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Predicting Somatic Symptom Disorder Using Facets of Neuroticism, Somatosensory Amplification, and Interoceptive Sensitivity: An Explainable Machine Learning Analysis

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ABSTRACT

The objective of this study was to utilize an explainable machine learning approach to predict Somatic Symptom Disorder by delineating the complex, non-linear contributions of specific neuroticism facets, somatosensory amplification, and multidimensional interoceptive sensitivity. A quantitative, cross-sectional design was employed with a sample of $N = 845$ Malaysian adults. Data were collected using the Patient Health Questionnaire-15 (PHQ-15), the Neuroticism domain of the NEO-PI-R, the Somatosensory Amplification Scale (SSAS), and the Multidimensional Assessment of Interoceptive Awareness (MAIA). Predictive modeling was conducted using advanced ensemble tree-based algorithms (Random Forest, Gradient Boosting, and XGBoost), and model interpretability was achieved using SHapley Additive exPlanations (SHAP) to evaluate the marginal contribution of each psychological feature. The XGBoost algorithm demonstrated superior predictive performance, achieving an overall accuracy of 87.57%and an Area Under the Curve (AUC) of 0.91. SHAP explainability metrics revealed that Somatosensory Amplification was the most profound positive predictor of somatic distress, followed by the specific Anxiety and Vulnerability facets of neuroticism. Conversely, adaptive interoceptive capacities, specifically the "Not-Worrying" and "Body Trusting" dimensions, emerged as the strongest negative (protective) predictors against Somatic Symptom Disorder classification. Explainable machine learning demonstrates that specific sensory appraisal mechanisms and interoceptive deficits are more critical than broad personality domains in driving somatic distress, providing highly specific targets for precision psychological interventions.

Keywords: *Somatic Symptom Disorder; Explainable Machine Learning; SHAP; Somatosensory Amplification; Interoceptive Sensitivity; Neuroticism.*

1. Introduction

Somatic Symptom Disorder represents a profoundly debilitating psychiatric condition characterized by an intense, disproportionate focus on physical symptoms, which causes significant emotional distress and substantial impairment in daily functioning. Historically conceptualized through the lens of medically unexplained symptoms, the diagnostic criteria have evolved to prioritize the positive psychological, cognitive, and behavioral responses to somatic sensations rather than merely the absence of a discernible medical etiology. This paradigm shift underscores the critical necessity of understanding the subjective perceptual and emotional frameworks through which individuals interpret their bodily states. The chronicity of this disorder places an immense burden on both the affected individuals and global healthcare systems, as patients frequently engage in excessive healthcare utilization, undergoing repetitive and often invasive medical investigations in pursuit of physiological explanations for their distress. Consequently, contemporary psychopathological research has increasingly pivoted toward exploring the intricate intersection of stable personality traits, maladaptive sensory appraisal mechanisms, and internal bodily awareness to elucidate the complex etiology of Somatic Symptom Disorder.

A prominent psychological vulnerability factor consistently implicated in the genesis and maintenance of somatic distress is the broad personality domain of neuroticism. Neuroticism encompasses a pervasive tendency to experience negative affective states, such as anxiety, anger, depression, and generalized psychological vulnerability. Individuals exhibiting elevated levels of neuroticism are predisposed to hypervigilance regarding potential threats, including those originating from within their own bodies. This trait significantly lowers the threshold for perceiving normal physiological fluctuations as anomalous or indicative of severe illness. Recent qualitative and quantitative explorations have emphasized the necessity of deconstructing neuroticism into its constituent facets to better understand its multidimensional impact on somatic and psychological health (Ahmadabadi, 2025). The concomitant effects of specific cognitive processes, such as worry and rumination, often act as catalysts that exacerbate the relationship between baseline neuroticism and the frequency of somatic complaints (Denovan et al., 2018). Furthermore, the interplay between neuroticism and cognitive variables like self-efficacy significantly influences pain catastrophizing, a cognitive distortion closely related to somatic symptom severity (Sayed Alitabar & Goli, 2023). Therefore, rather than treating neuroticism as a monolithic construct, it is imperative to investigate how its distinct facets differentially contribute to the cognitive and emotional architecture of somatic disorders.

Closely related to the emotional dysregulation inherent in neuroticism is the concept of somatosensory amplification, a specific cognitive-perceptual style defined by the tendency to experience normal, everyday somatic and visceral sensations as intense, noxious, and highly disturbing (Köteles & Witthöft, 2017). Somatosensory amplification acts as a magnifying glass for internal physiological noise, transforming benign bodily signals into profound sources of health anxiety. This amplification process is deeply intertwined with emotional regulation deficits, such as alexithymia, which can link perceived psychosocial stress directly to the manifestation of somatic symptoms in clinical populations (Nakao & Takeuchi, 2018). Moreover, deeper interpersonal factors, including attachment insecurity and associated interpersonal problems, have been shown to mediate the development of somatosensory amplification, suggesting that social and relational traumas may manifest through distorted somatic perception (Kealy et al., 2021). Metacognitive beliefs about health and illness further complicate this picture, demonstrating a unique contribution to health anxiety even when controlling for baseline neuroticism and somatosensory amplification (Bailey & Wells, 2013).

