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ORIGINAL PAPER

The psychometric properties of the Peters et al. Delusions Inventory (PDI) in Taiwan: reliability, validity, and utility

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Abstract
Purpose The Peters et al. Delusions Inventory (PDI) is a commonly used instrument to measure delusion proneness in the general population and includes dimensions that measure distress, preoccupation, and conviction of unusual beliefs. This self-report scale has already been translated into several languages. However, there has not been a validated Taiwanese version previously reported. The aims of the present study were to translate and test the cross-cultural reliability and validity of the PDI in Taiwanese as well as to establish its sensitivity, specificity, and discriminative validity.
Methods We administered the questionnaire to a consecutive sample of 253 participants with ($n = 154$; clinical group including schizophrenia and affective psychosis) or without psychotic disorders ($n = 99$; non-clinical group). In addition to the Taiwanese version of the PDI (PDI-T), the Taiwanese version of the Brief Psychiatric Symptom Rating Scale (BSRS) was used to measure the severity of psychopathology. We tested the psychometric properties of the PDI-T, including its construct validity, internal consistency, test–retest reliability, concurrent, and discriminative validity.
Results Overall, the PDI-T showed good construct validity, internal consistency, and stability over time, and it was significantly correlated with the BSRS subscales of psychotic symptoms. The convergent and discriminative validity was satisfactory. The area under the receiver operating characteristic curve of the PDI-T was 0.752. This research found that the most appropriate PDI-T yes/no cut-off scores for determining the absence and presence of delusion proneness were 5 and 13.
Conclusions The PDI is a reliable and valid instrument for measuring the dimensionality of delusion proneness and appears to complement subclinical psychosis assessment scales for both epidemiological and clinical research in Taiwan.

Keywords PDI · Delusion proneness · Reliability · Discriminative validity

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Introduction

Delusions are typically defined as fixed false beliefs that are held despite the presence of evidence to the contrary and that are qualitatively distinct from those beliefs ordinarily held by members of a person's culture [1]. They are a hallmark sign of psychosis in general and of schizophrenia in particular [1]. Delusions are both complex and varied and may have varying degrees of persistence and

systematization. The diagnosis of a delusion requires that it impacts on the individual's ability to function to some extent. In keeping with the cognitive approach to delusions in terms of attribution and beliefs, Hole et al. [2] posit that delusions can be distinguished from non-dysfunctional beliefs by the extent to which the person's moment-to-moment stream of consciousness is controlled by the belief (pervasiveness), the individual's certainty that the belief is true (conviction), the importance of the belief to the person's system of meaning (significance), and the imperviousness of the belief to logic, reason, and counterevidence (inflexibility and self-certainty). Hence, it seems that delusions may be more than the mere presence of an odd belief. How are delusions more than mere odd beliefs? It is hypothesized that other components of a delusion include distress associated with the belief, the preoccupation with the belief and the level of conviction [3, 4].

Although delusions and hallucinations are considered the hallmarks of psychosis in contemporary classifications of mental disorders, many recent studies have reported that large proportions of non-clinical populations experience these symptoms at some point in their lives [5–7]. In fact, when considering all of the different diagnostic categories that may be associated with psychotic features, psychotic disorders are rather rare conditions. Moreover, studies rarely estimate the prevalence of psychotic disorders to be above 2–3% [8, 9]. Previous epidemiological surveys have revealed that the experiences and beliefs that can be ascribed to psychosis are quite common in nonclinical populations [10–12]. For instance, in the national Comorbidity Survey, up to 28.4% of respondents reported positive answers to at least one of the questions concerning psychotic symptoms (i.e., hallucinations and delusions), compared to a prevalence of clinically identified non-affective psychotic syndromes between 0.2% (narrowly defined criteria) and 0.7% (broadly defined criteria) [13]. In the Dutch MEMESIS study, at least one out of the seventeen CIDI-positive psychotic items was endorsed by 17.5% of individuals in the general population, against a prevalence of non-affective psychosis of 2.1% in the same sample [14]. In general, there is clear evidence that the rate of delusional beliefs in the general population is higher than that of psychotic disorders.

The current approach to operationally defining delusions is to consider them as containing multiple dimensions, some of which are non-overlapping, and to consider that a person's potential level of delusional beliefs lies on a continuum [4, 5, 7, 12, 14]. The various "dimensions" of delusions have been measured using a wide variety of scales. In general, the psychometric instruments that are designed to measure the levels of delusions in individuals are grouped into two categories: researcher-rated scales and self-report scales. Researcher-rated scales are most often used in a clinical setting and are consistently used as the primary outcome in treatment studies of psychosis. However, despite many advantages, researcher-rated assessments are time-consuming, costly and prone to socially desirable answers; they are also quite susceptible to researcher bias [15, 16]. Some of the more common scales that use this format include the Positive and Negative Syndrome Scale (PANSS) [17], the Delusional Assessment Scale (DAS) [18], the Psychotic Symptom Rating Scale (PSYRATS) [19], and the Maudsley Assessment of Delusions Schedule (MADS) [20].

However, the most commonly used method for assessing psychotic symptoms by self-report is generally a paper and pencil task, which the person reads and answers on his/her own. Research on the continuum of psychosis in the population [5, 7, 12, 21] has produced reliable and valid self-report single-symptom measures, such as the Peters et al. Delusions Inventory (PDI; 1999) [4, 5, 7, 12] or the Paranoia Checklist [21]. Delusion proneness are assessed by providing lists of delusional beliefs (e.g., "I believe people are observing me") that are rated on several dimensions, such as distress, conviction, and frequency. These self-report scales are able to rate subclinical psychosis with sufficient reliability and validity. They are now widely used and could be useful for both epidemiological and clinical research [22, 23].

