Elucidating the relationship between noise sensitivity and personality

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Abstract

Sensitivity to unwanted sounds is common in general and clinical populations. Noise sensitivity refers to physiological and psychological internal states of an individual that increase the degree of reactivity to noise in general. The current study investigated the relationship between the Big Five personality dimensions and noise sensitivity using the 240-item NEO Personality Inventory (NEO-PI) and 35-item The Noise-Sensitivity-Questionnaire (NoiSeQ) scales, respectively. Overall, the Big Five accounted for 33% of the variance in noise sensitivity, with the Introversion-Extroversion dimension explaining the most variability. Furthermore, the Big Five personality dimensions (neuroticism, extroversion, openness, agreeableness, and conscientiousness) had an independent effect on noise sensitivity, which were linear. However, additional analyses indicated that the influence of gender and age must be considered when examining the relationship between personality and noise sensitivity. The findings caution against pooling data across genders, not controlling for age, and using personality dimensions in isolation.

Keywords: Age effects, extroversion, neuroticism, noise sensitivity, personality

Introduction

Noise is unwanted sound, that is, sound judged as undesirable, irritating, distracting, and discordant with one's expectations, or interfering with wanted sounds. What is judged as noise and what is not is highly subjective, and the literature contains numerous treatises exploring the underlying individual differences in this regard (e.g.,[1]) Job, 1999 conceptualized noise sensitivity as internal states (be they physiological or psychological) that typically amplify arousal to noise.[2] Pervasive, or trait, noise sensitivity manifests as a stable personality attribute describing tolerance to sound, measured on a continuum bracketed by individuals who are extremely noise reactive (i.e., high noise sensitivity) or extremely noise i.e., low sensitivity). It is a common trait. Reported estimates of noise-sensitive individuals have varied from 20% to 40% (see[3] for a review), with the prevalence of high noise sensitive individuals being about 12%.[4,5] Research indicates that noise sensitive individuals are more susceptible to noise-induced annoyance[6] and/or noise-induced awakenings.[7] Sensitive individuals are more likely to attend to sound, evaluate sound negatively (e.g., as threatening or annoying), have stronger emotional reactions to sound and, consequently, greater difficulty habituating.[8] Noise sensitivity aggregates in families and the estimate of heritability (36%)[9] is not associated with auditory acuity,[10] and mediates the relationship between noise and health.[11,12]

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Noise-sensitive individuals are more likely to report symptoms of inadequacy, depression, anxiety, sensitivity, anger, tension, inferiority, and nervousness than noise-resistant individuals.[13] When extreme, it is characterized by exhaustion, withdrawal, helplessness, and distress.[2] Unsurprisingly then, noise sensitivity is a common symptom in many psychological disorders, including anxiety disorder, autistic spectrum disorder, major depressive disorder, schizophrenia, and traumatic brain injury. This provides an opportunity to further explore the etiology of noise sensitivity, where phenomenological accounts of noise-induced distress can be mapped back to maladaptive cognitive processes associated with brain dysfunction. In schizophrenia, for example, the impairment of sensory gating or inhibition of selective attention may be considered a marker for noise sensitivity, reflecting a reduced ability to tune out goal-irrelevant background noise.[14] Experiential accounts of noise sensitivity in clinical populations are limited. In a traumatic brain injury study noise sensitivity was associated with a number of cognitive, emotional, and behavioral implications that severely impact on the functioning of the individual.[15]

The need for quiet is strongly influenced by sensitivity to noise and education level.[5] Given the omnipresence of noise in modern cities and towns, determining the impact of noise sensitivity on functioning and quality of life is an important public health question. However, inconsistent usage of terminology in both the clinical and epidemiological literature makes comparisons, replications and interpretation of data difficult. Early studies risked confusing noise sensitivity and noise annoyance by using terms such as "noise annoyance susceptibility,"[16] "personal tolerance on noise,"[17] or "susceptibility to noise/experience of noise."[18] Anderson, 1971 was the first to offer a formal definition of noise sensitivity, declaring it a pervasive and negative attitude towards sound in general (i.e., an enduring trait), while annoyance was an attitude towards a specific noise (i.e., a temporary state).[19] Clinically, terms such as "noise intolerance" or "sound sensitivity" have been used to denote noise sensitivity, while noise or sound sensitivity may be used to refer to a plethora of conditions such as selective sound intolerance, hyperacusis, misophonia, or phonophobia. This inconsistency in terminology has not gone unnoticed in the literature,[2] and Stansfeld, 1992[8] has done much to standardize the lexicon and permit more confident examination of the prevalence and etiology of noise sensitivity. However, as van Kamp *et al*. comment, in the past decade research has produced "a set of new hypotheses rather than new evidence on the complex relationship between noise and mental health, and the role of mediating factors."[20]

