Original Article

Short Form of Weinstein Noise Sensitivity Scale (NSS-SF): Reliability, Validity and Gender Invariance among Chinese Individuals

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Abstract

Objective Independent from noise exposure, noise sensitivity plays a pivotal role in people's noise annoyance perception and concomitant health deteriorations. The present study empirically investigated the psychometric properties of the Chinese version of the Weinstein Noise Sensitivity Scale-Short Form (CNSS-SF), the widely used inventory measuring individual differences in noise perception.

Methods In total, 373 Chinese participants (age = 21.41 ± 3.36) completed the online, anonymous questionnaire package. Examination of the CNSS-SF's reliability (internal consistency), factorial validity through validation and cross-validation, nomological validity and measurement invariance across gender groups were undertaken.

Results The Cronbach alpha coefficients and composite reliabilities indicated sufficient reliability of the CNSS-SF. Two confirmatory factor analyses (CFA), in two randomly partitioned groups of participants, substantiated the factorial validity of the scale. The nomological validity of the scale was also corroborated by the significant positive association of its score with the trait anxiety score. Measurement invariance of the CNSS-SF was also found across genders *via* multi-group CFA.

Conclusion Though not without limitations, findings from the present research provide promising evidence for the utility of the scale in measuring noise sensitivity among the Chinese population. The availability of the CNSS-SF can promote research related to environmental noise and health in China, as well as facilitate cross-cultural comparisons.

Key words: Environmental noise; Individual differences; Cross-cultural validation; Measurement; Public health

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INTRODUCTION

In contemporary society, urban noise pollution, as one of the most notorious forms of environmental pollution, has become a global public health concern[1]. Worryingly, this phenomenon is even more prominent in China. As a densely populated developing country, China is experiencing rapid urbanization and industrialization, while also suffering a negative, profound corresponding impact, including noise pollution, which accompanies its development[2,3]. Hence, noise pollution and corresponding noise annoyance have become a problem which warrants serious attention. In the extant literature, noise annoyance has been extensively researched and associated with a substantial effect on multiple health-related indicators. For instance, noise annoyance is

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positively linked with increased cardiovascular risk[4,5], and sleep disturbance[6,7], while inversely correlated with cognitive and psychological function[8], and quality of life[9,10].

Though noise exposure serves as an objective variable that can independently result in noise annoyance, noise sensitivity is also critically conducive to noise annoyance in affected individuals[11,12]. Noise sensitivity refers to relative individual differences in noise perception and endurance, which shape people's reaction towards environmental noise[13,14]. For instance, given the same noise exposure level, individuals may have a different noise-associated reaction, which could be attributed to character traits. People who are more noise-sensitive tend to perceive noise as more threatening and beyond their control, and adapt to noise harder and slower, which may result in increased annoyance[15,16]. Noise sensitivity has been identified as an independently contributing factor to noise annoyance and health deterioration[17]. For example, a cross-sectional study conducted among adult residents living adjacent to an airport found that noise sensitivity was related to noise annoyance and sleep disturbance[18]. In addition, sensitivity to noise is responsible for various detrimental conditions, such as hypertension and chest pain[19]. A laboratory study[20] showed that, when exposed to noise, individuals with high noise sensitivity performed worse in cognitive tasks, such as short-term memory (STM) and mental arithmetic (MA) test. An experimental study[21] also reported that, when asked to perform a cognitive task employing working memory, noise-sensitive participants were more easily distracted by noise compared to those who were less noise-sensitive.

As noise exposure or the physical characteristics of the sound environment cannot exclusively determine noise annoyance, and noise sensitivity, as a subjective individual propensity, can play a fundamental role in predicting people's reaction to noise, efforts have been made to quantify this variable, by developing measuring tools. The Weinstein's Noise Sensitivity Scale (NSS) is, to date, the most widely used instrument. The NSS constitutes of 21 items that describe individual responses to a wide array of situations in daily life[13,14]. The six-point Likert scale, ranging from (1) 'strongly disagree' to (6) 'strongly agree', is used to express to what extent an item is germane to a respondent's condition. Moreover, to counter the potential response bias, seven items are formulated as reverse scoring items. A higher score indicates higher noise sensitivity of the respondent.

