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Phenomenological Dimensions of Sensory Gating

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Contemporary sensory gating definitions are generally tied to the perceptual and attentional phenomenology described by McGhie and Chapman, including abnormalities in the quality of sensory input, heightened awareness of background noises, and poor selective attention reported by individuals with schizophrenia. Despite these explicit phenomenological origins, little is known about the experiential phenomena underlying contemporary operationalizations of the sensory gating construct, such as whether the construct is restricted to experiences associated with the modulation of sensory percepts includes selective attention and distractibility or even whether the construct is accessible via self-report. Because clarification of these issues has important implications for the development and testing of psychological theories and the study of psychopathology, a series of studies was conducted to (a) empirically identify the major dimensions of sensory gating–like perceptual and attentional phenomenology in healthy young adults and (b) develop a psychometrically sound self-report rating scale to capture these dimensions, the Sensory Gating Inventory (SGI). Factor analyses of Likert items measuring a broad range of sensory gating–like subjective experiences revealed 1 primary factor that encompassed anomalies of perceptual modulation (eg, perceptions of heightened stimulus sensitivity and sensory inundation) and 3 other factors measuring disturbances in the processes of focal and radial attention as well as exacerbation of sensory gating–like anomalies by fatigue and stress. Psychometrically, the SGI demonstrated strong reliability and validity. An empirically based conceptual demarcation of the sensory gating construct is offered, and directions for future research are described.

Key words: sensory gating/phenomenology/self-report/schizophrenia

Introduction

Sensory gating is of widespread importance to the study of both pathological and normative psychological conditions. In the case of schizophrenia, much of the observed psychopathology may be "the result of abnormalities in filtering stimuli, focusing attention, or sensory gating."[1] Similarly, McGhie and Chapman[2] proposed that symptoms of schizophrenia indicate a primary deficit in mechanisms of attention related to selection and inhibition. In their now-classic interview study, patients with schizophrenia reported anomalies in attention and perception, such as, "I just can't shut things out," "Everything seems to grip my attention although I am not particularly interested in anything," and "… noises all seem to be louder… It is as if someone has turned up the volume…." The authors reasoned that these experiential phenomena could be logically sorted into (a) disturbances in the process of "perception," including abnormalities in the quality of sensory input, perceived increases in stimulus intensity, and heightening of sensory vividness, and (b) disturbances in the process of "attention," including distractibility, inability to focus attention, and heightened awareness of background noises. They further hypothesized that a breakdown in selective inhibitory function results in a sensation of being "flooded" by an overwhelming mass of sensory input. Subsequent studies have continued this line of investigation, not only replicating the findings at the phenomenological level of analysis[3–6] but also specifying candidate neurophysiological mechanisms to account for these anomalies.[7–11]

Despite the impact of the article of McGhie and Chapman,[2] little has been done in the intervening decades to further characterize sensory gating at the phenomenological, or experiential, level of analysis. Instead, there have been tremendous advances in characterizing neurophysiological sensory gating deficits believed to produce the phenomenology McGhie and Chapman[2] characterized. Bunney and colleagues[3] are an exception to this general trend. They replicated and extended the qualitative findings of McGhie and Chapman by developing and validating the Structured Interview for Assessing Perceptual Anomalies (SIAPA). Building on the theoretical conceptualization of the sensory gating phenomenology of McGhie and Chapman, the SIAPA was designed to empirically assess 3 perceptual anomalies: perceived hypersensitivity, inundation, and selective attention to external sensory stimuli. Perceptual anomalies were significantly more prevalent in the self-reports of schizophrenics ($n = 67$) compared with healthy controls ($n = 98$), with prevalence rates of 52.2% and 25.5%, respectively. Compared with control participants, people with schizophrenia experienced anomalies more frequently in the auditory (41.8% vs 17.3%) and visual modalities (32.8% vs 8.2%). These findings provided the first estimates of the proportion of acutely ill schizophrenic patients and healthy individuals who report sensory gating–like perceptual anomalies. The present work extends this research by employing an empirical (eg, factor analytic) procedure to comprehensively assess and systematically identify the phenomenology most central to sensory gating.

Building on the initial delineation of the sensory gating construct of McGhie and Chapman, as well as indications that about one-quarter of healthy people and one-half of patients with schizophrenia report sensory gating–like anomalies of perception and attention,[3] the present study aimed to empirically derive and operationally define the sensory gating construct at the phenomenological/experiential level of analysis.

For several reasons, we elected to conduct this initial examination of sensory gating phenomenology in a healthy, nonpsychiatric sample. First, there is an increased potential for error variability in psychiatric populations, which may be influenced by poor insight and self-awareness.[12] Thus, for the purposes of scale development, less impaired populations may serve as better samples in which to conduct these analyses. Second, previous research indicates that the base rate of the target perceptual and attentional phenomena is about 25% in healthy, nonpsychiatric samples.[3] In another study, between 10% and 41% of college undergraduates reported perceptual anomalies such as "ordinary colors sometimes seem much too bright to me" (10% endorsement rate), "For several days at a time I have such a heightened awareness of sights and sounds that I cannot shut them out" (20% endorsement rate), "My hearing is sometimes so sensitive that ordinary sounds become uncomfortable" (29%), and "Often I have a day when indoor lights seem so bright that they bother my eyes" (41%) (Chapman, L. J. and Chapman, J. P., unpublished data, November 1989). These data suggest that sensory gating–like anomalies occur at sufficiently high rates to both warrant and support systematic analysis in nonpsychiatric samples. Third, psychophysiological investigations demonstrate that sensory gating, as measured by suppression of the P50 event-related potential (ERP), varies in healthy, nonpsychiatric people by age,[10] sex,[13,14] self-reported levels of tension and anxiety,[15] physical stressors,[16] and psychological stressors.[17,18] These observations strongly suggest that sensory gating in nonpsychiatric samples varies on a continuum that encompasses psychopathological states. The continuity of normal phenomena with clinical phenomena has been similarly exploited in analogue studies of more traditional symptoms of schizophrenia, including hallucinations and delusions.[19–21] Fourth, the study of sensory gating in a nonpsychiatric sample has the potential advantage of placing schizophrenia in a larger, more general theoretical framework of psychological phenomena relating perception, attention, and cognition.[22,23] Fifth, the study of the relevant phenomena in healthy people avoids the likely confound of the "generalized deficit" often observed in schizophrenia,[24] as well as avoiding the interpretive complexities raised by the effects of acute psychosis and medications on cognitive function and personal insight. Finally, careful attention to the factorial structure of sensory gating–like phenomena and their relationships with related psychological constructs will (a) facilitate the development of hypotheses about underlying mechanisms and (b) allow for clearer elaboration on the relationship between those underlying mechanisms and the resulting subjective experiences.[23] Factor analytic studies such as this, although extremely powerful, require large numbers of participants (ie, many hundreds), making it difficult to conduct this research in clinical populations.

The purpose of the present series of studies is to remedy the historical neglect of phenomenological dimensions of sensory gating so that neurophysiological investigations of related phenomena can be more firmly grounded both theoretically and empirically.[7,8] One important reason for the relative neglect of phenomenological elaboration is a lack of appropriate instrumentation. The absence of a comprehensive, quantitative and empirically derived demarcation of the relevant phenomenology limits the precision with which brain-behavior relationships can be studied. Thus, the overarching aim of the present work is to empirically ascertain and describe the major dimensions (ie, factors) of perceptual and attentional phenomenology related to sensory gating. Using an inductive-hypothetico-deductive approach to scale development,[25,26] we began by identifying items that appeared to tap the gating construct. We then examined the factor structure so as to parse the pertinent dimensions (Study 1). Following the initial exploratory analysis, we examined test-retest reliability (Study 2) and evaluated the factor structure in Studies 3 and 4. Finally, we performed a number of validity checks (Study 5) and examined sex differences in this self-report measure (Study 6). The present study therefore expanded upon the logical categorization of the phenomenology of

McGhie and Chapman[2] by empirically identifying the major dimensions of the sensory gating construct.