Though the physiological substrates of noise sensitivity have arguably been well-documented as part of clinical investigations into the phenomenon, epidemiological research has largely focused on the psychological origins of noise sensitivity,[21] particularly personality (e.g., negative affect). In fact, the description of personality remains an ongoing activity in the domain of individual differences research, where groupings of intercorrelated traits, termed facets, are selectively subordinated to higher-order factors such as those found in the Big Five model of personality: Neuroticism, extroversion, openness, agreeableness, and conscientiousness.[22] However, elucidating the links between the Big Five dimensions and other, lower order personality constructs is also important.[23] Noise sensitivity is one such trait that has rarely been explored in the individual differences research, though is of both theoretical interest as well as clinical importance.

Limited research has been conducted on the relationship between personality and noise sensitivity, and only one[24] has utilized the gold standard Big Five model and its five dimensions, albeit indirectly and using an abbreviated version. A handful of other studies report traits that are subsumed by the Big Five dimensions, for example, Weinstein (1978) reported that noise sensitivity in a student sample was associated with social insecurity and the desire for privacy.[25] Heinonen-Guzejev *et al*. found significant associations between noise sensitivity and hostility,[26] while Stansfeld *et al*, 1985 and Stansfeld, 1992 both reported a significant relationship between noise sensitivity and Neuroticism.[8,27] Belojević and Jakovljević reported that neuroticism, but not extroversion, predicted noise sensitivity,[25] while Dornic and Ekehammar identified extroversion, but not neuroticism, as a significant predictor.[28] Both Moreira and Bryan and Griffiths and Delauzun also failed to find associations between neuroticism and noise sensitivity.[16,29] Independently, Persson *et al*. and Stansfeld *et al*. reported small but significant correlations between noise sensitivity and trait anxiety, considered part of the Neuroticism dimension.[11,21] Ohrstrom, Bjorkman, and Rylander reported significant correlations between noise sensitivity and both extroversion and neuroticism.[30] More recently, Benfield *et al*. using short form versions of the Big Five and Weinstein's noise sensitivity scale found a small, but significant, negative correlation between noise sensitivity and extroversion, and a positive correlation with neuroticism.[24]

Of the few studies reporting the link between noise sensitivity and personality, less psychometrically robust, brief-form, or subsequently invalidated personality or noise sensitive measures have been utilized. Many studies have used all or parts of the 57-item Eysenck Personality Inventory,[16,25,26,29,30] with a three-factor structure which fails to capture key aspects of personality.[31] Other studies have utilized the Minnesota Multiphasic Personality Inventory (MMPI),[16] Rorschach Projection test,[16] or Cattell's PF-16,[29] all of which have been superseded by more valid measures of personality. Noise sensitivity measures tend to be the outdated Weinstein's noise sensitivity scale,[32,33] or single-item questions that may also lack psychometric robustness.[33-35] None have used the more psychometrically sound 100-item Eysenck Personality Questionnaire, the 240-item NEO-PI, or for noise sensitivity, the 35-item NOISEQ scale. Furthermore, none of the available studies have examined moderation effects between personality and noise sensitivity, pertinently gender and age.

It is clear that the existing literature constitutes only a preliminary description of the relationship between personality and noise sensitivity. None of the previous studies have focused directly on the relationship between the Big Five and noise sensitivity, and have used abbreviated scales lacking the refinement of their full-version donors. Given the clinical importance of noise sensitivity, and the usefulness of understanding where lower-order traits sit within the constellation of the Big Five's dimensions and facets, further research is warranted. The aim of this study is to investigate the association between the Big Five and noise sensitivity while avoiding the use of abbreviated or single-item scales. Further analyses will investigate differences in, and the moderating effects of, age and gender.