The Peters et al. Delusions Inventory (PDI) [4] is based on quasi-dimensional models and is derived from the Present State Examination to measure delusion proneness in the general population. It examines various experiences on a continuum and was created with the intent of assessing unusual beliefs in non-psychotic populations. The measure includes 40 items that represent unusual beliefs. For each item answered "yes", the participant rates the following components on a five-point scale: (a) how distressing the thought is to him/her; (b) how much he/she thinks about it; and (c) how much he/she believes it to be true. When all 40 items are summed, the possible range for the PDI-T yes/no is 0 (low) to 40 (high), and for each dimensions the possible range is 0–200. Previous research suggests that the PDI possesses adequate reliability ($\alpha = 0.88$, test–retest reliability = 0.82) and validity. Concurrent validity has been assessed by examining common variance between this measure and other measures designed to evaluate a similar construct and ranges from 33 to 58% [4].

In addition, the PDI has been widely used to measure the risk of subclinical psychosis in specific populations, such as twins [24], members of a specific religion [25], cannabis users [26], the relatives of individuals with schizophrenia and bipolar disorder [27], and people with schizophrenia and its spectrum of symptoms [28]. The PDI has already been translated into several languages, including Italian [28], Spanish [29], Japanese [30], and Korean [31], and its

validity and psychometric properties have been reported for each of these languages. Currently, research on the discriminative properties of the PDI (i.e., thresholds drawing on the combination of sensitivity and specificity) is scarce. To date, only one study has reported that the best PDI threshold in discriminating between cases and non-cases was 8 (sensitivity, 74%; specificity, 79%) [32].

Psychotic symptoms, psychotic-like experiences, and schizotypal signs can emerge in different socio-cultural circumstances and cause clinical or non-clinical presentations [13, 33–35]. To our knowledge, the PDI has not been validated and published in Taiwanese. Thus, the purpose of this study was to produce a Taiwanese translation of the PDI (PDI-T) and to cross-validate it with a Taiwanese population. Furthermore, we present additional statistical support for the PDI-T using a receiver operating characteristics (ROC) curve analysis [36].

Methods

Translation

The repeated forward–backward procedure was applied to translate the PDI from English to Chinese. Two bilingual researchers (the first author and a clinical psychologist) independently translated the PDI from English to Chinese. The authors then reconciled these two Chinese translations into one final version for independent back translation by a bilingual psychiatrist who had not previously seen the original English questionnaire. Back translations were subsequently reviewed as a mean to check the conceptual equivalence between the English (UK) and Taiwanese versions of the PDI. The Taiwanese PDI was further modified to improve readability after a pilot test with ten individuals with or without psychotic diagnoses.

Participants

We conducted a cross-sectional study using the translated PDI on three groups of participants. Each participant completed a survey on delusion proneness, psychopathology, and personal background information. Participants with potential histories of an organic brain pathology including cerebral tumor, epilepsy, systemic disease, cranial trauma history, brain surgery, substance abuse, or dependence were excluded from this study. Of the 265 subjects initially invited to participate in this study, 12 failed to complete all of the procedures required of the study, yielding a final sample of 253 subjects (95.5% of those contacted). Group 1 consisted of 99 healthy control (non-clinical) participants (29 males and 70 females), including undergraduate nursing students ($n = 72$) and staff members ($n = 27$) at a general hospital with no history of psychiatric illness. Group 2 consisted of 47 outpatients (26 males and 21 females) with affective disorders with psychotic features (affective psychosis), including major depressive disorders and bipolar disorders, either single episode or recurrent, with psychotic features. Group 3 included 107 outpatients (57 males and 50 females) with schizophrenia spectrum disorders, including schizophrenia and schizoaffective disorder. These patients were recruited from the psychiatric outpatient department of a general hospital. All of the diagnoses in our sample were made by a trained psychiatrist based on the DSM-IV criteria [1]. No patients had been hospitalized over the previous 6 months. All patients received outpatient treatment regularly before recruitment and were clinically judged to be stable enough to undergo the assessment. We obtained approval to carry out this study from the local research ethics committee. Following a comprehensive explanation of the study, we obtained informed consent from all participants.

Baseline demographic data consisted of sex, age, and years of formal education. Age of illness onset was defined as the age when the patients met the DSM-IV [1] criteria for the first time. The duration of the illness was defined as the time since the first psychiatric illness episode.

To identify the test–retest reliability of the PDI-T, 15 non-clinical participants and 50 clinical patients, including 13 patients with affective psychosis and 37 patients with schizophrenia spectrum disorders, completed the PDI-T again over 6 months. All 50 patients were clinically stable and received outpatient treatment regularly before they completed the test–retest procedure.

Measures

To estimate the convergent validity of the PDI-T, we evaluated the extent to which the PDI-T was correlated with the scores derived from the Taiwanese version of the Brief Psychiatric Symptom Rating Scale (BSRS) [37]. The Taiwanese version of the BSRS has an excellent split-half reliability and good internal structure [37]. It consists of seven higher-order factors called domains (anxiety-depression, sensitivity-paranoid, obsession, phobic anxiety, somatization, psychoticism-additional, and hostility), resulting in 50 items.

Statistical analysis

Data from the Taiwanese PDI version were analyzed separately using the Statistical Package for the Social Science (SPSS), version 15.0 for Windows, to examine construct validity and reliability. All statistical analyses were conducted at a significance level of 0.05, and all tests were two-tailed whenever appropriate.

After the administration of the PDI-T to the non-clinical ($n = 99$) and clinical populations ($n = 154$), we conducted an exploratory principal components analysis (PCA) on the correlation matrix of the 40 items of the PDI-T (yes/no answer). To clarify the statistical interpretation, we used a varimax orthogonal rotation. We extracted factors with eigenvalues greater than or equal to 1.0 during the exploratory phase of this study. For both the Kaiser–Meyer–Olkin test (KMO) and the measure of sampling adequacy (MSA), values greater than 0.6 represent an acceptable factor loading [38].