The broader study of somatosensory processing extends far beyond psychiatric conditions, highlighting the fundamental role of sensory integration in human functioning. For instance, interventions focusing on somatosensory stimulation have been utilized to improve dynamic balance and physiological outcomes in elderly populations (Abdullah et al., 2022). In neuro-rehabilitation contexts, somatosensory integration is critical for restoring motor functions, such as in robot-assisted therapies for post-stroke patients (Lin et al., 2024), and plantar somatosensory restoration has been shown to enhance gait and speed perception (Kim et al., 2023). Sensory processing differences are also a hallmark of neurodevelopmental conditions; altered somatosensory temporal discrimination is frequently observed in individuals with Autism Spectrum Disorder (Büyüktaşkın et al., 2021), where skin-mediated somatosensory signals profoundly impact emotion regulation and behavioral profiles (Riquelme et al., 2023). Furthermore, foundational research on sensory processing

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sensitivity reveals distinct patterns of somatosensory brain activation during tactile experiences (Schaefer et al., 2022). Even specific breathwork interventions, such as the Wim Hof method, have been documented to influence the autonomic nervous system and subsequently alter somatosensory perception (Sakaj, 2025). This vast array of research underscores that somatosensory processing is a fundamental neurocognitive domain, the dysregulation of which is uniquely central to the pathology of Somatic Symptom Disorder.

Parallel to somatosensory amplification is the construct of interoception, defined as the central nervous system's perception, interpretation, and integration of signals originating from within the body, providing a continuous mapping of the organism's internal landscape. Interoceptive sensitivity and awareness dictate how accurately individuals perceive sensations such as their heartbeat, respiration, and gastrointestinal activity. In the context of Somatic Symptom Disorder, there are profound changes in interoceptive accuracy, particularly when cognitive processing is subjected to emotional interference (Lee et al., 2024). Expanding clinical tolerance to physical discomfort through interoceptive exposure has emerged as a vital therapeutic mechanism across various physical and mental health conditions (Farris et al., 2025). Adaptive interoceptive awareness acts as a critical buffer against pathological symptom reporting, significantly impacting how patients interpret illness and catastrophize pain (Hooshmandi et al., 2023; Hooshmandi et al., 2024).

The domain-general importance of interoceptive awareness is evident in its pervasive influence across various psychological states and developmental stages. In healthy adolescents, strong interoceptive abilities are closely linked to enhanced emotional state regulation during periods of acute stress and subsequent recovery (Braet & Braet, 2024). Neuroimaging studies further reveal that mindfulness-based training can actively modulate the interoceptive brain networks in younger populations, promoting psychological resilience (Tymofiyeva et al., 2024). The implications of interoceptive sensitivity extend heavily into eating-related pathologies and body schema distortions. Anomalies in interoceptive capabilities are fundamental to the pathophysiology of severe eating disorders, including Avoidant/Restrictive Food Intake Disorder and Anorexia Nervosa (Datta & Lock, 2023). In non-clinical collegiate populations, interoceptive awareness significantly mediates emotional eating behaviors, influenced heavily by appetite and baseline emotional awareness (Bullock & Goldbacher, 2023). Furthermore, a growing body of literature identifies interoceptive sensibility as a paramount predictor of body image disturbances across female adulthood, often superseding traditional sociocultural predictors (Naraindas & Cooney, 2023; Naraindas et al., 2023). Network analyses have demonstrated that the pathways connecting interoceptive sensibility to self-objectification differ significantly depending on the severity of body dissatisfaction (Naraindas et al., 2025). Together, these studies illustrate that maladaptive processing of internal signals is a transdiagnostic vulnerability, positioning interoceptive dysregulation as a critical independent variable in predicting somatic symptom severity.

Despite the wealth of literature identifying neuroticism, somatosensory amplification, and interoceptive sensitivity as critical factors in Somatic Symptom Disorder, the vast majority of prior studies have relied heavily on traditional linear regression models and basic correlational analyses. These conventional statistical methodologies are inherently limited in their capacity to capture the complex, non-linear interactions and high-dimensional relationships that characterize human psychopathology. A comprehensive risk profile for somatic distress cannot be adequately modeled by assuming that psychological traits operate in isolated, additive silos. Machine learning, particularly advanced ensemble tree-based algorithms, offers a mathematically robust alternative to model these intricate psychiatric data spaces. By recursively partitioning data, machine learning algorithms can uncover hidden interactions between specific neuroticism facets, sensory amplification tendencies, and interoceptive awareness sub-dimensions that traditional linear models invariably overlook.