Methods

Participants

A total of 185 students and members of staff were recruited from the Auckland University of Technology, Auckland, New Zealand. There were 112 females (mean age = 33.3 years, SD = 12.43, minimum = 20, maximum = 66) and 73 males (mean age = 34.3 years, SD = 13.74, minimum = 20, maximum = 70).

Instruments

Personality was measured using the self-report 240-item NEO Personality Inventory-Revised (NEO-PI-R), assessing the dimensions of neuroticism (vs. emotional stability), extroversion (vs. introversion), openness (vs. closed to experience), conscientiousness (vs. lack of direction), and agreeableness (vs. antagonism).[22] Each dimension is comprised of six facets which in turn are constructed from 8 five-point Likert scale items. The respondents are required to read a statement reflecting a personal characteristic and then select the appropriate response, with the first response category representing "strongly disagree" and the fifth "strongly agree". The Cronbach's alphas for the five subscales were as follows: Neuroticism (α_c = 0.94), extroversion (α_c = 0.90), openness (α_c = 0.85), agreeableness (α_c = 0.88), and conscientiousness (α_c = 0.92).

The 35-item NOISEQ scale was developed to measure global noise sensitivity Schütte *et al*.[34] Noise sensitivity is estimated in four different domains of everyday life: Leisure, work, sleep, and communication, and also probes the capacity of the individual to habituate to sound. Respondents indicated the extent to which the items apply to their attitudes towards noise using a five-point Likert scale, which are then averaged to obtain a global noise sensitivity score. Higher scores on this scale indicated higher sensitivity to noise, and lower scores indicated higher resistance. The Cronbach's alpha for NOISEQ scales was 0.792.

Procedure

Participants were recruited using poster (students) and email (staff) invitations. Once informed consent was obtained the participants were seated in a small office designated for research purposes. All questionnaires were completed in isolation, with order counterbalanced, and typically took between 40-60 min to finish. The University of Auckland Human Participants Ethics Committee approved the study.

Statistical analysis

Analyses adhere to the framework and rationale described by Robins *et al*.[23] who conducted a conceptually similar investigation into the Big Five and self-esteem. First, zero-order correlations between the Big Five and noise sensitivity are computed for the entire sample, and for females and males separately, so that moderating effects of gender can be gauged. Because age is a known moderator of noise sensitivity,[6] partial correlations are also reported. Second, the form of the Big Five/noise-sensitivity relationship is examined using multiple regression analyses. Pertinently, the independent, interactive, and nonlinear effects of the Big Five on noise sensitivity is estimated. Third, the moderating effects of age and gender are more thoroughly examined using moderator analyses.[36] Specifically, the moderating effects are studied by comparing interaction models using linear regression analyses with the dimensions of the Big Five as independent variables explaining noise sensitivity.

Results

Associations between the Big Five and noise sensitivity

Table 1 displays zero-order and partial correlations for the Big Five personality dimensions and global noise sensitivity for the entire sample, and separately for gender. For the zero order correlations, noise sensitivity is correlated with four of the five personality dimensions, the exception being neuroticism. For the entire sample, the zero-order correlation between the noise sensitivity and age was $r = 0.36$ ($P < .001$). Including age as a covariate eliminates statistical significance between agreeableness and noise sensitivity, and makes the correlation between neuroticism and noise sensitivity significant. However, examination of Table 1 also reveals substantial gender differences, notably for the neuroticism, openness, and agreeableness dimensions, indicating that gender may be an important moderator. For completeness, Table 2 presents zero-order and partial (controlling for age) correlation coefficients for noise sensitivity and the six

Table 1: Descriptive statistics (M = Mean, SD = Standard deviation) and correlations between noise sensitivity (NS) and the Big Five personality dimensions, for the entire sample, male, and female data

Trait	M	Sample (n = 185) SD	r	M	Females (n = 112) SD	r	M	Males (n = 73) SD	r
N	89.20	22.58	.064 (.184)	93.69	21.80	.106 (.211)	82.11	22.11	−.040 (.086)
E	110.46	18.47	−.375 (−.377)	112.85	17.40	−.450 (−.457)	106.70	19.59	−.300 (−.315)
O	119.69	17.35	−.209 (−.200)	117.74	16.52	−.260 (−.273)	122.76	18.29	−.116 (−.057)
A	119.63	15.30	.180 (.108)	119.81	14.59	.027 (−.065)	119.35	16.47	.421 (.373)
C	117.27	20.0	.333 (.250)	117.24	20.46	.364 (.303)	117.32	19.41	.277 (.144)
NS	3.07	0.47	—	3.11	0.49	—	3.06	0.44	—