Study 1: Initial Identification and Exploration of the Sensory Gating Construct

The purpose of this first experiment was to use classic inventory development methods to empirically ascertain and describe the major dimensions (ie, factors) of phenomenology related to sensory gating. Two primary hypotheses were tested: first, that factor analysis would yield a multifactorial solution given that previous studies have revealed several dimensions of related abnormality such as (a) perceived increases in the intensity of exteroceptive stimuli; (b) perceived inundation by sensory stimuli; (c) difficulty concentrating and focusing on exteroceptive stimuli; and (d) increased awareness of irrelevant background noises.[2,27] Second, based on the observations that perceptual and attentional anomalies tend to covary with each other,[3] it was hypothesized that the emergent factors would be moderately correlated with one another.

Method

Construct Explication and Item Pool Generation. For an initial working definition of the sensory gating construct, we turned to the classic descriptions offered by McGhie and Chapman[2] and Venables.[27] In order to broadly sample perceptual and attentional item content,[28] 4 sources were consulted: (1) verbatim, first-person quotes collected by McGhie and Chapman[2]; (2) verbatim quotes from SIAPA interviews with schizophrenics and healthy controls[3]; (3) 4 items from the Perceptual Aberration Scale (PAS) that assess external perceptual experiences[29]; and (4) new items written to assess content that was otherwise underrepresented in the pool, including exacerbation of perceptual and attentional anomalies by fatigue and stress. The impetus for the latter items came from the finding of Bunney et al[3] that healthy controls reported higher frequencies of perceptual and attentional anomalies under fatigue and stress.

An effort was also made to ensure that a representative number of items directly tapped perceptual and attentional constructs proposed by McGhie and Chapman.[2] Specifically, items reflecting the following 3 hypothesized "perceptual processes" were included: (1) sensory flooding/inundation; (2) perceived increases in the intensity of exteroceptive stimuli; and (3) abnormalities in the quality of sensory input. Within the domain of "attentional processes," items were included to capture the following 3 phenomena: (1) distractibility; (2) difficulty focusing on single exteroceptive stimuli; and (3) heightened awareness of background sensation.

All the candidate items were reviewed to ensure that they referred to perceptual and attentional anomalies arising from "external" (or environmental) "sensory stimuli," as opposed to apparently more cognitive, higher order disturbances such as those associated with bodily awareness (eg, body-image aberration[29]), thinking (eg, thought disorder[30,31]), and affect (eg, arousability[32,33]). Also, the item content was limited to phenomenology related to the auditory and visual modalities because tactile, olfactory, and gustatory anomalies are exceedingly rare in both healthy and schizophrenic people.[3]

One hundred twenty-four items were initially generated, and a pilot study was conducted to evaluate item endorsement distributions. A pilot sample of 128 university student volunteers rated each item on a 6-point Likert scale ranging from "never true" to "always true." A 6-point Likert response format was selected in order to maximize variability of responses without allowing so many options as to make the response anchors indistinguishable to the participants. Furthermore, an even number of response choices eliminates the problem of participants selecting a middle "neutral" option. Thirteen items that were rarely endorsed or almost always endorsed or whose distributions were characterized by skewness or kurtosis values more extreme than ± 1.0 were reworded to normalize the endorsement distributions and then included in the instrument administered in this first study.

Participants. After providing written informed consent, the 124-item Sensory Gating Inventory (SGI) was administered to 582 undergraduates who received course credits. Minimal instruction was provided for participants, and they were not instructed to exclude experiences related to illicit drug use. Data from 50 participants were excluded because (1) they were incomplete, (2) the participant reported hearing or vision problems, or (3) the participant failed to endorse 2 or more items on the Chapman Infrequency Scale,[34] thus indicating that a subject may not have read the items. The demographic characteristics of the remaining 532 participants were as follows: 45% women, 83% Caucasian/White, 7% Asian/Pacific Islander, and 6% African American/Black. The average age was 20.81 years (SD = 3.11). The entire project was approved by the Human Subjects Institutional Review Board at Ohio State University where the data were collected.

Results

Descriptive Statistics. For each item, the distribution of endorsement frequencies across the Likert categories was examined. Thirty-five items were deleted from the item pool because (a) the mode was zero, (b) the ratio of the corresponding skewness value to its standard error was greater than 3 and one-half, or (c) the ratio of the kurtosis value to its standard error was greater than 3 and one-half.

Table 1. Items from the Sensory Gating Inventory and Their Factor Loadings Greater than 0.30

	Factor Loadings			
Content	PM (α = 0.92)	D (α = 0.89)	OI (α = 0.80)	FS (α = 0.75)
My hearing is so sensitive that ordinary sounds become uncomfortable.	0.787			
There have been times when it seems that sounds and sights are coming in too fast.	0.708			
For several days at a time I have such heightened awareness of sights and sounds that I cannot shut them out.	0.683			
Every now and then colors seem more vivid to me than usual.	0.681			
At times I have feelings of being flooded by sounds.	0.680			
Sometimes it seems like someone has turned the volume up—things seem really loud.	0.629			
I have feelings of being flooded by visual experiences, sights, or colors.	0.591			
It seems like I take in too much.	0.512	0.300		
Sometimes I find it difficult to focus on one visual sight to the exclusion of others.	0.508			
I hear sounds but I can't make sense of them all because it's like trying to do 2 or 3 things at once.	0.494			
It's not bad when just one person is speaking but if others join in, then I can't pick it up at all. I just can't get into tune with that conversation.	0.468			
Sometimes I notice background noises more than usual.	0.449			
Background noises are just as loud or louder than the main noises.	0.448			
I can't focus on one sound or voice to the exclusion of others.	0.413			
It seems like I hear everything at once.	0.400			
There are days when indoor lights seem so bright that they bother my eyes.	0.379			
At times I have trouble focusing because I am easily distracted.		0.810		
I am easily distracted.		0.758		
I have more trouble concentrating than others seem to have.		0.691		
I find it hard to concentrate on just one thing.		0.633		
It is hard to keep my mind on one thing when there's so much else going on.		0.572		
There are times when I can't concentrate with even the slightest sounds going on.		0.498		
I find it difficult to shut out background noise and that makes it difficult for me to concentrate.		0.456		
When I am in a group of people I have trouble listening to one person.		0.372		
Not only the color of things fascinates me but all sorts of little things, like markings in the surface, attract my attention, too.			0.539	
I notice background noises more than other people.			0.525	

Table 1. Continued

Content	Factor Loadings			
	PM (α = 0.92)	D (α = 0.89)	OI (α = 0.80)	FS (α = 0.75)
Everything grips my attention even though I am not particularly interested in any of it.			0.523	
The silliest little things that are going on interest me.			0.494	
Maybe it's because I notice so much more about things that I find myself looking at them for a longer time.			0.488	
I seem to hear the smallest details of sound.			0.469	
I seem to always notice when automatic appliances turn on and off (like the refrigerator or the heating and cooling system).			0.439	
When I'm tired sounds seem amplified.				0.839
It seems that sounds are more intense when I'm stressed.				0.669
When I am tired, the brightness of lights bothers me.				0.664
I cannot focus on visual images when I am tired or stressed.				0.449
When I am driving at night, I am bothered by the bright lights of oncoming traffic.				0.329

Note: The refined, 36-item SGI is presented here as 4 items were later removed (see Study 3). PM, Perceptual Modulation factor; D, Distractibility factor; OI, Over-Inclusion factor; FS, Fatigue and Stress Vulnerability factor. $N = 532$ (Study 1). Factors were extracted using principal axis factor (PAF) analysis with Oblimin rotation. Items are presented with their loadings onto their assigned factors.