Since the development of the NSS, it has been widely translated into different languages to cater to various populations. For example, it has been translated into Swedish[22], German[23], Persian[24], as well as Italian[25]. Moreover, considering the complete 21-item NSS might be too long to be administered in time-sensitive field settings, it was shortened into a 5-item field-friendly version, named NSS-SF. Its psychometric properties were initially demonstrated among US participants, which revealed that the shorter version represented the structure of the NSS well[26]. Following this, the NSS-SF was translated and validated among Bulgarian participants, yielding psychometric soundness[27].

However, certain limitations were also noted in the aforementioned translation and validation papers. First, regarding the examination of the NSS/NSS-SF's factorial validity, exploratory factor analysis (EFA)[22,24] or univariate analysis[13,23] were employed in some studies, perhaps partly because the studies were undertaken in relatively early time when other specific methods were unavailable. EFA is a statistical method used to unravel the underpinning structure of a measurement. It is commonly used in scale development and serves to identify the latent construct underlying a battery of items[28]. As such, this technique is not entirely appropriate for validation when the theoretical construct of the scale is already established. In contrast, the objective of confirmatory factor analysis (CFA) is to test a hypothesized measurement model fit which is based on an early scale development study. Considering the goal of validation, CFA seems to be more relevant for the factorial validity assessment of a scale[29]. Furthermore, studies using the CFA technique[25-27] only validated the measurement model in one data set, lacking cross-validation information[30]. Last but not least, even though measurement invariance can be used for psychometric property evaluation[31], to date, a single study[25] examined the measurement invariance of the NSS, while the invariance information for the NSS-SF is still lacking.

Additionally, though the NSS/NSS-SF has been widely used and translated into different languages, an easy administered, field-friendly shortened Chinese version of the scale is still unavailable. This hinders the filed investigation of noise sensitivity in the Chinese population, as the world's largest population, and constrains cross-cultural comparisons. Therefore, the aim of the present study was to translate the NSS-SF into Chinese and validate it, which could provide a more practical instrument for use in real settings. In contrast with the NSS, the NSS-SF reached a balancing point between instrument brevity and decent quality[26], it was deemed reasonable to target the short version. In the following validation process, the reliability, validity and gender invariance of the CNSS-SF were assessed.

METHODS

Participants

The participants were recruited through the online survey approach *via* convenience sampling. They were students/staff from three universities in Guangdong province, China. The online survey package consisted of a cover page concerning information such as purpose of the research, demographic information items (i.e. age and gender) and measurements used in the study. In total, 373 individuals voluntarily participated in the present research and completed the survey. The total sample was randomly split into two parts as calibration and validations samples for subsequent statistical analysis. The demographic information can be seen in Table 1.

Procedure

Prior to questionnaire administration, ethical clearance was obtained from the local university research ethics committee. Translation and back translation techniques[32,33] were adopted in the present study, to ensure equivalency when translating the NSS-SF into Chinese (CNSS-SF). Specifically, two professional translators were invited to translate the original English version into Chinese, independently. A comparison was made between their translations, and modifications were made until consensus was achieved between the two translators. Subsequently, two other professional translators were invited to translate the CNSS-SF back into English. Comparison was conducted to locate gaps to the original English version, and revisions were made until consensus was reached between the two translators. Subsequently, five Chinese adults were invited to check the comprehensibility of the CNSS-SF. Based on their assessment, the translated scale was well comprehensible and no suggestion was elicited for further adjustment. Hence, the CNSS-SF for subsequent administration was finalized.

The anonymous, structured questionnaire package was created and posted online *via* an online survey platform (https://www.wjx.cn/), which is popular in China. Invitation pamphlets/posters containing basic information of the research as well as online survey quick response (QR) code were created. Pamphlets were circulated in universities and posters were posted on poster board on campuses by the researcher. Students/staff interested in the present investigation could access the electronic questionnaire battery *via* QR code. No monetary/material incentive was provided for participants. In the cover page of the online survey, participants were informed the aim of the study, and their participation was anonymous, confidential and voluntary. They were entitled to withdraw at any time. Furthermore, they were asked to respond honestly, as there were neither right, nor wrong answers.