Delusion proneness scores were calculated by summing the following, each from the PDI-T: (1) number of unusual beliefs that were answered "yes" by the participant and (2) the amount of distress, preoccupation, and conviction rated for each belief answered "yes" on a scale of 1–5. Because the PDI-T includes 40 items and each item assesses three dimensions of the unusual belief (distress, preoccupation, and conviction), the possible score range was 0–640. Such a score is useful if a global measure of delusion proneness is required that includes distress, preoccupation, and conviction [39].

Internal consistency reliability and test–retest reliability were assessed using Cronbach's alpha [40] and the intraclass correlation coefficient (ICC) [38, 40]. An alpha or ICC value of 0.7 or higher indicates satisfactory reliability [38, 40]. We also calculated the item-total correlation to assess the internal consistency of the PDI-T. One study [41] suggested that an item measuring the same construct as another item in that domain should have an item-total correlation larger than 0.4.

Convergent validity was performed by determining correlations between the PDI-T yes/no scores and the BSRS subscale scores as a general measure of psychopathology. Demographic characteristics were also correlated with the PDI-T yes/no score for all three groups. Because the delusion proneness scores were skewed, Spearman correlation analyses were performed to investigate the relationships between demographic variables, clinical diagnoses, BSRS score, and delusion proneness measures. Because a large number of correlation factors were examined in this analysis, the threshold for significance was set at $P < 0.01$.

To gain information concerning which unusual beliefs could be relevant in differentiating between the populations, unusual beliefs were compared on an item level using the χ^2-test. Associations between the diagnosis of psychosis and the dichotomous response of unusual beliefs endorsed were explored in univariate analyses that used 2×2 contingency tables.

To examine differences among the groups (i.e., schizophrenia, affective psychosis, and healthy controls) on non-normally distributed variables such as the PDI-T yes/no, three-dimensional, and total scores, a nonparametric statistic, the Kruskal–Wallis H-test with the Dunn multiple comparison test for further post hoc comparisons, was utilized. The ability of the PDI-T to differentiate between psychotic and healthy control samples addressed the issue of discriminative validity. Mann–Whitney *U*-tests were used to analyze any gender differences in the three groups.

Finally, to explore the discriminatory power of the PDI-T, ROC analyses evaluated the performance of the yes/no mean score against DSM-IV diagnoses of psychotic disorders. The ROC curve is a plot of a measure's sensitivity (true positive rate) over the false positive rate (1-specificity) [36]. Furthermore, the Youden's index [42, 43], the maximum potential effectiveness of a test, was conducted to determine which cut-off points on the PDI-T maximize both sensitivity and specificity. This index is calculated by subtracting one from the sum of a test's sensitivity and specificity, expressed not as a percentage but as a part of a whole number: max (sensitivity + specificity) − 1 [44, 45]. The area under curve (AUC) of the ROC represents the diagnostic efficiency of a given measure based on the method developed by Hanley and McNeil [45]. Because this study was designed to provide practical thresholds that could serve as clinical markers with acceptable discriminability, we focused on the thresholds that were obtained when the AUC was 0.7 or above [46]. ROC analyses were performed using MedCalc for Windows, Version 9.2.1.0 (MedCalc Software, Mariakerke, Belgium).

Results

Participant characteristics

Tables 1 and 2 present the demographic and clinical characteristics of the sample as well as the scores on the BSRS and the PDI-T based on psychiatric diagnoses. The groups based on psychiatric diagnoses were not similar with regard to sex ($\chi^2 = 14.78$, $df = 2$, $P < 0.001$), age ($F = 13.07$, $df = 2$, $P < 0.001$) and education ($F = 4.81$, $df = 2$, $P = 0.009$).The sample with psychosis was significantly older than the healthy controls. The control group, however, contained a higher proportion of females (71%) compared to the groups diagnosed with affective psychosis (45%) or schizophrenia spectrum disorders (47%). The data also suggest that psychotic patients had a significantly lower level of formal education. For psychotic groups (Table 1), the differences in the onset and duration of psychotic illness were statistically significant (onset of illness: $t = 5.28$, $P < 0.001$; duration of illness: $t = -8.43$, $P < 0.001$), which indicated that participants with schizophrenia had significantly earlier onset of mental illness and longer duration of mental illness as compared to those with affective psychosis.

Table 1 Demographic and clinical characteristics of participants ($n = 253$)

Variables	Total, mean (SD)			Range		
	Healthy controls ($n = 99$)	Affective psychosis ($n = 47$)	Schizophrenia ($n = 107$)	Healthy controls	Affective psychosis	Schizophrenia
Age	30.96 (11.42)	40.98 (13.27)	40.22 (10.38)	19–59	19–65	23–55
Education	14.69 (2.72)	14.34 (3.15)	13.47 (2.89)	9–22	9–24	9–21
Onset of illness	–	35.62 (11.87)	25.75 (7.29)	–	15–55	12–45
Duration of illness	–	5.4 (4.64)	14.65 (8.94)	–	2–17	2–36
Depression (BSRS)	5.0 (5.93)	19.0 (11.64)	12.64 (13.17)	0–24	0–42	0–56
Paranoid (BSRS)	2.6 (3.66)	8.89 (6.3)	7.26 (6.32)	0–18	0–24	0–29
Obsession (BSRS)	4.32 (4.13)	9.66 (5.25)	7.07 (5.41)	0–22	0–22	0–26
Phobia (BSRS)	1.41 (2.4)	5.34 (5.05)	4.89 (5.49)	0–9	0–27	0–25
Somatization (BSRS)	3.1 (3.4)	10.77 (6.09)	7.09 (6.69)	0–14	0–25	0–37
Psychoticism (BSRS)	1.0 (1.87)	5.7 (4.93)	4.83 (5.68)	0–9	0–21	0–26
Hostility (BSRS)	2.12 (2.24)	6.94 (4.54)	3.0 (4.05)	0–9	0–19	0–19