Factor Analyses. Principal axis factor (PAF) analysis with Oblimin rotations was used to examine the factor structure of the remaining 89 items of the SGI. When determining the number of factors to extract, balanced consideration was given to (a) the absolute value of the eigenvalues, (b) the visual screening test, and (3) the theoretical interpretability of the factors.[35–37] Consideration of these criteria suggested a 4-factor solution that optimized parsimony and ease of interpretation. One primary factor accounted for 31.6% of the variance in the data and 3 other factors accounted for an additional 15.1% of the variance combined. In order to enhance the homogeneity of each factor, an item was retained only if its factor loading exceeded 0.30 on the corresponding factor and the loading value was at least 0.15 greater on the given factor than on any other factor.[38,39] Forty-nine items were removed from the SGI because they did not meet these criteria.

The remaining 40 items were then subjected to another PAF Oblimin analysis in which a 4-factor solution was specified. In this new analysis, the 4 factors accounted for 32.1%, 6.4%, 6.1%, and 3.5% of the variance, respectively, and 48.1% of the variance cumulatively. The first factor was labeled the "Perceptual Modulation" factor because the content of its 17 items primarily related to modulation of stimulus intensity and perceptual inundation. The 10 items on the second factor appeared to measure anomalies of focal attention, or distractibility, and thus the factor was named the "Distractibility" factor. The third factor was named the "Over-Inclusion" factor because its 9 items appeared to assess anomalies of radial attention as a result of a low threshold of perception (over-inclusion and hyperawareness). The fourth, and final, factor was comprised of 4 items reflecting vulnerability to perceptual and attentional anomalies during periods of fatigue and stress; thus, it was named the "Fatigue and Stress Vulnerability" factor (see table 1). Factor intercorrelations were moderate-to-strong, indicating shared variance between the factors ranging from 19.4% to 43.6% (see supplementary table 1). Correlations between each factor and the total SGI score, excluding each target factor successively, were stronger, with the proportion of shared variance ranging from 29.2% to 50.4%. The internal consistency reliability, as measured by Cronbach's alpha, was moderate-to-large for each of the 4 factors, ranging from 0.75 (Fatigue and Stress Vulnerability) to 0.92 (Perceptual Modulation; see supplementary table 1). Differences in alpha between the factors may be a consequence of differences in the number of items contributing to each factor.

Discussion

The results of Study 1 confirmed 2 primary predictions. First, the factor analysis yielded a multidimensional solution consisting of a primary factor, accounting for aberrations in the modulation of exteroceptive inputs (the Perceptual Modulation factor), and 3 minor factors measuring distractibility due to difficulties focusing attention (Distractibility factor), over-inclusion or hyperattention (Over-Inclusion factor), and vulnerability to perceptual anomalies during periods of fatigue and stress (Fatigue and Stress Vulnerability factor). The Perceptual Modulation factor unified 2 types of disturbances that were combined in conceptualization of McGhie and Chapman: (a) perceived increases in the intensity of exteroceptive stimuli and (b) the experience of being flooded, or inundated, by sensory inputs. The results support the theoretical classification of the pertinent anomalies into 2 domains of McGhie and Chapman[2] (disturbances in the processes of perception and attention). However, 2 factors related to disturbances of attention emerged instead of just one as they proposed.

The findings of the present study also confirmed the second prediction that the emergent factors of the SGI would be intercorrelated. This finding is consistent with observations of Bunney et al,[3] McGhie and Chapman,[2] and Venables[27] that perceptual and attentional anomalies tend to occur together. The magnitude of the intercorrelations among the SGI factors indicated that these factors share a substantial amount of variance, ranging from 19% to 44%.

Thus, poor sensory gating appears to be primarily comprised of aberrations in the modulation of sensory inputs, but it also includes anomalies of focal attention (distractibility), radial attention (over-inclusion), and susceptibility to perceptual aberrations during periods of fatigue and stress. The extraction of 2 SGI factors assessing disturbances in attention also confirms the relevance of attentional disturbance in the constellation of sensory gating–like phenomena.

Study 2: Test-Retest Reliability of the SGI

The available evidence suggests that sensory gating should be relatively stable across time in healthy, unaffected people. For example, scores on the PAS, which measures a related construct, demonstrated relatively strong test-retest reliability in healthy controls across a 12-week test-retest interval (0.75 correlation coefficients for men and 0.76 for women[39]). Similarly, studies of arousability, which has been linked to poor sensory screening,[40] indicate that arousability is stable enough to be considered trait like. We expected that SGI scores would be consistent across time in healthy participants.

Method

Participants and Procedures. Ninety new undergraduate volunteers (mean age = 19.68, SD = 3.57) completed the 40-item SGI twice. Test-retest reliability of the SGI's full-scale and factor scores were examined at 1 of 3 intertrial intervals; 25 participants were reassessed at 4.5 weeks following the first testing session, 29 participants were reassessed at 6.5 weeks, and 36 participants were reassessed at 9 weeks.

Results

The test-retest intraclass correlations for the overall SGI scores were $r(25) = 0.88$, $r(29) = 0.88$, and $r(36) = 0.86$ across the retest intervals of 4.5, 6.5, and 9 weeks, respectively, indicating good retest reliability. The test-retest intraclass correlations for the Perceptual Modulation factor scores were 0.84, 0.83, and 0.84 across the same 3 intervals, indicating good retest reliability. Similarly, the correlations for the Distractibility scale were 0.90, 0.91, and 0.80; Over-Inclusion scale: 0.84, 0.83, and 0.87; and Fatigue and Stress Vulnerability scale: 0.85, 0.77, and 0.68. With the exception of the Over-Inclusion and Perceptual Modulation factor score, the magnitudes of the reliability coefficients decreased from the 4.5-week retest interval to the 9-week interval as one would expect with increasing time between test administrations. These decreases in intraclass reliability coefficients were not significant for any of the factors, however (z values < 1.64, P values $> .05$).

Discussion

Test-retest correlations indicated substantial temporal stability of the SGI and its factors across intervals of 4–9 weeks in these healthy individuals.

Study 3: Replication of Factor Structure and Scale Refinement

In the interest of taking a conservative approach to scale development, this study was conducted to examine the reproducibility of the SGI's factor structure across independent samples and to refine the scale by eliminating items that did not consistently load on the same factor across samples.

Method

Participants and Procedure. The 40-item version of the SGI was administered to 2 new, large samples of undergraduates (sample 1: $n = 568$; sample 2: $n = 532$). The average age for sample 1 was 19.13 years (SD = 2.61), and the average age for sample 2 was 19.93 years (SD = 3.10). Two separate exploratory PAF analyses with Oblimin rotations were conducted. In accordance with the factor analytic findings described in Study 1, the number of factors was set to 4. The factorial stability of each item was examined by comparing factor loadings across the 2 samples.

Results

Eigenvalues from each sample were similar and suggested the extraction of a primary factor that accounted for 34.2% and 33.8% of the variance, respectively. The 3 remaining factors accounted for 7.4%, 4.8%, and 3.8% of the variance in the first sample and 7.4%, 4.3%, and 3.7% of the variance from the second sample. The cumulative percentage of variance accounted for by all 4 factors was 50.3 and 49.2.

Twenty-six of the 40 SGI items met inclusion criteria by loading at least 0.30 on the same factor in each analysis and exhibiting loadings that were at least 0.15 greater on their highest loading factor than on any other factor in that analysis. Of 14 items that did not meet the inclusion criteria, 9 had their highest loadings on the same factor in both samples but did not meet the established factorial independence threshold (ie, the loading on the primary factor was not greater than 0.15 from the next highest factor loading); the other 5 items changed their primary loading from 1 factor to another across analyses.

The factor intercorrelations in Sample 1 were quite similar to those seen in Sample 2 (see supplementary table 2). In both samples, the correlations between Perceptual Modulation factor and each of the 3 other factors were rather robust (r values ranged from 0.61 to 0.66), indicating proportions of shared variance ranging from 37% to 44%. Stronger correlations were observed between each subscale score and the full-scale score (excluding the target subscale score), with r values ranging from 0.57 to 0.80.