Measurements

Chinese Version of the Weinstein Noise Sensitivity Scale-short Form (CNSS-SF) The scale consists of 5 items, deriving from the long-form scale, originally coded as items 7, 8, 18, 19, and 21. The six-point Likert

Table 1. Demographic Statistics of Participants

Variable	Total Sample (*N* = 373)	Calibration Sample (*N* = 187)	Validation Sample (*N* = 186)
Age (years)			
Mean ± SD	21.41 ± 3.36	21.19 ± 2.87	21.62 ± 3.79
Range	18-42	18-39	18-42
Gender, *n*(%)			
Male	207 (55.50%)	101 (54.01%)	106 (56.99%)
Female	166 (44.50%)	86 (45.99%)	80 (43.01%)

***Note*.** SD, Standard deviation.

scale is applied, ranging from 'strongly disagree (1)' to 'strongly agree (6)'. Among the 5 items, one item (item 2) is negatively worded. The final score is obtained by reversely coding item that is negatively worded and summing up all the items[26]. A higher score indicates higher degree of noise sensitivity.

Chinese Version of the State-trait Anxiety Inventory Form Y-2 (STAI-C, Y-2) The STAI, as an instrument to assess trait and state anxiety, has been widely used. It comprises a total of 40 items, with 20 items for state anxiety (Form Y-1) and 20 items for trait anxiety (Form Y-2). The four-point Likert scale is used for quantification, ranging from 1 (almost never) to 4 (almost always). In the present study only the trait anxiety sub-scale (Form Y-2) was adopted, which assesses stable manifestation of anxiety by means of asking respondents how they typically feel. Particularly, items 21, 23, 26, 27, 30, 33, 34, 36, and 39 in the Form Y-2 are negatively worded. The scoring of the scale is done by reversely coding items that are negatively worded and summing up all the items. A higher resulting score denotes a higher level of trait anxiety. Since its development[34,35], the STAI has been extensively translated and well-validated in different languages, including Greek[36], Malaysian[37], Japanese[38], Portuguese[39], Spanish[40], Norwegian[41], French[42], Brazilian[43], and Chinese[44], revealing adequate psychometric property.

Data Analyses

Descriptive statistical analysis was adopted for mean value, standard deviation, skewness and kurtosis of each item. The data was evenly split into two samples, in a random fashion. Specifically, sample 1 (N = 187) served as the calibration sample, while sample 2 (N = 186) served as the validation sample. CFA was performed to examine the factorial validity of the CNSS-SF in AMOS 22.0. The sample size met the ratio of 10:1 required in CFA between sample size and total items of the scale[45]. Maximum-likelihood (ML) estimation with 5,000 bootstrap samples[46] was introduced to examine the factorial validity of the CNSS-SF[47]. As for model fit indices used to examine the fit of the constructed model, the ratio of χ^2/df with a value of less than 3 indicates reasonable fit[48,49]. Meanwhile, in line with the recommendations of Hu and Bentler[50], comparative fit index (*CFI*), Tucker-Lewis index (*TLI*), standardized root mean square residual (*SRMR*) and the root mean square error of approximation (*RMSEA*) accompanied by its 90% confidence interval (90% *CI*) were also employed in the present study. Cut-off values of 0.90 and 0.95 for *CFI/TLI* demonstrate acceptable and good model fit, respectively. Likewise, cut-off values of 0.08 and 0.06 for RMSEA/SRMR represent acceptable and good fit, respectively[50]. Regarding factor loading determination, the standardized factor loading cut-off larger than 0.40 was applied, which has been widely used in past researches adopting factor analysis[51,52].