BSRS Brief Psychiatric Symptom Rating Scale

Table 2 Descriptive data of the PDI-T for a Taiwanese population

Scale	Total mean (SD)	Men mean (SD)	Women mean (SD)	Range	Kurtosis	Skewness	Gender difference (U)[a]	Age (r)[b]
Healthy controls ($n = 99$)								
PDI yes/no	5.85 (8.29)	2.41 (4.27)	5.31 (5.85)	0–20	0.481	1.247	709 (0.015)	−0.164
D	7.79 (11.03)	4.76 (10.03)	10.7 (12.33)	0–47	0.94	1.401	702 (0.013)	−0.175
P	9.90 (12.82)	5.76 (10.58)	11.84 (13.53)	0–49	0.776	1.341	725 (0.022)	−0.152
C	10.89 (14.71)	6.52 (12.07)	12.79 (15.48)	0–67	2.112	1.618	733 (0.026)	−0.133
PDI Total	34.43 (44.71)	19.45 (36.8)	40.64 (46.44)	0–172	0.872	1.371	717 (0.019)	−0.154
Affective psychosis ($n = 47$)								
PDI yes/no	11.53 (6.98)	9.71 (6.75)	13.0 (6.95)	0–26	−0.632	0.535	204 (0.139)	−0.187
D	31.89 (23.28)	26.19 (23.22)	36.5 (22.72)	0–82	−0.67	0.683	179 (0.044)	−0.266
P	32.26 (21.75)	26.52 (21.43)	36.88 (21.28)	0–75	−0.886	0.519	186 (0.062)	−0.262
C	34.09 (23.97)	25.05 (20.04)	41.38 (24.73)	0–93	−0.203	0.767	153 (0.011)	−0.355*
PDI total	109.77 (74.77)	87.48 (70.52)	127.77 (74.53)	0–274	−0.621	0.637	167 (0.023)	−0.311*
Schizophrenia ($n = 107$)								
PDI yes/no	13.49 (10.73)	12.40 (9.67)	14.72 (11.8)	0–39	−0.071	0.909	1305 (0.453)	−0.273**
D	35.64 (34.22)	31.84 (27.18)	39.96 (40.65)	0–188	3.365	1.615	1343 (0.609)	−0.269**
P	38.24 (34.28)	35.40 (29.61)	41.48 (38.98)	0–152	0.811	1.218	1370 (0.731)	−0.308**
C	40.78 (36.16)	37.51 (30.56)	44.50 (41.65)	0–161	0.767	1.175	1355 (0.664)	−0.318**
PDI total	128.14 (113.46)	117.16 (95.48)	140.66 (131.2)	0–540	1.082	1.229	1346 (0.624)	−0.302**

D distress rating scale, *P* preoccupation rating scale, *C* conviction rating scale

* $P < 0.05$; ** $P < 0.01$

[a] Mann–Whitney U test (two-tailed)

[b] Spearman's rho correlation (two-tailed)

In the descriptive statistical data for the PDI-T yes/no, three-dimensional, and total scores for the sample (Table 2), age was negatively correlated with the conviction rating scale and the total scale scores for the PDI-T in patients with affective psychosis as well as the PDI-T scores for yes/no, distress, preoccupation, conviction, and total scores in patients with schizophrenia. However, there were no significant relationships between age and PDI-T scores in the control group. In the control group, females scored significantly higher on PDI-T scores than males; however, there were no sex differences for any scale on the PDI-T in the sample with schizophrenia. All PDI-T ratings had a skewed distribution in the healthy control (1.247–1.618), affective psychosis (0.519–0.767), and schizophrenia (0.909–1.615) groups.

The PDI-T means and SDs for the three groups are illustrated in Table 2. Kruskal–Wallis tests showed significant differences between the groups on all PDI-T scores (PDI-T yes/no: $\chi^2 = 45.96$, $df = 2$, $P < 0.001$; Distress: $\chi^2 = 78.10$, $df = 2$, $P < 0.001$; Preoccupation: $\chi^2 = 70.74$, $df = 2$, $P < 0.001$; Conviction: $\chi^2 = 69.92$, $df = 2$, $P < 0.001$: Total PDI-T scores: $\chi^2 = 69.43$, $df = 2$, $P < 0.001$). Dunn's multiple comparison tests showed significant difference between the healthy controls and the schizophrenia group on all scores ($P < 0.01$ for all comparisons), but no differences between the two psychotic groups ($P > 0.05$).

Although the clinical participants' mean PDI-T yes/no scores were more than twice that of the healthy controls, there was a considerable overlap in the ranges of scores, with 14 and 12% of the healthy controls having higher scores than the mean of the affective psychosis and schizophrenia groups, respectively.

Internal validity and reliability analyses

For the factor analysis, the PDI-T 40 items were submitted to an exploratory principal component analysis with varimax rotation. Bartlett's sphericity test was significant (4488.69, $P < 0.001$), indicating that the PDI-T was suitable for principal components analysis (PCA). In our data, the KMO was 0.91 and the MSA was between 0.76 and 0.94, thereby indicating that a reliable factor solution can be possible in the sample population [38]. According to a PCA with a varimax-rotated solution for all 253 cases, the overall 10 components, accounting for 62.48% of the total variances, were suggested by both a scree plot test and the Kaiser–Guttman criterion (eigenvalues >1). The eigenvalues and percentage of variance accounted for by each component are listed in Table 3, as are the loadings of each item on the 10 components and their labels (factor loading >0.4).

Cronbach's alpha coefficient assessed the internal consistency of the PDI-T yes/no for 253 completed cases and showed satisfactory reliability ($\alpha = 0.94$, $P < 0.001$ for the non-clinical sample; $\alpha = 0.94$, $P < 0.001$ for affective psychosis sample; $\alpha = 0.90$, $P < 0.001$ for schizophrenia sample). We also found adequate item-total correlations for all 40 items of PDI-T yes/no, ranging between 0.42 and 0.62 (all $P < 0.01$), indicating that the corresponding items correlated well with the scale overall and, thus, none of the 40 items could be discarded.