Although we had specified cross-loading as an item exclusion criterion (see Study 1), at this early stage of development, we decided to err on the side of retaining these cross-loading items rather than eliminate them on the assumption that the inventory was multidimensional. Elimination of such items would be reasonable only to the extent that the inventory was multidimensional; however, multiple cross-loadings could indicate unidimensionality rather than that a given item was a poor indicator of a multidimensional construct. Whether the inventory was multi- or unidimensional was an empirical question that was further addressed by a confirmatory factor analysis (CFA) in Study 4. Therefore, we elected to retain extra items so they could be subjected to this additional empirical scrutiny.

Most importantly, the results showed that all but 4 items achieved loadings of 0.30 or greater in both analyses. With these 4 items eliminated, the Spearman rank-order correlation coefficient of the factor loadings was $r(36) = 0.93$, $P < .001$, across the samples, indicating reasonable structural stability.

Discussion

The general structure of the SGI factor solution from Study 1 was quite stable across the 2 additional large and independent samples collected in Study 3. Although the specific item loadings obtained in Study 1 were less stable when examined in these new samples, the evidence for a provisional multifactorial solution remained strong, as indicated by (a) the consistent interpretability and variance accounted for by the 4-factor solutions; (b) the observation that 35 of the 40 original items loaded most robustly on the same factor in these new samples; and (c) the consistency of cross-loadings between samples.

Study 4: Validation of the Factor Structure

The purpose of this study was to validate the 4-factor structure by conducting a CFA on a new sample of healthy undergraduate participants.

Method

Participants and Procedure. The 36-item SGI was administered to a new sample of undergraduates who had not participated in Studies 1, 2, or 3 ($n = 349$). The average age of this sample was 19.72 years (SD = 3.63). Thirty-three participants were removed due to missing responses for various scale items for a total of 316 included in the final analysis. AMOS 16.0 was used to conduct a CFA to test the hypothesized 4-factor structure of the scale.[41] Model fit was assessed using χ^2, comparative fit index (CFI), the root mean square error of approximation (RMSEA), the Akaike information criterion (AIC), and the Bayesian information criterion (BIC) for both a unidimensional and 4-factor solution. The range of possible CFI values is from 0 to 1, with larger values indicating a better fit. As for the RMSEA index, low values indicate a better fit, with values below 0.05 indicative of a "good" fit and values from 0.06 to 0.09 indicative of a "moderate" fit. Smaller χ^2, AIC, and BIC values indicate a better model fit than larger values.[42]

Results

The indices of fit for both the unidimensional and 4-factor models are presented in supplementary table 3. Differences in χ^2 between the 2 models revealed a significant improvement in model fit for the 4-factor solution, $\Delta\chi^2 = 598.59$, $\Delta df = 6$, $P < .001$. Similarly, the differences between CFI, RMSEA, AIC, and BIC between the 2 models indicated a better fit for the 4-factor model. Although improvement in fit was observed in all 5 indices with the 4-factor model, the moderate CFI and RMSEA values suggest some remaining problems in fit. These values are consistent with observations from Study 3 that some items had high cross-loadings on other factors. Finally, Cronbach's alpha values for the individual subscales using the refined, 36-item questionnaire were very similar to values obtained in Study 1. Cronbach's alpha for the Perceptual Modulation factor was 0.92; Distractibility, 0.88; Over-Inclusion, 0.80; and Fatigue and Stress Vulnerability, 0.75.

Discussion

CFA revealed that the phenomenology of sensory gating is not unidimensional. The observed fit values, however, indicated only a moderate fit of the hypothesized 4-factor

Table 2. Correlations between SGI and Its Factors and Other Self-Report Measures

	Sensory Gating Inventory				
		Factor			
Self-Report Scale	Total Score (α = 0.95)	Perceptual Modulation (α = 0.93)	Distractibility (α = 0.91)	Over-Inclusion (α = 0.80)	Fatigue-Stress Modulation (α = 0.77)
TAIS: OET (*n* = 219; α = 0.91)	0.79***	0.73*	0.79*	0.59	0.63
TAIS: OIT (*n* = 219; α = 0.88)	0.71***	0.64*	0.75*	0.50	0.55
Arousal Predisposition Scale (*n* = 454; α = 0.86)	0.65***	0.58	0.62	0.46	0.56
Highly Sensitive Person Scale (*n* = 219; α = 0.91)	0.65***	0.58	0.60	0.51	0.59
IPI Mind Wandering (*n* = 181; α = 0.91)	0.63*	0.52	0.67*	0.41	0.55
Attentional Instability Questionnaire (*n* = 513; α = 0.92)	0.61**	0.49	0.74**	0.41	0.48
Cognitive Failures Questionnaire (*n* = 513; α = 0.94)	0.60***	0.53	0.63**	0.36	0.47
Fatigue (*n* = 454; α = 0.92)	0.59***	0.50*	0.66*	0.34	0.43
Perceptual Aberration Scale (*n* = 513; α = 0.94)	0.57***	0.62**	0.42	0.38	0.40
Trait Anxiety Inventory (*n* = 332; α = 0.94)	0.53**	0.49	0.57	0.31	0.38
IPI Distractibility (*n* = 181; α = 0.79)	0.51*	0.42	0.65*	0.27	0.41
Trait Arousability Scale (*n* = 332; α = 0.88)	0.45***	0.36	0.46**	0.36	0.45**

Note: Cronbach's alpha is presented for each instrument. ***$P < .001$; **$P < .01$; *$P < .05$. IPI, Imaginal Processes Inventory; TAIS, Test of Attentional and Interpersonal Style.

model to the observed item covariances, suggesting further refinements might be beneficial. For example, item phrasing could introduce unintended redundancy, which can cause covariation between items to become artifactually inflated.[38,43] A future study could examine whether a shorter version of the scale that eliminates item redundancy may produce a closer fit with the hypothesized model. Nevertheless, a significant improvement of the 4-factor solution over a unidimensional model indicates that 4 separable dimensions comprise the sensory gating construct. Study 5 was conducted to explore the relationships between SGI dimensions and established measures of constructs of theoretical interest.

Study 5: Convergent and Discriminant Validation

The relationships between the SGI and a variety of other theoretically relevant measures were examined to determine the inventory's convergent and discriminant validity. Measures were selected for their ability to assess cognitive, attentional, and perceptual processes hypothesized to be linked to the sensory gating construct, thus providing a test of the convergent validity of the SGI.

Method and Results

Participants and Procedure. The 36-item SGI was administered along with 12 other self-report scales to a new sample of 556 undergraduates (mean age = 20.06, SD = 1.94), none of whom had participated in Studies 1, 2, 3, or 4. Data from 43 participants who reported hearing problems were excluded from the analyses. The entire battery of instruments was not administered to all participants; thus, sample sizes for the various correlation coefficients ranged from 181 to 513.

Instruments, Hypotheses, and Findings. Spearman correlation coefficients and Cronbach's alpha internal consistency coefficients are produced in table 2. The battery of instruments and findings are summarized below; see supplementary material for description of self-report measures.

Perceptual Aberration Scale Moderate correlations between the PAS and the SGI were predicted because the body-image distortions measured by the PAS have been conceptually linked to a putatively broader range of perceptual dysfunction in psychotic and psychotic-prone people.[29] Furthermore, 2 items were shared by these instruments, and several other items on the PAS refer to perceptual aberrations of exteroceptive stimuli, as does the primary factor on the SGI.

The magnitude of the correlation between the PAS and the composite SGI score was moderate, as predicted, $r(513) = 0.57$, $P < .001$. In support of the multidimensional model of the SGI, the Perceptual Modulation factor correlated significantly higher with the PAS, $r = 0.62$, than did any of the other 3 SGI factors (r values ranged from 0.38 to 0.42 P values $< .01$).