Note the partial correlations controlling for age in parentheses, Underlined values indicate $P < .05$, bold values $P < .001$, and for values not either bold nor underlined $P > .05$ (all two-tailed). Significant differences (Students t-tests) between female and male means are indicated in the third-to-last column

Table 2: Zero order (top section) and partial (middle section) correlation coefficients for the dimensions and facets of the Big Five

Sample (n = 185)					Female (n = 112)					Male (n = 73)				
N	E	O	A	C	N	E	O	A	C	N	E	O	A	C
.105	−.234	−.203	.022	.183	−.010	−.131	−.115	.121	.269	.149	−.321	−.255	−.030	.140
.007	−.373	−.169	.285	.352	−.114	−.361	−.122	.509	.238	.076	−.412	−.191	.147	.404
.066	−.132	−.135	−.080	.271	−.041	−.234	−.123	.019	.266	.112	−.071	−.154	−.164	.279
.108	.044	−.137	.191	.003	.131	.119	−.060	.272	.109	.083	−.012	−.186	.144	.276
−.094	−.382	−.171	.191	.257	−.063	−.356	−.039	.453	.197	−.133	−.408	−.229	.016	.288
.085	−.297	.031	.044	.206	−.067	−.120	.011	.211	.163	.151	−.432	.067	−.073	.230
Partial correlation coefficients (Age)														
.204	−.308	−.173	−.092	.059	.208	−.382	−.224	−.160	.038	.136	−.256	−.066	.032	.115
.067	−.359	−.185	.240	.281	.133	−.433	−.237	.100	.341	−.061	−.318	−.084	.472	.132
.175	−.206	−.139	−.110	.162	.216	−.133	−.189	−.193	.183	.067	−.340	−.101	−.032	.125
.199	.039	−.169	.145	.210	.165	.010	−.231	.098	.287	.227	.069	−.070	.224	.054
−.035	−.280	−.131	.191	.202	−.097	−.324	−.201	−.010	.235	.017	−.220	.061	.490	.127
.188	−.329	.033	.017	.168	.265	−.460	.064	−.131	.221	.002	−.175	.044	.220	.070

Key

N = Neuroticism	E = Extroversion	O = Openness	A = Agreeableness	C = Contentiousness
N1 = Anxiety	E1 = Warmth	O1 = Fantasy	A1 = Trust	C1 = Competence
N2 = Angry hostility	E2 = Gregariousness	O2 = Aesthetics	A2 = Straightforwardness	C2 = Order
N3 = Depression	E3 = Assertiveness	O3 = Feelings	A3 = Altruism	C3 = Dutifulness
N4 =Self-consciousness	E4 = Activity	O4 = Actions	A4 = Compliance	C4 = Achievement Striving
N5 = Impulsiveness	E5 = Excitement-seeking	O5 = Ideas	A5 = Modesty	C5 = Self-discipline
N6 = Vulnerability	E6 = Positive emotions	O6 = Values	A6 = Tender-mindedness	C6 = Deliberation

Columns are for sample, male, and female data respectively, and rows represent facets (see key at bottom of table), Underlined values indicate $P < .05$, bold values $P < .001$, and for values not either bold or underlined $P > .05$ (all two tailed)

facets of each Big Five dimension. Note how the pattern of correlations differs across gender and age, mirroring those in Table 1.

Independent, interaction and nonlinear effects of the big five on noise sensitivity

A simultaneous multiple regression analysis was conducted to examine the independent effects of the Big Five on noise sensitivity. Together, the five dimensions accounted for 33% of the variance in noise sensitivity (R = 0.57), supporting their importance as predictors. Consistent with Table 1, extroversion (β = -0.38) and conscientiousness (β = 0.34) had the greatest influence, but the impact of Openness was reduced (β = -0.07) and non-significant, while the influence of agreeableness (β = 0.25) and neuroticism (β = 0.19) increased, the latter to significance. Adding age to the model produced little change in the β weights. Using only male (R = 0.58) or only female (R = 0.62) data resulted in the same significance patterns of association reported in Table 1, though only for females did the openness dimension become non-significant.