In addition, we determined test–retest reliability by assessing the 65 participants who were administered the PDI-T on two occasions separated by 6 months. Highly significant relationships were found for all rating scores (PDI-T yes/no: Spearman's $r = 0.81$, $n = 65$, $P < 0.001$; distress: Spearman's $r = 0.83$, $n = 65$, $P < 0.001$; preoccupation: Spearman's $r = 0.85$, $n = 65$, $P < 0.001$; conviction: Spearman's $r = 0.87$, $n = 65$, $P < 0.001$).

Association of demographic and clinical variables with the PDI-T yes/no

Table 4 presents the correlations of the PDI-T yes/no score with the psychosocial and clinical variables of the three groups. There were no significant correlations between the PDI-T yes/no and the psychosocial variables in healthy controls or those with affective psychosis. However, these PDI-T yes/no scores did correlate negatively with the duration of mental illness ($r = -0.369$, $P < 0.01$) in patients with schizophrenia, indicating that those who reported lower scores in delusion proneness were more likely to be patients with longer schizophrenia illness duration.

The convergent validity between the different BSRS symptom subscales and PDI-T yes/no scores was examined in the three groups separately (Table 4). All of the BSRS subscales were significantly positively correlated to PDI-T yes/no scores in the three groups (all $P < 0.01$), apart from "somatisation" and "phobia" in the affective psychosis group. These results suggest a strong relationship between delusion proneness and various psychiatric symptoms, such as psychotic, anxious, and depressive symptoms.

Comparisons of the PDI-T among the selected groups

Table 5 describes the comparisons between the psychosis groups and the healthy control group by item level. The frequency of PDI-T item endorsement was rather widespread in the psychotic patients' group and was much higher than that in the healthy controls group. Of the 40 items of the PDI-T, 36 items were endorsed more often by patients with psychosis than by individuals from the general population (all $P < 0.01$), whereas for item 23 ("Electric devices influencing thinking") and item 32 ("People looking oddly at you"), there were no significant differences between the groups. In general, the frequency of positive endorsement of the PDI-T items rarely fell below 30% among psychotic patients. Of the controls, 21 items were endorsed by less than 10% of the sample, and 34 items were endorsed by 20% or less of the sample. However, only four items, including item 6 ("Hints/double meanings"), item 9 ("People not what they seem), item 19 ("Being very important"), and item 33 ("Having no thoughts") were endorsed by 30% or more of the controls. The item "Being persecuted in some way" was positively endorsed by 8.1% of controls, but "Conspiracy against you" was endorsed by 1% of the controls; the corresponding results among psychotic patients were 60 and 42%, respectively.

Using the PDI-T to identify individuals who are prone to delusions (ROC analyses)

Diagnostic validity based on the areas under the ROC curves and the optimal cut-off points (Youden's index) for

Table 3 Principal component analysis of the PDI-T 40 items in a Taiwanese population

PDI-40 items[a]	1	2	3	4	5	6	7	8	9	10
Eigenvalues	3.28	3.12	3.04	2.79	2.58	2.41	2.08	2.07	1.94	1.69
Variance explained (%)	8.20	7.78	7.60	6.97	6.44	6.02	5.2	5.18	4.84	4.23
Cumulative (%)	8.2	16.0	23.6	30.56	37.01	43.02	48.23	53.41	58.25	62.48
P12 Being persecuted in some way	0.619									
P14 Organization has it in for me	0.562									
P19 Being very important	0.560									
P20 Being a special person	0.554									
P16 Special abilities or powers	0.495									
P24 Being affected by forces	0.433									
P1 Under control of other force		0.782								
P2 Robot or zombie without will		0.679								
P4 Feelings or actions not under control		0.639								
P3 Feel possessed		0.531								
P29 Body is changing peculiarly		0.420								
P35 The end of the world		0.404								
P8 Everyone gossiping about me			0.732							
P6 Hints/double meanings			0.597							
P11 Deliberately being harmed			0.541							
P5 Playing games with mind			0.478							
P13 Conspiracy against you			0.476							
P27 Worrying about partners unfaithfulness			0.458							
P7 Special messages form TV			0.476							
P10 Things seem unusual			0.467							
P25 Being chosen by God				0.803						
P21 Being especially close to God				0.735						
P17 Special purposes or mission				0.527						
P9 People not what they seem to be					0.668					
P33 Having no thoughts					0.578					
P36 Alien thoughts					0.568					
P39 Thoughts blocked					0.452					
P23 Electric devices influences thinking						0.706				
P18 Mysterious power working for the good of the world						0.608				
P38 Thoughts echoing						0.412				
P37 Vivid thoughts can be heard						0.454				
P34 Insides are rotting							0.697			
P31 Sinning more than average							0.572			
P32 People looking oddly at you								0.715		
P15 Being watched								0.685		
P30 Strangers want to have sex									0.729	
P40 People can read mind									0.461	
P26 Power of witchcraft, the occult										0.747
P28 Smelling unusual										0.469
P22 Telepathic communication										0.414

Extraction with rotation method: principal component analysis with Varimax

sensitivity and specificity were used to assess diagnostic validity when comparing psychotic groups with the control group and are summarized in Table 6. Based on the ROC analyses, the PDI-T yes/no was able to correctly classify participants with psychosis and healthy controls. The cut-off threshold that discriminates between psychotic patients

Table 4 Correlations of the PDI-T yes/no with demographic and clinical characteristics for a Taiwanese population

Variables	Healthy controls	Affective psychosis	Schizophrenia
Education (years)	−0.103	−0.039	0.126
Onset of mental illness	–	−0.092	0.056
Duration of mental illness	–	−0.06	−0.369**
Depression (BSRS)	0.599**	0.43**	0.438**
Paranoid (BSRS)	0.62**	0.466**	0.534**
Obsession (BSRS)	0.566**	0.495**	0.535**
Phobia (BSRS)	0.521**	0.254	0.431**
Somatization (BSRS)	0.448**	0.309	0.453**
Psychoticism (BSRS)	0.6**	0.535**	0.476**
Hostility (BSRS)	0.45**	0.486**	0.453**