Given the magnitude of these correlations, we examined the extent to which the latent constructs assessed by each of these instruments could be discriminated by factor analytic methods[26] in a sample of 456 subjects. PAS and SGI items were jointly entered into a principal components factor analysis in which 2 factors were specified for extraction (varimax rotation). Each inventory contributed an equal number of items ($n = 35$) to the analysis, and all items were rated on the same 6-point Likert scale. The vast majority of SGI and PAS items loaded strongly on separate rotated factors and showed only weak cross-loadings. For example, all unique SGI items (the inventories shared 2 items) had their highest loadings on the same factor, the SGI factor; similarly, all but 2 of the unique PAS items had their highest loadings on the PAS factor. The difference between an item's factor loading on the primary vs secondary factor exceeded 0.30 for 62 of the 70 unique items in the analysis. Finally, the overall Spearman rank-order correlation between the full-scale SGI and PAS was $r(456) = 0.60$. Therefore, we concluded that the SGI and PAS tap related but empirically distinguishable constructs, sharing only 36% of their variance.

Trait Arousability Scale Arousability is believed to be inversely related to stimulus screening, which is conceptually similar to sensory gating, and "non-screeners" are more arousable than "screeners."[32,44] It was predicted that the SGI and Trait Arousability Scale (TAS) would correlate moderately. The correlation between the TAS and SGI was $r(332) = 0.45$, $P < .001$. At the factorial level of analysis, the TAS correlated significantly higher with the Distractibility ($P < .01$) and Fatigue and Stress Vulnerability factors ($P < .01$) than with the other 2 factors, t values(332) > 3.45, not significant.

Arousal Predisposition Scale It was predicted that the SGI and Arousal Predisposition Scale (APS) would be moderately correlated.[45,46] Consistent with this prediction, the composite SGI score was moderately correlated with the APS, $r(454) = 0.65$, $P < .001$.

Test of Attentional and Interpersonal Style Two subscales of the Test of Attentional and Interpersonal Style (TAIS) were of particular interest because they assessed attentional "overload" by external stimuli (OET subscale) and overload by internal stimuli (OIT).[47] A moderate correlation was predicted between the SGI and the OIT subscale, while a moderate-to-strong relationship between the SGI and OET was expected due to similarities in item content and construct definition.

Moderate-to-strong correlations were observed between the composite SGI score and the OIT, $r(219) = 0.71$, $P < .001$, and the OET, $r(219) = 0.79$, $P < .001$, subscales of the TAIS. For both the OIT and OET subscales, the relationships were strongest with the Perceptual Modulation and Distractibility factors of the SGI and significantly stronger with the Distractibility factor than with the Perceptual Modulation factor, t values(219) > 2.48, P values $< .05$.

Cognitive Failures Questionnaire Studies of divided attention to auditory and visual stimuli suggest that cognitive failures may emanate from difficulty allocating and switching attention between multiple goal-directed activities.[48,49–51] In contrast to higher order "resource allocation" models proposed to underlie the construct measured by the Cognitive Failures Questionnaire (CFQ), sensory gating phenomena are thought to reflect an earlier stage of selective attention wherein the flow of sensory afferents along neural pathways to perceptual mechanisms is "gated" or inhibited to prevent sensory flooding.[57] Thus, the latent constructs that are presumably tapped by these 2 instruments may be related but should not be redundant. Accordingly, it was predicted that the SGI and the CFQ would moderately correlate, with the strongest association to the Distractibility factor—whose manifest content appears most similar to the CFQ.

As predicted, the correlation between the composite SGI score and CFQ was moderately strong, $r(513) = 0.60$, $P < .001$. Furthermore, in support of the discriminant validity of the factor structure, the Distractibility factor of the SGI correlated significantly higher with the CFQ, $r = 0.63$, t values(510) > 4.9, P values $< .01$, than did any of the other SGI factors.

Trait Anxiety Inventory The relationship between the SGI and Trait Anxiety Inventory (TAI) was examined because anxiety appears to be an important contributor to sensory gating, as measured by suppression of the P50 ERP waveform.[53] For example, increased levels of anxiety in recent-onset schizophrenics[54] as well as healthy controls[17,18,55] have been found to correlate with higher P50 gating ratios (ie, poorer gating). Based on these reports, it was predicted that scores on the SGI would show moderate positive correlations with the TAI. Consistent with this prediction, the TAI and SGI were significantly correlated, $r(332) = 0.53$, $P < .001$, indicating that 28% of the variance was shared.

Highly Sensitive Person Scale In addition to the conceptual convergence between the latent constructs measured by the SGI and Highly Sensitive Person Scale (HSPS), several HSPS items refer to phenomena that are similar to that found on the SGI.[56] Accordingly, it was expected that there would be a moderately positive correlation between the HSPS and the SGI. As predicted, the obtained correlation was 0.65 ($n = 219$, $P < .001$).

Attentional Instability Questionnaire A moderately positive correlation was predicted between the SGI and the Attentional Instability Questionnaire (AIQ), with the SGI's Distractibility factor having the strongest correlation (Allan L., unpublished data). Consistent with this prediction, the correlation between the composite SGI score and the AIQ was 0.61 (n = 513), and the Distractibility factor of the SGI correlated significantly more strongly with the AIQ (r = 0.74) than any of the other factors, $t(510) = 14.89$, $P < .01$.

Imaginal Processes Inventory: Distractibility and Mind Wandering Subscales A moderately positive correlation was predicted between the composite SGI score and these 2 subscales of the Imaginal Processes Inventory (IPI), and a strong correlation was expected with the SGI's Distractibility factor because they appear to measure difficulties allocating and modulating attention more so than modulation of perceptual processes (Perceptual Modulation factor) or habitual hyperattention (Over-Inclusion factor).[57–59] The obtained correlations between the SGI and the IPI Distractibility and Mind Wandering subscales were 0.51 (n = 181) and 0.63 (n = 181), respectively, and both subscales correlated significantly higher with the SGI's Distractibility factor score than any of the other SGI factors (r values = 0.65 and 0.67; P values < .05).

Fatigue Scale The impetus for including a measure of fatigue came from the finding of Bunney et al[3] that healthy controls reported higher frequencies of perceptual and attentional anomalies under fatigue and stress.[60] A weak-to-moderate positive correlation was predicted between the full-scale SGI and the Fatigue Scale of Chalder et al.[60] It was also predicted that the Fatigue Scale would correlate most strongly with the SGI's Fatigue and Stress Vulnerability factor. The results indicated that although the magnitude of the correlation between the Fatigue Scale and the SGI was within the predicted range, $r(454) = 0.59$, $P < .001$, the Fatigue Scale correlated significantly more strongly with the Distractibility (0.66) and the Perceptual Modulation factors (0.50) than the Fatigue and Stress Vulnerability factor, $r = 0.43$; t values$(451) > 2.19$, P values $< .05$. One possible explanation for this unanticipated result is that the Fatigue and Stress Vulnerability factor of the SGI has fewer items in it, which reduces its reliability. Given that the reliability of a subscale constrains its validity, it is possible that the Fatigue Scale could exhibit a stronger relationship with Fatigue and Stress Vulnerability if more items were added to this factor to increase its reliability.

Discussion

Study 5 provides substantial convergent validity evidence for the SGI. The sensory gating construct systematically correlated with a variety of constructs related to individual differences in perceptual and attentional processes. An examination of the rank-order correlation coefficients showed that the full-scale SGI was most positively and strongly correlated (r = 0.79) with a measure of attentional OET. The SGI also strongly correlated with measures of attentional overload arising from internal stimuli, such as irrelevant thoughts (0.71), and with arousability (0.65) and sensitivity to exteroceptive stimuli (0.65). The SGI correlated somewhat more modestly—but statistically significantly—with measures of poor attention allocation and modulation, including mind wandering (0.63), attentional instability (0.61), and cognitive failures or lapses (0.59). The full-scale SGI also was modestly associated with measures of fatigue (0.59) and body-image aberrations (0.57). Although still statistically significant, the weakest correlations of the full-scale SGI score were with measures of trait anxiety (0.53), trait arousability (0.45), and distractibility (0.51).