Measurement invariance (*MI*) was introduced to examine whether the scale would exhibit gender invariance. In particular, a configural model and two increasingly constrained models, *viz.* measurement weights and structural covariances models, were assessed. Since error variance covariance is of little interest and usually deemed unnecessary[53], it was not performed in the present study. A non-significant χ^2 value, an alteration of *CFI* of less than 0.01 between competing models, as well as an alteration of *RMSEA* of less than 0.015 between comparison models, served as benchmark of group invariance assessment[53,54].

Nomological validity was tested for the CNSS-SF by examining its association with the STAI-C-Y2, which was found linked to noise sensitivity in previous studies[23,25]. In line with previous results, it was hypothesized that respondents' scores in the CNSS-SF would be positively correlated with scores of trait anxiety.

Estimation of internal consistency was carried out using Cronbach's alpha and composite reliability. The advantage of adopting composite reliability is that it is able to account for measurement errors of all indicators[55], as well as provide better estimation of the internal consistency reliability of the measure[56]. A value of 0.70 or greater is considered evidence of acceptable internal consistency of the CNSS-SF scale for both Cronbach's alpha[57,58] and composite reliability[55].

RESULTS

Factorial Validity Analysis: Confirmatory Factor Analysis

The descriptive analysis results for both the calibration sample and the validation sample are displayed in Table 2. Sufficient model fit for both the calibration and validation sample data was demonstrated in CFA analyses. The specific model fit statistics and standardized factor loadings for the two sample data are displayed in Table 3 and Table 4, separately.

Nomological Validity and Internal Consistency

Nomological validity is regarded as a core facet for assessing the overall validity of a measurement[59]. It was tested by investigating the association between score of CNSS-SF and trait anxiety. As expected, score of noise sensitivity was significantly positively correlated with score of trait anxiety (r = 0.155, P < 0.01).

The reliability of the CNSS-SF was evaluated by internal consistency (Cronbach's alpha and composite reliability) in the calibration sample and the validation sample, respectively. For the calibration sample, Cronbach's alpha and composite reliability were 0.715 and 0.720, respectively, while in the validation sample, Cronbach's alpha and composite reliability were 0.712 and 0.726, respectively. Internal consistency values in both samples exceeded the acceptable standard of 0.7, demonstrating that the CNSS-SF had acceptable reliability.

Gender Invariance of the CNSS-SF

Results showed that the unconstrained model (default model) specified for male and female participants demonstrated sufficient goodness-of-fit. When the factor loadings were further constrained to be equal across gender, the model displayed adequate goodness-of-fit, which supported the factor loadings invariance across gender. In the third model, an additional constraint (set the factor variances, as well as co-variances, to be equal across males and females) was added, whilst the model still maintained acceptable goodness-of-fit overall.

Table 5 displays goodness-of-fit indices for the invariance analysis of the CNSS-SF. It revealed that the χ^2 difference between M1 and M2 was insignificant (P = 0.225), and there was no substantial change in the *CFI* value (ΔCFI = 0.006 < 0.01), as well as in the RMSEA value ($\Delta RMSEA$ = 0.001 < 0.015). Therefore, we concluded that the factor loadings of CNSS-SF model were invariant across gender. Likewise, results exhibited that the χ^2 difference between M2 and M3 was insignificant (P = 0.240), and there was no substantial change in either the *CFI* value (ΔCFI = 0.006 < 0.01), or the RMSEA value ($\Delta RMSEA$ = 0.000 < 0.015), suggesting invariance in factor variances/co-variances. In sum, the above results suggested that factor loadings, factor variances, as well as co-variances, were invariant across gender (male and female participants), in the current study.

Table 2. Item Means, Standard Deviation, Skewness and Kurtosis across Samples

Item	Calibration Sample (N = 187)				Validation Sample (N = 186)			
	Mean	SD	SK	KU	Mean	SD	SK	KU
1	4.37	1.256	-0.530	-0.264	4.37	1.241	-0.434	-0.285
2	4.02	1.222	-0.238	-0.462	3.97	1.311	-0.289	-0.346
3	3.99	1.416	-0.163	-0.797	4.05	1.421	-0.153	-0.927
4	4.56	1.240	-0.403	-0.820	4.46	1.395	-0.579	-0.672
5	4.19	1.146	-0.103	-0.856	3.89	1.249	-0.031	-0.632

Note. SD, Standard deviation; SK, Skewness; KU, Kurtosis.