Spearman's rho correlation (two-tailed)

BSRS Brief Psychiatric Symptom Rating Scale

** $P < 0.01$

and controls was 5, with a sensitivity of 0.81 and a specificity of 0.61 (AUC = 0.752, 95% Confidence Interval (CI) = 0.694–0.804, $P < 0.001$). The best performance of the PDI-T to putatively discriminate healthy controls from patients diagnosed with schizophrenia was a PDI-T yes/no score of 5, yielding a sensitivity of 0.79 and a specificity of 0.61 (AUC = 0.749, 95% CI = 0.684–0.807, $P < 0.001$). For patients diagnosed with affective psychosis, a PDI-T yes/no score of 5, yielding a sensitivity of 0.85 and a specificity of 0.62 (AUC = 0.757, 95% CI = 0.679–0.824, $P < 0.001$) performed best.

Discussion

The main purpose of this study was to validate the PDI-T capable of measuring delusion proneness in the Taiwanese population. The results of this study provide preliminary evidence for the reliability, stability over time, and validity of the PDI-T. The optimal cut-off point has been determined for this scale.

The 40-item PDI had a near-normal distribution in a healthy British sample [4]; however, its distributions in the healthy Taiwanese and healthy Korean populations [31] were more skewed. This skewed distribution is most likely a reflection of the "real" distribution of subclinical delusional ideation, considering the rather pathological tone of the questionnaire [4]. Although there are considerable differences between our study and earlier published investigations [4, 30, 31] with regard to the mean subscales of the PDI-T, some apparent and interesting similarities exist. On the mean PDI yes/no and distress, preoccupation, and conviction dimensional scores, the healthy Taiwanese sample (5.85, 7.79, 9.9, 10.89, respectively) had lower ratings than the healthy Japanese sample [30] (9, 26.4, 25.1, 28.1, respectively). The difference between the two groups could be, in part, explained by the differing characteristic of mean age and the fact that the healthy Taiwanese sample had an older mean age (30.96 ± 11.42) than the healthy Japanese sample (19.1). These results appear to be consistent with previous study findings, which indicated that the slightly older mean age of participants in two European studies [24, 47] might have contributed to their lower mean PDI when compared to the healthy British sample. However, despite the fact that the healthy Taiwanese sample had a younger mean age (30.96 ± 11.42) than the healthy British sample (36.5 ± 10.2) and the healthy Korean sample (32.07 ± 9.58), when comparing the mean PDI scores of the original PDI, the Korean version, and the Taiwanese version, the mean PDI yes/no and three-dimensional scores were slightly lower in the healthy Taiwanese sample (5.85, 7.79, 9.9, 10.89, respectively) than in the healthy British (9.7, 21.6, 21.3, 29.8, respectively) or healthy Korean samples (7.82, 16.5, 18.0, 19.81, respectively). Such dispersion might be caused by the differences in cultural background or the origins and sizes of the sample.

For non-clinical sample, there were significant sex differences; however, no significant correlation was revealed between age and the four rating scores of the PDI-T. This finding is consistent with other empirical research in this area [48, 49], specifically, the finding shows that women have more positive "paranormal" and psychosis-like experiences than men. However, other studies have found that no sex differences existed but that there were significantly inverse relationships between age and four types of PDI-40 scores when the PDI was applied to non-clinical samples [4, 12, 50]. Cultural heterogeneity among the samples may account, in part, for this divergent finding.

In the present study, the results of the principal components analysis of PDI responses from the non-clinical and clinical populations suggest that delusion proneness is made up of multiple factors. Although the ten components obtained were closely linked to those in the British (11) [4] and Korean (10) [31] populations, differences were observed in the item compositions of the overall factor structure between these studies. However, sample differences may partially account for these divergent findings, as