The pattern of relations observed between the full-scale SGI score and these other measures constitutes the manifest portion of the sensory gating construct's nomological network,[61] in which poor sensory gating is most closely related to difficulties modulating exteroceptive inputs to the nervous system (eg, attentional overload due to external stimulation). In addition, the SGI is somewhat less related to difficulties modulating and/or allocating attention (eg, mind wandering); even less related to physical and mental manifestations of fatigue and psychotic-like body-image distortions; and modestly related to trait anxiety and trait arousability.

The discriminant validity of the SGI's factors was supported by several observations. First, the PAS correlated significantly higher with the SGI's Perceptual Modulation factor than with any of the other SGI factors. This is consistent with the supposition that the PAS measures one aspect of a larger domain of perceptual aberration,[29] and the SGI's Perceptual Modulation factor measures another aspect of the same domain to a greater extent than the other SGI factors. Second, the Perceptual Modulation and Distractibility factors of the SGI correlated significantly higher with both the OET and the OIT subscales of Nideffer's[47] TAIS than did either the Over-Inclusion factor or the Fatigue and Stress Vulnerability factor. Furthermore, the Distractibility factor, compared with the Perceptual Modulation factor, correlated more strongly with both the OET and the OIT. Examination of the content of the OET, OIT, and Distractibility factor of the SGI suggests that the commonality among these scales may be their measurement of similar aspects of the sequelae of poor sensory gating, as opposed to what could be considered the primary sensory gating deficit—aberrant modulation of perceptual processes. Third, the Distractibility factor of the SGI, compared with the other SGI factors, correlated significantly more strongly with the AIQ (Allan L., unpublished data), CFQ,[48] Distractibility and Mind Wandering subscales of the IPI,[59] OIT subscale of the TAIS,[47] and TAI.[53]

Some correlates of the SGI's factors, however, failed to support its hypothesized structure. For example, the Fatigue Scale[60] did not correlate most strongly with the Fatigue and Stress Vulnerability factor of the SGI as predicted. Also, the HSPS,[56] which measures sensory sensitivity, did not correlate most strongly with the Perceptual Modulation factor, which assesses, among other phenomena, perceived increases in stimulus intensity and sensitivity to perceptual subtleties. However, taken together, the results of this study justify the retention and further examination of the 4 factors.

Study 6: Sex Differences on the SGI

Sex differences have been reported for both P50 suppression[13,62] and acoustic startle suppression,[14] indicating that women exhibit poorer sensory gating than men, especially under stress.[55] Mehrabian[33] reported a significant positive correlation (0.38) between arousability/stimulus screening (as measured by the TAS) and sex, indicating that men tend to filter, or screen, to a greater extent than women. Similarly, normative data for the APS[46] suggest that women report greater arousability than men. Also, subscale scores on the IPI[60] suggest that women report greater distractibility (factor 23) and mind wandering (factor 24) than men. Finally, there is evidence suggesting that women may be more distractible than men in competing aural message paradigms[63] and have less tolerance for loud tones than men.[64]

Method and Results

The participants were 1517 undergraduate students (734 men). Sex differences on the SGI and its factors were tested by independent samples t tests. Following a conservative nonparametric strategy, sex differences were examined with order statistics. Women scored significantly higher on the Distractibility factor score (M = 18.39, SEM = 0.29) than men (M = 16.95, SEM = 0.28), Mann-Whitney U[M-W] statistic (1517) = 279057, P = .001, and on the Fatigue and Stress Vulnerability factor (women: M = 12.81, SEM = 0.19; men: M = 11.59, SEM = 0.18), M-W U statistic (1517) = 247181, $P < .001$. The groups did not significantly differ on the Perceptual Modulation (women = 26.19 [0.47], men = 27.22 [0.49]), Over-Inclusion (women = 17.48 [0.21], men = 17.75 [0.21]), or the overall SGI scores (women = 74.88 [0.99], men = 73.51 [0.99]).

Discussion

Women reported greater distractibility and greater susceptibility to perceptual anomalies under conditions of perceived fatigue and stress than men. However, there were no significant differences between men and women in the composite SGI score or the other subscales. A recent meta-analysis examining sex differences in several measures of schizotypy found that, among older individuals, women tended to score higher on the PAS,[29] which correlated highly with the Perceptual Modulation factor (see table 2).[65] One possible reason for the discrepancy between the results reported by the meta-analysis and those presented here is that the authors found the sex differences on the PAS to be most prominent in older subjects, while the participants in the present study were young college students.

The sex differences on the SGI's Distractibility factor score were consistent with Mehrabian's findings that women scored significantly higher on his arousability/poor stimulus screening measure, the TAS. Coren[46] also reported that women scored higher on the APS, and Giambra[59] observed that women reported greater distractibility and "mind wandering" than men on the IPI. In Study 5, all 3 of these measures correlated significantly higher with the Distractibility factor than with the Perceptual Modulation factor of the SGI, providing additional support for the discriminant validity of the SGI's factors.

The sex differences on the Fatigue and Stress Vulnerability factor are consistent with a number of methodologically diverse reports in the literature. First, the observed findings are consistent with evidence that, during a stressor task, women showed significantly more disrupted P50 sensory gating compared with men.[55] Second, there are reports that women, compared with men, describe themselves as more susceptible to the effects of stress than men. Finally, women have been found to report more symptoms of fatigue than men.[67]

Conclusions

These studies provide empirical characterization of the sensory gating construct at the phenomenological level of analysis and a self-report instrument, the SGI, with which to measure this construct. The data indicate that sensory gating is principally comprised of anomalies in the modulation of percepts, including both the modulation of stimulus intensity and perceptual inundation. The perceptual anomalies are meaningfully related to, but not identical with, disturbances of focal and radial attention—a conclusion that is supported by 2 kinds of evidence. First, item-level analyses conducted in independent samples consistently revealed 4 distinct and meaningful factors that differentially intercorrelated with each other (Studies 1 and 3). Second, the 4 factors consistently exhibited substantial intercorrelations across samples, indicating strong relationships between factors; yet, a CFA ruled out the hypothesis that sensory gating is a unidimensional construct (Study 4). Third, these factors evidenced a conceptually meaningful pattern of associations with other constructs, supporting both the multidimensionality of sensory gating and the validity of the SGI (Study 5). Further, the data suggest that fatigue and stress exacerbate sensory gating–like anomalies, especially in women—a finding that directly mirrors results from a P50 sensory gating study (Study 6).[55] Convergent validation efforts indicated that poor sensory gating was most closely related to difficulties modulating exteroceptive inputs to the nervous system followed by difficulties modulating and allocating attention. Finally, poor sensory gating, as operationalized with the SGI, was modestly related to both physical and mental manifestations of fatigue and psychotic-like body-image distortions, as well as being weakly related to trait anxiety and trait arousability.

When considered in conjunction with a prior study that operationalized sensory gating using the SIAPA,[3] a number of tentative conclusions about the sensory gating construct emerge. First, measures of phenomenological aspects of sensory gating exhibited psychometric properties that would be expected of a meaningful individual differences construct. Specifically, it demonstrated good test-retest and interrater reliability as well as manifested content, discriminant, and factorial validity. Furthermore, our previous findings indicated that sensory gating phenomena are important features of schizophrenia insofar as they distinguished people with schizophrenia from healthy controls.[3] Taken together, the SIAPA and SGI provide complementary means of assessing sensory gating phenomenology, with the SGI possibly better suited for less impaired samples such as those with schizotypal personality disorder, first-degree relatives of people with schizophrenia, and psychiatrically stable individuals with schizophrenia. How the SIAPA and SGI relate to each other, whether the SGI's present factor structure will persist in clinical samples and whether high SGI scores predict a proneness to psychosis, remain to be determined.