A total of 68 moderated multiple regression analyses were performed to test for two, three, and four-way interactions, for the entire sample and males and females separately. None of the interaction terms contributed significantly to the model, and accounted for only a trivial amount of the variance, with most changes in R^2 being less than half a percent (minimum = 0.001, maximum = 0.017). Thus for the group data, the interaction terms confer no additional predictive validity. To test for nonlinear relationships between the Big Five and noise sensitivity, each Big Five dimension was transformed to produce a quadratic term and each entered into a hierarchical multiple linear equation (step two), following its non-transformed term (step one). Confirming visual representations provided by scatterplots, the addition of the quadratic term increased R^2 by less than 0.5% for each of the Big Five. These results held when males and females were tested in isolation, and suggest that the relationships between the Big Five and noise sensitivity are not curvilinear.

Moderating effects of age and gender

Moderation analyses examining the relationship between the Big Five, age and noise sensitivity were performed using five separate hierarchical linear regression analyses. The first step contained the Big Five dimension of interest, the second step contained age, and the third step the interaction term between the two. If the interaction term explains a significant amount of the variance beyond that explained by the Big Five dimension and age (i.e., the moderator), then evidence of a moderating effect is obtained. For these data, there was no global evidence of changes in the relationship between the Big Five and noise sensitivity across the age range, even when the two genders are examined in isolation. Thus, the Big Five appear to have an independent effect beyond the influence of age.

Scrutiny of Table 1, and the observation that a number of non-significant relationships become significant when age is included as a covariate, suggests that age may have an effect

on the relationship between noise sensitivity, gender, and the Big Five. Three consecutive models were conceived, one with the measure of interest (i.e., a Big Five dimension) and age; another with the Big Five measure, age, and gender; and a third with the interaction added. For reference, a model with gender and age was performed. In all models the predictor variables were all standardized (*z*-score) separately for males and females, though not the gender variable itself. Here only the significant coefficients of interactions are reported, and those models commented on. Agreeableness had a significant interaction with gender (β = -0.29, P = 0.01); however, agreeableness alone was not significant. The agreeableness x gender interaction occurs because of the moderate correlation (r = 0.42, P < .001) between agreeableness and noise sensitivity among males, which holds across age groups. In the female sample, there is no such significance (r = 0.03, P = .78). Thus there is evidence that gender moderates the relationship between agreeableness and noise sensitivity, even after controlling for age.

Discussion

The current study utilized comprehensive psychometric instruments to investigate the relationship between personality and noise sensitivity. Examining the dataset without respect to moderators, the introversion-extroversion dimension was the best predictor of noise sensitivity, while neuroticism was the poorest and the only member of the Big Five failing to reach statistical significance. This latter finding does not concur with Benfield *et al*.[24] who also used a Big Five approach, though they used abbreviated scales and had a sizable female bias in their sample. While not using the Big Five like Benfield *et al*. the same observations hold for the Stansfeld studies (1985, 1992),[8,27] and the impact of gender differences are discussed below. Our findings do, however, concur with those reported by Dornic and Ekehamma.[28] Noise sensitivity has been shown to positively covary with age,[6,8] negatively with age,[3] or not at all.[25] Partialing out the effects of age resulted in the neuroticism dimension attaining significance, though it was still a poor predictor, better only than the agreeableness dimension [Table 1]. Furthermore, a moderator analysis failed to uncover a significant moderating effect of age between neuroticism and noise sensitivity.

Regardless of whether age was controlled for, distinct patterns of correlations between females and males were noted. Adjusting for age, higher noise sensitive females tend to be more conscientious, less extroverted, less Open to Experience, and with mild Neuroticism. Higher noise sensitive males tend to be more agreeable and conscientious, and less extroverted. The weak correlation between neuroticism and noise sensitivity in the female data set concords with other studies, indicating a gender difference. In females, noise sensitivity has been correlated with anxiety and nervous complaints,[37] and with stress and hostility.[26] This finding suggests caution must be taken when working with noise sensitivity data, and that females and males may respond differently to sound. That said, others have found consistency across the genders. Stansfeld *et al*. reported that noise sensitivity was associated with significantly higher rates of psychiatric symptoms across both males[11] and females.[27]