Table 3. Model Goodness-of-fit for Calibration and Validation Samples

Model	χ^2	*df*	χ^2/df	*P*	*CFI*	*TLI*	*RMSEA* (90% *CI*)	*SRMR*
Calibration sample (N = 187)	9.207	5	1.841	0.101	0.972	0.944	0.067 (0.000-0.135)	0.0377
Validation sample (N = 186)	10.353	5	2.071	0.066	0.969	0.939	0.076 (0.000-0.142)	0.0366

Table 4. Standardized Factor Loadings across Samples

Item Content	Calibration Sample (N = 187)	Validation Sample (N = 186)
1. I get annoyed when my neighbors are noisy.	0.655	0.406
2. I get used to most noises without much difficulty.	0.552	0.449
3. I find it hard to relax in a place that's noisy.	0.531	0.529
4. I get mad at people who make noise that keeps me from falling asleep or getting work done.	0.587	0.765
5. I am sensitive to noise.	0.584	0.759

Note. The Chinese version of the NSS-SF is available on request if necessary. Please direct your request to the correspondence author in Chinese or English.

DISCUSSION

Noise sensitivity, characterized as individual aversion towards noise environment[13], is considered an essential individual differences variable in noise research. High noise sensitivity was linked with higher noise annoyance[60] and successive degradation of health-related quality of life[18], elevated risk of cardiovascular disease[61], poor sleep quality[62,63], as well as mental disturbances, such as poorer performance in cognitive tests[20,64] and higher perception of stress[65].

The NSS, as well as its shorter version the NSS-SF, were developed aiming to produce a measurement for individual differences in the aspect of noise sensitivity. A widely used instrument, the NSS/NSS-SF facilitates the understanding of noise sensitivity, as well as of subsequent noise annoyance and health impact. Compared with the 21-item NSS, the 5-item NSS-SF can significantly reduce participant's burden during administration, while simultaneously maintaining the scientific rigor of its original scale NSS. To further substantiate the psychometric properties of the NSS-SF and promote its use in pertinent research in China, the paper delineated the validation procedure of the Chinese version of the NSS-SF among Chinese adults, *viz.* the CNSS-SF. Overall, supportive results were obtained regarding reliability and validity, as well as gender invariance of the CNSS-SF, in the current study.

The analytical rigor in the study was strengthened through employing two CFAs (*i.e.* validation and cross-validation) in independent samples (*i.e.* the calibration sample and the validation sample) for the examination of the factorial validity of the CNSS-SF. In comparison with a previous study[26,27], finding from the present study demonstrated consistency. For instance, Benfield et al.'s study[26] found an acceptable model fit of the NSS-SF in CFA, *CFI* = 0.97, *RMSEA* = 0.078, with standardized factor loadings of CFA ranging from 0.564 to 0.750. Similarly, Dzhambov and Dimitrova[27] reported good model fit of the CNSS-SF, with χ^2 = 7.55, *df* = 5, *P* = 0.183, *CFI* = 0.996, *RMSEA* = 0.067 and *SRMR* = 0.011, with standardized factor loadings ranging from 0.88 to 0.94. The present study further substantiated the structure of the NSS-SF among Chinese individuals, reporting comparable results from two CFAs in two independent samples. It appears this paper provided more convincing factorial validity evidence for the scale by taking advantage of the cross-validation of CFA.

Nomological validity of the translated NSS was also tested. Similar to past research[23,25], scores of the CNSS-SF were positively associated with scores of trait anxiety. That is, participants who scored higher on the noise sensitivity scale were also likely to report higher trait anxiety scores. Moreover, the magnitude (*r* = 0.155) of their association detected in the present study was comparable with results obtained in early studies (*r* = 0.247 in Zimmer and Ellermeier's study[23]; *r* = 0.237 in Senese et al.'s study[25]). Thus, the nomological validity of the CNSS-SF was further substantiated.