Although the empirical explication and demarcation of sensory gating provided here builds upon the seminal theoretical investigation of McGhie and Chapman,[2] as both an empirical and conceptual contribution, our findings have the potential to contribute in a variety of new ways. First, attempts to relate experiential manifestations of sensory gating to other indices of gating (eg, psychophysiological) will be most informative when the attendant hypotheses are explicit about which phenomena are implicated (eg, Perceptual Modulation, Over-Inclusion, Distractibility, and/or Fatigue-Stress). Such specificity may shed light on whether mechanisms assessed by these methods (eg, P50 and prepulse inhibition) subserve the suppression of either exteroceptive stimuli (as is widely assumed) or interoceptive stimuli[68] or both.[69] Second, given the specificity available owing to the factorial structure of the SGI, general references to the phenomenology described by McGhie and Chapman[2] and others should give way to more specific identification of which "symptoms" are under scrutiny in subsequent studies—especially because both rational and empirical methods indicate potentially important distinctions among them. Emerging evidence from independent research groups indicates that subscales of the SGI differentially correlate with event-related brain potential measures of information processing in the P50 suppression paradigm[70] as well as distinguish samples that vary on clinical and diagnostic dimensions (eg, trauma exposure and post-traumatic stress disorder[71]). Third, the factor structure of the SGI suggests 4 substantive areas to pursue experimentally: Perceptual Modulation, Over-Inclusion, Distractibility, and the effects of Fatigue and Stress. Given the large proportion of variance accounted for in the item pool (see Studies 1 and 2) and the observed correlates with other constructs (Study 5), subsequent studies of Perceptual Modulation, including sensory reactivity and inhibition, would be most germane to the phenomenology of sensory gating. This supports the continued use of P50 and acoustic startle suppression paradigms to assess sensory gating, as well as the reexamination of other paradigms that similarly index how the central nervous system modulates sensory inputs (eg, augmenting-reducing[72]). It seems prudent to keep in mind that any given psychological or neuropsychological construct is distinct from its operationalization and may never be fully captured by any 1 measurement.[73] Finally, the suggestion from our findings that "over-inclusive" attention captures an important aspect of sensory gating problems also warrants further study. Interestingly, the concept of "over-inclusiveness" has been previously used to describe cognitive deficits observed in schizophrenia[74,75] and is consistent with experimental findings of hyperattentiveness in schizophrenia.[76] Similarly, additional research is needed to understand the relationships among Distractibility, Fatigue and Stress Vulnerability, and sensory gating, especially given promising preliminary reports of their interrelations.[16–18,55,77–79]

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Supplementary Material

Supplementary material is available at http://schizophreniabulletin.oxfordjournals.org/.

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References

1. Andreasen NC, Arndt S, Swayze V, et al. Thalamic abnormalities in schizophrenia visualized through magnetic-resonance image averaging. *Science*. 1994;266:294–298.
2. McGhie A, Chapman J. Disorders of attention and perception in schizophrenia. *Br J Med Psychol*. 1961;34:103–116.
3. Bunney WE Jr. Hetrick WP, Garland-Bunney B, et al. The structured interview for assessing perceptual anomalies (SIAPA). *Schizophr Bull*. 1999;25:577–592.

4. Cutting J, Dunne F. The nature of the abnormal perceptual experiences at the onset of schizophrenia. *Psychopathology*. 1986;19:347–352.
5. Cutting J, Dunne FJ. Subjective experience of schizophrenia. *Schizophr Bull*. 1989;15:217–231.
6. Phillipson OT, Harris JP. Perceptual changes in schizophrenia: a questionnaire survey. *Psychol Med*. 1985;15: 859–866.
7. Adler LE, Pachtman E, Franks RD, Pecevich M, Waldo MC, Freedman R. Neurophysiological evidence for a defect in neural mechanisms involved in sensory gating in schizophrenia. *Biol Psychiatry*. 1982;17:639–654.
8. Braff BL, Geyer MA. Sensorimotor gating and schizophrenia. *Arch Gen Psychiatry*. 1990;47:181–188.
9. Freedman R, Adler LE, Gerhardt GA, et al. Neurobiological studies of sensory gating in schizophrenia. *Schizophr Bull*. 1987;13:669–678.
10. Freedman R, Adler LE, Waldo M. Gating of the auditory evoked potential in children and adults. *Psychophysiology*. 1987;24:223–227.
11. Vohs JL, Chambers RA, Krishnan GP. Auditory sensory gating in the neonatal ventral hippocampal lesion model of schizophrenia. *Neuropsychobiology*. 2009;60:12–22.
12. Light GA, Braff DL. Do self-reports of perceptual anomalies reflect gating deficits in schizophrenia patients? *Biol Psychiatry*. 2000;47:463–467.
13. Hetrick WP, Sandman CA, Bunney WE Jr. Jin Y, Potkin SG, White MH. Gender differences in the gating of the auditory evoked potential in normal subjects. *Biol Psychiatry*. 1996;39:51–58.
14. Swerdlow NR, Auerbach P, Monroe SM, Hartson H, Geyer MA, Braff DL. Men are more inhibited than women by weak prepulses. *Biol Psychiatry*. 1993;34:253–260.
15. Waldo MC, Freedman R. Gating of auditory evoked responses in normal college students. *Psychiatry Res*. 1986; 19:223–239.
16. Johnson MR, Adler LE. Transient impairment in P50 auditory sensory gating induced by a cold-pressor test. *Biol Psychiatry*. 1993;33:380–387.
17. White PM, Yee CM. Effects of attentional and stressor manipulations on the P50 gating response. *Psychophysiology*. 1997;34:703–711.
18. Yee CM, White PM. Experimental modification of P50 suppression. *Psychophysiology*. 2001;38:531–539.
19. Cromwell RL. Assessment of schizophrenia. *Annu Rev Psychol*. 1975;26:593–619.
20. Strauss JS. Hallucinations and delusions as points on continua function: rating scale evidence. *Arch Gen Psychiatry*. 1969;21:581–586.
21. Strauss JS, Carpenter WT, Bartko JJ. Speculations on the processes that underlie schizophrenic symptoms and signs. *Schizophr Bull*. 1975;11:61–69.
22. Bannister D. The logical requirements of research into schizophrenia. *Br J Psychiatry*. 1968;114:789–794.
23. Persons JB. The advantages of studying psychological phenomena rather than psychiatric diagnoses. *Am Psychol*. 1986;41:1252–1260.
24. Chapman LJ, Chapman JP. Problems in the measurement of cognitive deficits. *Psychol Bull*. 1973;79:380–385.
25. Cattell RB. Psychological theory and scientific method. In: Cattell RB, ed. *Handbook of Multivariate Experimental Psychology.* Chicago, IL: Rand McNally; 1966:1–18.
26. Clark LA, Watson D. Constructing validity: basic issues in objective scale development. *Psychol Assess*. 1995;7: 309–319.
27. Venables P. Input dysfunction in schizophrenia. In: Maher BA, ed. *Progress in Experimental Personality Research.* New York, NY: Academic Press; 1964:1–47.
28. Loevinger J. Objective tests as instruments of psychological theory. *Psychol Rep*. 1957;3:635–694.
29. Chapman LJ, Chapman JP, Raulin ML. Body image aberration in schizophrenia. *J Abnorm Psychol*. 1978;87:399–407.
30. Holzman P. Cognitive impairment and cognitive stability: towards a theory of thought disorder. In: Serban G, ed. *Cognitive Defects in the Development of Mental Illness.* New York, NY: Brunner-Mazel; 1978:361–376.
31. Marengo JT, Harrow M, Lanin-Kettering I, Wilson A. Evaluating bizarre idiosyncratic thinking: a comprehensive index of positive thought disorder. *Schizophr Bull*. 1986;12: 497–508.
32. Mehrabian A. A questionnaire measure of individual differences in stimulus screening and associated differences in arousability. *Environ Psychol Nonverbal behav*. 1977;1:89–103.
33. Mehrabian A. Individual differences in stimulus screening and arousability. *J Personal*. 1977;45:237–250.
34. Chapman LJ, Chapman JP, Raulin ML. Scales for physical and social anhedonia. *J Abnorm Psychol*. 1976;85(4):374–382.
35. DeVellis RT. *Scale Development: Theory and Applications.* Newbury Park, CA: Sage; 1991.
36. Kim J, Mueller CW. *Factor Analysis: Statistical Methods and Practical Issues.* London, England: Sage; 1978.
37. Spector PE. *Summated Rating Scale Construction.* Newbury Park, CA: Sage; 1992.
38. Floyd FJ, Widaman KF. Factor analysis in the development and refinement of clinical assessment instruments. *Psychol Assess*. 1995;7:286–299.
39. Chapman LJ, Edell WS, Chapman JP. Physical anhedonia, perceptual aberration, and psychosis proneness. *Schizophr Bull*. 1980;6:639–653.
40. Mehrabian A. Theory and evidence bearing on a scale of trait arousability. *Curr Psychol Dev Learn Personal Soc*. 1995; 14:3–28.
41. Arbuckle JL. *AMOS 16.0 User's Guide.* Chicago, IL: SPSS, Inc.; 2007.
42. Byrne BM. *Structural Equation Modeling with AMOS—Basic Concepts, Applications, and Programming.* New York, NY: Taylor and Francis Group; 2001.
43. Gignac GE, Bates TC, Jang KL. Implications relevant to CFA model misfit, reliability, and the five-factor model as measured by the NEO-FFI. *Pers Individual Diff*. 2007;43:1051–1062.
44. Mehrabian A. *Manual for the Revised Trait Arousability (Converse of the Stimulus Screening) Scale.* Montery, CA.
45. Coren S. Prediction of insomnia from arousability predisposition scores: scale development and cross-validation. *Behav Res Ther*. 1988;26:415–420.
46. Coren S. The arousal predisposition scale: normative data. *Bull Psychon Soc*. 1990;28:551–552.
47. Nideffer RM. Test of attentional and interpersonal style. *J Personal Soc Psychol*. 1976;34:394–404.
48. Broadbent DE, Cooper PF, FitzGerald P, et al. The cognitive failures questionnaire (CFQ) and its correlates. *Br J Clin Psychol*. 1982;21:1–16.

