.* 2002; **54**: 121–130.
20. Klein C, Berg P, Rockstroh B, Andresen B. Topography of the auditory P300 in schizotypal personality. *Biol. Psychiatry* 1999; **45**: 1612–1621.
21. Lenzenweger MF, Gold JM. Auditory working memory and verbal recall memory in schizotypy. *Schizophr. Res.* 2000; **42**: 101–110.
22. Niznikiewicz MA, Voglmaier MM, Shenton ME *et al.* Lateralized P3 deficit in schizotypal personality disorder. *Biol. Psychiatry* 2000; **48**: 702–705.
23. Kontsevich LL, Tyler CW. Distraction of attention and the slope of the psychometric function. *J. Opt. Soc. Am. A Opt. Image Sci. Vision* 1999; **16**: 217–222.
24. Pelli DG. Uncertainty explains many aspects of visual contrast detection and discrimination. *J. Opt. Soc. Am. A* 1985; **2**: 1508–1531.
25. Li C-SR, Chen M, Yang Y-Y, Chen M-C, Tsai P-K. Altered performance of schizophrenia patients in an auditory detection and discrimination task: Exploring the 'self-monitoring' model of hallucination. *Schizophr. Res.* 2002; **55**: 115–128.
26. Cahill C, Frith C. A cognitive basis for the signs and symptoms of schizophrenia. In: Pantelis C, Nelson HE, Barnes TRE (eds). *Schizophrenia: a Neuropsychological Perspective*. John Wiley and Sons, New York, 1996; 372–395.
27. Frith CD. The role of the prefrontal cortex in self-consciousness: Rhe case of auditory hallucinations. *Philos. Trans. R. Soc. Lond. B* 1996; **351**: 1505–1512.
28. Rappaport M, Hopkins HK, Silverman J, Hall K. Auditory signal detection in schizophrenics. *Psychopharmacologia* 1972; **24**: 6–28.
29. Korboot PJ, Damiani N. Auditory processing speed and signal detection in schizophrenia. *J. Abnorm. Psychol.* 1976; **85**: 287–295.
30. Collicutt JR, Hemsley DR. A psychophysical investigation of auditory functioning in schizophrenia. *Br. J. Clin. Psychol.* 1981; **20**: 199–204.
31. Bentall RP, Slade PD. Reality testing and auditory hallucination: A signal detection analysis. *Br. J. Clin. Psychol.* 1985; **24**: 159–169.
32. Mussgay L, Hertwig R. Signal detection indices in schizophrenics on a visual, auditory, and bimodal continuous performance test. *Schizophr. Res.* 1990; **3**: 303–310.
33. Nestor PG, Faux SF, McCarley RW, Shenton ME, Sands SF. Measurement of visual sustained attention in schizophrenia using signal detection analysis and a newly developed computerized CPT task. *Schizophr. Res.* 1990; **3**: 329–332.
34. Corrigan PW, Green MF. Signal detection analysis of short-term recall in schizophrenia. *J. Nerv. Ment. Dis.* 1991; **179**: 495–498.
35. Servan-Schreiber D, Cohen J, Steingard S. Schizophrenic deficits in the processing of context: A test of a theoretical model. *Arch. Gen. Psychiatry* 1996; **53**: 1105–1112.

36. Ishigaki T, Tanno Y. The signal detection ability of patients with auditory hallucination: Analysis using the continuous performance test. *Psychiatry Clin. Neurosci.* 1999; **53**: 471–476.
37. Chapman LJ, Chapman JP, Raulin ML. Body-image aberration in schizophrenia. *J. Abnorm. Psychol.* 1978; **87**: 399–407.
38. Raine A, The SPQ. A scale for the assessment of schizotypal personality based on DSM-III-R criteria. *Schizophr. Bull.* 1991; **17**: 555–564.
39. Macmillan NA, Creelman CD. *Detection Theory: a User's Guide*. Cambridge University Press, Cambridge, 1991.
40. Pan X, Metz CE. The 'proper' binormal model: Raramet-ric ROC curve estimation with degenerate data. *Acad. Radiol.* 1997; **4**: 380–389.
41. Emmerich DS, Levine FM. Differences in auditory sensitivity of chronic schizophrenic patients and normal controls determined by use of a forced-choice procedure. *Dis. Nerv. Syst.* 1970; **31**: 552–557.
42. Rappaport M, Hopkins HK, Hall K. Auditory signal detection in paranoid and nonparanoid schizophrenics. *Arch. Gen. Psychiatry* 1972; **27**: 747–752.
43. Shelley AM, Ward PB, Catts SV, Michie PT, Andrews S, McConaghy N. Mismatch negativity: An index of preattentive processing deficit in schizophrenia. *Biol. Psychiatry* 1991; **30**: 1059–1062.
44. Kugler BT, Caudrey DJ. Phoneme discrimination in schizophrenia. *Br. J. Psychiatry* 1983; **142**: 53–59.
45. Braunstein-Bercovitz H. Is the attention dysfunction in schizotypy related to anxiety? *Schizophr. Res.* 2000; **46**: 255–267.