Table 5 Frequency of endorsement of delusion proneness 40 items of the PDI-T

PDI-T item		Healthy controls *N* (%)	Psychotic patients *N* (%)	χ^2 (*p*) All *df* = 1
1	Under control of other force	7 (7.1)	61 (39.6)	32.47 (<0.001)
2	Robot or zombie without will	5 (5.1)	36 (23.4)	14.9 (<0.001)
3	Feel possessed	3 (3.0)	36 (23.4)	19.13 (<0.001)
4	Feelings or actions not under control	6 (6.1)	65 (42.2)	39.0 (<0.001)
5	Playing games with mind	12 (12.1)	54 (35.1)	16.45 (<0.001)
6	Hints/double meanings	31 (31.3)	84 (54.5)	13.12 (<0.001)
7	Special messages form TV	2 (2.0)	55 (35.7)	39.2 (<0.001)
8	Everyone gossiping about me	12 (12.1)	53 (34.4)	15.69 (<0.001)
9	People not what they seem to be	35 (35.4)	93 (60.4)	15.11 (<0.001)
10	Things seem unusual	7 (7.1)	35 (22.7)	16.67 (<0.001)
11	Deliberately being harmed	14 (14.1)	76 (49.4)	32.6 (<0.001)
12	Being persecuted in some way	8 (8.1)	60 (39.2)	29.57 (<0.001)
13	Conspiracy against you	1 (1.0)	42 (27.3)	29.46 (<0.001)
14	Organization has it in for me	2 (2.0)	25 (16.2)	12.77 (<0.001)
15	Being watched	6 (6.1)	45 (29.2)	20.08 (<0.001)
16	Special abilities or powers	8 (8.1)	34 (22.1)	8.53 (0.003)
17	Special purposes or mission	5 (5.1)	38 (24.7)	16.45 (<0.001)
18	Mysterious power working for the good of the world	11 (11.1)	45 (29.2)	11.47 (<0.001)
19	Being very important	31 (31.3)	70 (45.5)	5.03 (0.025)
20	Being a special person	11 (11.1)	47 (30.5)	12.85 (<0.001)
21	Being especially close to God	6 (6.1)	48 (31.2)	22.63 (<0.001)
22	Telepathic communication	19 (19.2)	53 (34.4)	6.86 (0.009)
23	Electric devices influences thinking	12 (12.1)	29 (18.8)	2.0 (0.158)
24	Being affected by forces	6 (6.1)	37 (24.0)	13.79 (<0.001)
25	Being chosen by God	3 (3.0)	27 (17.5)	12.13 (<0.001)
26	Power of witchcraft, the occult	20 (20.2)	49 (31.8)	4.1 (0.043)
27	Worrying about partners unfaithfulness	17 (17.2)	67 (43.5)	18.84 (<0.001)
28	Smelling unusual	10 (10.1)	41 (26.6)	10.22 (0.001)
29	Body is changing peculiarly	5 (5.1)	41 (26.6)	18.85 (<0.001)
30	Strangers want to have sex	0 (0)	31 (20.1)	22.71 (<0.001)
31	Sinning more than average	9 (9.1)	40 (26.1)	11.0 (0.001)
32	People looking oddly at you	16 (16.2)	40 (26.0)	3.37 (0.067)
33	Having no thoughts	30 (30.3)	78 (50.6)	10.2 (0.001)
34	Insides are rotting	2 (2.0)	37 (24.0)	22.38 (<0.001)
35	The end of the world	2 (2.0)	28 (18.2)	15.06 (<0.001)
36	Alien thoughts	19 (19.2)	61 (39.6)	11.62 (0.001)
37	Vivid thoughts can be heard	6 (6.1)	31 (20.1)	9.55 (0.002)
38	Thoughts echoing	4 (4.0)	48 (31.2)	27.16 (<0.001)
39	Thoughts blocked	19 (19.2)	73 (47.4)	20.73 (<0.001)
40	People can read mind	19 (19.2)	59 (38.3)	10.33 (0.001)

the Jung et al. [31] and Peters et al. [4] studies used a healthy sample alone to investigate the factor structure of the PDI.

In the present study, delusion proneness, as measured with the PDI-T, was strongly correlated with the psychotic symptom subscales of the BSRS, supporting the convergent validity of the PDI-T. Similarly, it was strongly correlated with common psychiatric symptoms such as depression and anxiety. Such findings are comparable to that of the Netherlands Mental Health Survey and Incidence Study survey [14], where strong associations existed between all types of psychosis ratings on the Composite International Diagnostic Interview (CIDI) and other psychiatric symptoms, such as depressive symptoms. Thus, the

Table 6 Sensitivity and specificity at various cut-off points of the PDI-T for delusion proneness

Score threshold	Sensitivity (%)	Specificity (%)	Yuden index
Psychotic disorders ($n = 47 + 107$)			
2	88	49	1.37
3	84	57	1.41
4	82	59	1.41
5*	**81**	**61**	**1.42**
6	72	67	1.39
7	65	71	1.36
8	58	75	1.33
9	55	79	1.34
10	53	81	1.34
11	49	83	1.32
12	42	83	1.25
13	37	85	1.22
Schizophrenia ($n = 107$)			
2	86	49	1.35
3	81	57	1.38
4	79	59	1.38
5*	**79**	**61**	**1.4**
6	70	67	1.37
7	66	71	1.37
8	60	75	1.35
9	57	79	1.36
10	55	81	1.36
11	50	83	1.33
12	43	83	1.26
13	38	85	1.23
Affective psychosis ($n = 47$)			
2	91	49	1.40
3	89	57	1.46
4	89	57	1.46
5*	**85**	**62**	**1.47**
6	77	67	1.44
7	62	71	1.33
8	53	75	1.28
9	51	79	1.30
10	49	81	1.30
11	47	83	1.30
12	40	83	1.23
13	34	85	1.19

* Optimal cut-off point (maximum sensitivity and specificity) shown in bold

broad psychosis phenotype may include variations in other symptoms, as do the clinical disorders [14, 51–53]. A number of studies have been conducted using the PDI as an instrument to assess delusion proneness. These studies have suggested that these experiences are associated with depression or anxiety [22, 54–56]. Furthermore, it was somewhat surprising that the correlations between delusion proneness and the psychotic symptoms were not higher than those between delusion proneness and common psychiatric symptoms, such as depression and anxiety. One reason for these results could be the item composition of the PDI, which has been attempted to include a wider range of beliefs (including delusion-like beliefs) and to minimize the social stigma attached to endorsing psychosis-like beliefs by embedding such questions in a broader range of paranormal and religious beliefs. The inclusion of questions in the PDI-T that cover more common, less stigmatizing beliefs served to reduce the psychiatric associations with such beliefs and to encourage participants to engage honestly with the questions. Together, these findings support the notion that psychotic-like experiences reflect a wider spectrum of mental disorders than just psychotic disorders [56]. While we found a significant association between the presence of non-psychotic symptoms and delusion proneness in this cross-sectional study, we cannot draw conclusions regarding the direction of causality.

In the present study, item 3 of the PDI-T ("People are not what they seem to be") seemed to evoke a relatively high rate of endorsement in the non-clinical sample, suggesting that this theme found in delusion proneness is frequent in the general population, at least in samples of Taiwanese and Italian [57] background. The endorsement rate of item 8 ("Be especially close to God") was lower in Taiwan (6%), a non-Catholic country, than Italy (22%), a Catholic country. One reason for these different results could be that the delusion proneness phenomena captured by the different socio-cultural backgrounds may have different clinical/predictive values. In fact, different phenomena of delusion proneness are likely to be elicited in different cultural situations.