49. Harris JE, Wilkins AJ. Remembering to do things: a theoretical framework and an illustrative example. *Hum Learn*. 1982;10:123–136.
50. Martin M, Jones GV. Distribution of attention in cognitive failure. *Hum Learn*. 1983;2:221–226.
51. Martin M, Jones GV. Cognitive failures in everyday life. In: Harris JE, Morris PE, eds. *Everyday Memory: Actions and Absent-Mindedness*. London, England: Academic Press; 1984: 173–190.
52. Hillyard SA, Mangun GR. Commentary: sensory gating as a physiological mechanism for visual selective attention. In: Rohrbaugh JW, Parasurama R, eds. *Current Trends in Event-Related Potential Research (EEG Suppl. 40)*. London, England: Elsevier; 1987:61–67.
53. Spielberger CD, Gorsuch RL, Lushene RE. *Manual for the State-Trait Anxiety Inventory*. Palo Alto, CA: Consulting Psychologists Press.
54. Yee CM, Nuechterlein KH, Morris SE, White PM. P50 suppression in recent-onset schizophrenia: clinical correlates and risperidone effects. *J Abnorm Psychol*. 1998;107:691–698.
55. White PM, Kanazawa A, Yee CM. Gender and suppression of mid-latency ERP components during stress. *Psychophysiology*. 2005;42:720–725.
56. Aron EN, Aron A. Sensory-processing sensitivity and its relation to introversion and emotionality. *J Personal Soc Psychol*. 1997;73:345–368.
57. Singer JL, Antrobus JS. *Manual for the Imaginal Processes Inventory*. Princeton, NJ: Educational Testing Service; 1970.
58. Singer JL, Antrobus JS. Day dreaming, imaginal processes, and personality: a normative study. In: Sheehan P, ed. *The Function and Nature of Imagery*. New York, NY: Academic Press; 1972.
59. Giambra LM. A factor analysis of the items of the imaginal processes inventory. *J Clin Psychol*. 1980;36:383–409.
60. Chalder T, Berelowitz G, Pawlikowska T, et al. Development of a fatigue scale. *J Psychosom Res*. 1993;37:147–153.
61. Cronbach LJ, Meehl PE. Construct validity in psychological tests. *Psychol Bull*. 1955;52:281–302.
62. Patterson JV, Hetrick WP, Boutros NN, et al. P50 sensory gating ratios in schizophrenics and controls: a review and data analysis. *Psychiatry Res*. 2008;158:226–247.
63. Halley RD. Distractibility of males and females in competing aural message situations: a research note. *Hum Commun Res*. 1975;2:79–82.
64. McGuinness D. Equating individual differences for auditory input. *Psychophysiology*. 1974;11:113–120.
65. Miettunen J, Jaaskelainen E. Sex differences in Wisconsin schizotypy scales—a meta-analysis. *Schizophr Bull*. 2010;36:347–358.
66. Horowitz M, et al. Life event questionnaires for measuring presumptive stress. *Psychosom Med*. 1977;39:413–431.
67. Jason LA, Jordan KM, Richman JA, et al. A community-based study of prolonged fatigue and chronic fatigue. *J Health Psychol*. 1999;4:9–26.
68. VinogradovS,SolomonS,OberBA,BigginsCA,ShenautGK,Fein G. Do semantic priming effects correlate with sensory gating in schizophrenia?*BiolPsychiatry*.1996;39:821–824.
69. Perry W, Braff DL. Information-processing deficits and thought disorder in schizophrenia. *Am J Psychiatry*. 1994; 151:363–367.
70. Kisley MA, Noecker TL, Guinther PM. Comparison of sensory gating to mismatch negativity and self-reported perceptual phenomena in healthy adults. *Psychophysiology*. 2004; 41:604–612.
71. Stewart LP, White PM. Sensory filtering phenomenology in PTSD. *Depress Anxiety*. 2007;1–8.
72. Silverman J, Buchsbaum M, Henkin R. Stimulus sensitivity and stimulus intensity control. *Percept Mot Skills*. 1969;28:71–78.
73. Foster SL, Cone JD. Validity issues in clinical assessment. *Psychol Assess*. 1995;7:248–260.
74. Cameron N. Reasoning, regression, and communication in schizophrenics. *Psychol Monogr*. 1938;50:221.
75. Payne RW. The measurement and significance of overinclusive thinking and retardation in schizophrenic patients. In: Hach PH, Zubin J, eds. *Psychopathology of schizophrenia*. New York, NY: Grune & Stratton; 1966:77–79.
76. Mar CM, Smith DA, Sarter M. Behavioral vigilance in schizophrenia: evidence for hyperattentional processing. *Br J Psychiatry*. 1996;169:781–789.
77. Ambrosini A, De P, Afra J, Sandor PS, Schoenen J. Reduced gating of middle-latency auditory evoked potentials (P50) in migrane patients: another indication of abnormal sensory processing? *Neurosci Lett*. 2001;306:132–134.
78. ErwinRJ,TuretskyBI,MobergP,GurRC,GurRE.P50abnormalitiesinschizophrenia:relationshiptoclinicalandneuropsychologicalindicesofattention.*SchizophrRes*.1998;33:157–167.
79. Karper LP, Freeman GK, Grillon C, Morgan CA, Charney DS, Krystal JH. Preliminary evidence of an association between sensorimotor gating and distractibility in psychosis. *J Neuropsychiatr Clin Neurosci*. 1996;8:60–66.