In both clinical practice[15] and environmental health,[21,38] noise sensitivity is commonly thought to reflect a negative, or belligerent, personality type characterized by critical tendencies[32] rather than some underlying biological or cognitive phenomenon involving maladaptive processing of ambient sound. In epidemiology, noise sensitivity has emerged as a better predictor of human response to environmental sound than physical measures such as sound pressure level.[4,25] Indeed, annoyance is not necessarily a given in the presence of loud noises (e.g., road traffic or a lawn mower), and quieter noises can still elicit high level of annoyance (e.g., rustling papers at the movies, people talking while watching television).[2] Our results show that while personality is an important predictor of noise sensitivity, it still does not account for the majority of variance, and thus other factors need to be considered. For example, autism spectrum disorder is associated with both noise sensitivity and impaired ability to segregate auditory stimuli into distinct auditory objects, and that this difficulty arises at an early pre-attentive level of processing.[39] Evidently, processes downstream from personality will likely play an important role in explaining noise sensitivity.

Noise sensitivity *prima facie* presents as a valid personality trait or expressed state that differs in intensity across the population, with a number of international studies estimating the prevalence of severe noise sensitivity to be 10-15%.[4,5] While research has suggested that noise sensitivity is associated with psychiatric symptoms,[27] this does not mean that psychiatric illness is a necessary prerequisite for reporting high sensitivity to noise, nor that noise sensitivity is an exclusive symptom of psychiatric illness. However, a bias in selecting only the neuroticism and/or the extroversion dimension is noted in the literature. This suggests that noise sensitivity is being treated purely as a clinical phenomenon, with the facets of neuroticism garnering excessive attention at the expense of other domains. This is counterproductive for a number of reasons. First, personality traits are often combinations of two or more Big Five dimensions, and should not be summarized with reference to a restricted model of personality.[22] Second, as reflected in our data, neuroticism may not in fact covary as highly as other dimensions and their underlying facets. Third, such an approach risks unfairly pathologizing a trait that is not necessarily indicative of severe maladaptive thinking or behavior and vice versa, especially as "individuals low in N are not necessarily high in positive mental health" (p. 195).[31]

The study's limitations, while common for research of this type, can be addressed in future research. The moderate sample

size (n = 185) was countered by using sensitive psychometric instruments giving substantial increases in precision and accuracy over abbreviated versions. However, larger sample sizes would have afforded greater analytical options to study noise sensitivity within the framework of the Big Five. Convenience sampling and the use of university staff and students also puts a limitation on generalization, and broader samples including clinical populations would further elucidate the relationship between noise sensitivity and the Big Five. Future research is also needed to replicate the gender and age differences reported in this study, and if the findings are upheld, then explanations forwarded. Finally, having established a feasible pattern of covariance between noise sensitivity and the Big Five, the present analysis is unable to extricate causal relationships between the two. Of most relevance is the emergence of feasible underlying biological mechanisms explaining noise sensitivity (e.g.,[14,40]), and so it is not inconceivable that noise sensitivity is a major influence on certain Big Five domains and facets, for example, the Extroversion dimension.

A further qualification and suggested direction for future research is that more sharply refined analyses will be possible through the identification of noise sensitivity subgroups. There is likely no single cause of noise sensitivity, and no existing noise sensitivity measure is differentiating individuals on the basis of underlying causes. This has implications on our results, as it may be that strong relationships between noise sensitivity and personality would emerge in some subgroups but not others. Thus a logical next step in determining the relationship between noise sensitivity and personality is the construction of a questionnaire that not only attempts to measure its severity, but also its origins. Such a scale may also address a broader issue associated with the current operationalization of noise sensitivity, pertinently, the lack of a gold standard. It is not inconceivable that the conflicting findings reported within the literature, including the current study, are attributable to differences in the way that noise sensitivity is operationalized. Additionally, such a scale would need to address another of the weaknesses evident in current noise sensitivity inventories, that is, more certainty in what is being measured: State or trait sensitivity.

Conclusion

The present study indicates that the relationship between noise sensitivity and personality is complex and that comprehensive personality scales should be deployed rather than isolated personality dimensions. Further, while previous studies have indicated that either neuroticism or extroversion covary with noise sensitivity, our data support extroversion as a key predictor. Further studies are needed to explore the gender differences we report, as well as the moderating effect of age. We also suggest that a new generation of noise sensitivity instruments need to be developed for both research and clinical usage.

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