To evaluate the reliability of the translated NSS-SF, its internal consistency was examined. Specifically, in both the calibration sample and the validation sample, values of Cronbach's alpha and composite reliability all exceeded the cut-off point of

Table 5. Measurement Invariance across Gender (male = 207; female = 166)

Model	Model Comparison	χ^2	*df*	*P*	*CFI*	*ΔCFI*	*TLI*	RMSEA (90% *CI*)	*ΔRMSEA*	*SRMR*
Male	-	7.205	5	0.206	0.988	-	0.976	0.046 (0.000-0.115)	-	0.0305
Female	-	6.039	5	0.302	0.992	-	0.984	0.035 (0.000-0.118)	-	0.0328
M1	-	13.244	10	0.210	0.990	-	0.979	0.030 (0.000-0.067)	-	0.0305
M2	M1 *vs*. M2	18.920	14	0.168	0.984	0.006	0.977	0.031 (0.000-0.063)	0.001	0.0382
M3	M1 *vs*. M3	19.993	15	0.172	0.984	0.006	0.978	0.030 (0.000-0.061)	0.00	0.0378

Note. M1, Unconstrained model; M2, Equality of factor loading; M3, Equality of factor loading, factor variances/co-variances.

0.70, indicating sufficient reliability of the CNSS-SF. The outcome aligned with findings from previous research, such as in Benfield et al.'s result (Cronbach's alpha = 0.75)[26] and Dzhambov and Dimitrova's result (Cronbach's alpha = 0.841)[27]. Additionally, this paper advanced past research by estimating the composite reliability of the translated NSS-SF's[56], which gave stronger internal consistency support for the scale.

Furthermore, the property of gender invariance was also displayed in the CNSS-SF, which added extra merit to the translated scale. To the best of our knowledge, this paper presents the only attempt to test the measurement invariance of the NSS-SF. As a key indicator of the psychometric property of measurement[31], measurement invariance is used to test whether a given scale is interpreted in a conceptually similar fashion across different groups, with different background. Its violation may diminish meaningful interpretation of measurement[66]. The measurement invariance (gender invariance) of the translated scale, in the current study, confirmed that the same construct was measured across designated groups (male and female participants). In all, this finding added evidence of the CNSS-SF's psychometric property.

As outlined, though the research has both theoretical and practical value (e.g. substantiate the psychometric properties of the CNSS-SF), limitations and future recommendations should also be acknowledged. First, though the NSS/NSS-SF was independent of noise exposure level which was in accord with the attribute of noise sensitivity notion[67], some studies[27,68] noted that certain item contents including 'I get annoyed when my neighbors are noisy'[68] and 'I get mad at people who make noise that keeps me from falling asleep or getting work done'[27] in the NSS/NSS-SF to some extent measure noise annoyance, thus were liable to be impacted by noise exposure. Therefore, the two items need further modification in future study to be more appropriately representing noise sensitivity. Kishikawa et al.'s study[68] also pointed out the original six-point Likert format used in the scale were susceptible to response bias, and binary codding was adopted (i.e. '0' or '1' was assigned to each item according to agree or disagree with it) to reduce such effect. Therefore, to account for the potential influence of response bias when using the CNSS-SF, it is suggested to apply the binary coding for scale scoring. Second, participants in the current study were chiefly young adults (i.e. students) *via* convenience sampling, thus the generalization of conclusions should be made with caution. Future research testing the CNSS-SF in an enlarged Chinese sample covering broader age range is required. Also, the scale's temporal stability test is also recommended in future studies, to provide more reliability information, apart from Cronbach's alpha coefficient and composite score.

CONCLUSION

This is the first study to validate the Chinese version of the NSS-SF. The study provided evidence for the reliability, validity and measurement invariance of the CNSS-SF. Yet, certain items' further modification is needed in future examination. Nevertheless, the psychometric soundness of the shortened and field-friendly instrument was initially established. It is believed the present study can facilitate further research in field settings germane to noise and health among the Chinese population.

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