In the present study, despite differences in group means between the healthy control and psychotic groups, the distributions of the PDI-T scores overlapped considerably. These results support previous findings [4, 25, 31] on two levels. First, they support the notion that there is a continuum phenomenon between subjects from the general population and clinical cases of psychosis, with "normal" individuals being at one end of the continuum and the psychotic patients at the other extreme. Second, it provides further support for the necessity to consider the multidimensionality of delusion proneness, as the healthy control and psychotic groups could be differentiated by their scores on the distress, preoccupation, and conviction dimensions. In other words, it is not what you think; it is how you think about it [39]. Several studies have also concluded that the distress associated with psychotic-like experiences may play an important role in the formation of clinical cases or psychotic symptoms requiring care [58, 59]. Therefore,

these studies further suggest that the analysis of these dimensions may reveal more than the content of the beliefs alone when placing a person on the continuum between normality and psychosis.

ROC was applied to explore how well the PDI-T is able to distinguish between individuals with and without delusion proneness. An AUC of 0.75 indicated an acceptable ability of the PDI-T yes/no scores to predict the delusion proneness status [46]. Thus, these results support the appropriateness of selecting two distinct groups, representing the opposite ends of such a continuum (i.e., healthy controls and psychotic patients), to establish the PDI-T cut-off scores that index the absence or presence of delusion proneness. In preliminary explorations of the topic, we found that a PDI-T yes/no cut-off of 5 presented the best compromise between specificity and sensitivity. However, the PDI-T yes/no mean score of the controls (who were mainly non-psychotic) was 5.85, while that of the patients (who were mainly psychotic) was 12.89.

In the present study, our goal was to validate the PDI-T to screen for delusion proneness, for which it is important to minimize the rates of "false-positives". There is a potential for high rates of false positives particularly at the community level given the difficulty in discriminating mild symptoms from normal variants and low base rates of the syndrome in the general population [60]. Several studies have investigated whether the high rates of these "false positives" (i.e. individuals at risk for developing psychosis based on the presence of attenuated psychotic symptoms who do not develop a psychotic disorder within 2–3 years) ranges from 50 to 84% [60–63]. It has been argued by Corcoran et al. [64] and others that false positives labeled as at risk are liable to social and personal costs as well as unnecessary medical care. There is further evidence that antipsychotic medications and other treatments may have some efficacy for individuals with "psychosis risk syndrome", although with variable side effects, including weight gain [60, 65], motor abnormalities [60, 66], and significant risk to cardiovascular and general health [60]. However, controversy remains about some of the inherent risk in psychosis proneness-related research, such as unnecessary exposure to antipsychotic medications, sigma, and discrimination [60, 64]. On the basis of these various findings, we believed that 5 is an appropriate cut-off score for indexing the absence of delusion proneness. Furthermore, the results of the different approaches for selecting the upper cut-off score suggested that a score of 13 on the PDI-T yes/no would be appropriate cut-off score for indexing the presence of delusion proneness. Therefore, it is possible to distinguish three categories on the basis of the PDI-T yes/no scores: individuals scoring higher than or equal to 13 were considered delusional; those scoring lower than or equal to 5 were considered non-delusional, and those with a score ranging from 6 to 12 were considered intermediate-delusional in the Taiwanese population. However, cut-off scores provided in this and similar studies largely depend on sample characteristics (in particular, sample sizes and types of psychiatric disorders or conditions considered in the studies) as well as on the procedures used during assessment, diagnostic, and data analyses. Given the number of differences across the studies in these and other variables, it is difficult to compare these results with previous evidence and, therefore, cut-off scores provided in this study should be used with care [67].

This study has several limitations. Most importantly, non-clinical participants with a medical or psychological background were not more formally screened, and, therefore, it is not possible to rule out an effect of this on the results reported here. In addition, the non-clinical sample was largely drawn from undergraduate students and may not be truly representative of the wider population. Second, we did not recruit the participants using a random sample from the community; instead, the participants were recruited to the study using a convenient sample. Most of our healthy controls and psychotic outpatients were enrolled at a local area hospital. Thus, these participants were not representative of all patients with mental illness or the general population. Third, the sample size for the present study ($n = 253$), especially the size of affective psychosis group ($n = 47$), was not very large, making any conclusions only preliminary. Larger sample size would be needed to get more precise and valid cut-off scores in the future. Fourth, the data are based solely on self-report measures. Hanssen et al. [68] discussed the need to combine self-report and interview-based measures of subclinical psychosis, as results can differ. However, the goal of this research was to validate the Taiwanese version of the PDI, rather than to engage in a detailed understanding of phenomena, and we expect that the limitations of self-report measures affected our three groups equally. Previous work has also demonstrated that self-reports of delusion proneness are valid because they are etiologically [69] and longitudinally on a continuum with clinical psychotic disorders [10]. The final limitation concerns the nature of the questionnaire. The assessment of delusion proneness may be affected by many factors, such as participants misunderstanding of the nature of certain items. For example, queries concerning religious themes might be perceived as being consistent with one's personal background or, on the contrary, they might raise suspicion or even conviction of incongruence, thus leading to answers that are less reliable than answers that were more clearly characterized on the grounds of the investigated psychological experiences [57]. Particularly in the general population, queries on psychotic-like experiences might be falsely denied because of the perceived stigma associated with such experiences [4, 70].

Conclusion

We confirmed the reliability and validity of the Taiwanese version of the PDI-40. The present finding supports the former results, that is, the multidimensionality of delusions may be more important than the content of belief alone. The PDI is a clinically useful and comprehensive measure of delusion proneness in the Taiwanese non-clinical populations and this scale can be used as a valid additional source when investigating psychosis proneness in individuals at high risk for psychosis [31]. Because the PDI was originally developed in the UK and has been translated into many different languages, validating it in this study provides a common ground for international researchers to understand the dimensionality of delusion proneness in the Taiwanese population.

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Conflict of interest The authors declare that they have no competing interests.

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