However, a major historical impediment to the integration of machine learning in clinical psychology has been the "black-box" nature of advanced predictive algorithms. While highly accurate, these models often fail to provide researchers and clinicians with transparent, interpretable mechanisms detailing how specific predictions are derived. To bridge this gap, the integration of Explainable Artificial Intelligence (XAI) frameworks, specifically SHapley Additive exPlanations (SHAP), has revolutionized the field. Based on cooperative game theory, SHAP values calculate the exact, unbiased marginal contribution of every single psychological feature to the model's final output. This allows for both global interpretability—understanding which variables are most important across the entire population—and local interpretability—understanding precisely why a specific individual was classified as high-risk for somatic distress. By deploying an explainable machine learning architecture, this research transcends traditional predictive limitations, aiming to provide a highly granular, interactive map of the psychological and sensory drivers of somatic symptoms.

Therefore, the primary aim of this study is to utilize an explainable machine learning approach to predict Somatic Symptom Disorder by delineating the complex, non-linear contributions of specific neuroticism facets, somatosensory amplification, and multidimensional interoceptive sensitivity.

2. Methods and Materials

2.1. Study Design and Participants

This study employed a quantitative, cross-sectional predictive research design to investigate the psychological and sensory predictors of Somatic Symptom Disorder among adults. The target population comprised individuals residing across various states in Malaysia, recruited through a combination of convenience and snowball sampling techniques facilitated by digital survey platforms and local community networks. After the rigorous screening of the initial responses to remove incomplete submissions and those failing attention checks, the final sample consisted of exactly 845participants. The inclusion criteria required participants to be at least 18years of age, fluent in English or Malay, and currently residing in Malaysia. Individuals with a self-reported history of severe neurological damage or active psychotic disorders were excluded to prevent confounding effects on self-reported psychological metrics. Participants were provided with comprehensive informed consent forms detailing the study's purpose, the voluntary nature of their participation, and strict assurances regarding data anonymity and confidentiality before accessing the primary questionnaire.

2.2. Measures

Data collection was conducted using a comprehensive battery of standardized, self-report psychometric instruments chosen for their established reliability and validity. To assess the severity and presence of Somatic Symptom Disorder, the Patient Health Questionnaire-15 was utilized, which evaluates the burden of various somatic symptoms over the preceding four weeks. The facets of neuroticism, including anxiety, angry hostility, depression, self-consciousness, impulsiveness, and vulnerability, were measured using the Neuroticism domain of the Revised NEO Personality Inventory. Somatosensory amplification, defined as the tendency to experience normal somatic sensations as intense, noxious, and disturbing, was quantified using the Somatosensory Amplification Scale. Finally, interoceptive sensitivity and awareness were assessed using the Multidimensional Assessment of Interoceptive Awareness, which captures distinct facets of how individuals perceive and attend to their internal bodily signals. Demographic variables, including age, gender, educational attainment, and socioeconomic status, were also collected to serve as potential covariates in the predictive modeling phase. All instruments underwent rigorous forward and backward translation processes for the Malay-speaking cohort to ensure cross-cultural semantic equivalence.

2.3. Data Analysis

The data analysis pipeline was constructed utilizing advanced explainable machine learning methodologies to predict Somatic Symptom Disorder while maintaining high interpretability of the contributing psychological variables. Initial data preprocessing involved handling missing values through K-Nearest Neighbors imputation and normalizing the continuous variables using standard scalar techniques to ensure that no single feature disproportionately influenced the model training process. The dataset was randomly partitioned into a training set comprising 80%of the data and a testing set comprising the remaining 20%. Several machine learning algorithms, including Random Forest, Gradient Boosting, and Extreme Gradient Boosting, were trained to identify complex, non-linear patterns between the predictor variables and somatic symptom severity. Model performance was evaluated on the unseen testing set using standard classification metrics, including accuracy, precision, recall, the F1-score, and the Area Under the Receiver Operating Characteristic Curve. To address the inherent "black-box" nature of these advanced algorithms, SHapley Additive exPlanations were implemented. This game-theoretic approach provided local and global explainability by quantifying the exact marginal contribution of each neuroticism facet, somatosensory amplification score, and interoceptive sensitivity dimension to the final predictive output. All computational analyses and predictive modeling procedures were executed using the Python programming language, leveraging the scikit-learn and SHAP libraries.

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3. Findings and Results

The initial phase of the data analysis focused on outlining the demographic characteristics of the sample to contextualize the subsequent predictive modeling. The final cohort comprised exactly 845Malaysian adults, reflecting a diverse cross-section of the population. As detailed in the demographic summary, the sample demonstrated a slightly higher proportion of female participants compared to males, which aligns with typical response patterns in self-reported psychological surveys. The age distribution indicated a predominantly young to middle-aged adult population, with the majority falling between 18and 35years old, though adequate representation was secured across older age brackets to ensure generalizability. Educational attainment within the sample was notably high, with a significant majority holding at least a bachelor's degree or an equivalent tertiary qualification. Socioeconomic status, categorized by estimated household income brackets standard to the Malaysian demographic context, revealed a normative distribution centered around the middle-income tiers. The exact distributions of these sociodemographic variables, which later served as foundational covariates in the machine learning models, are presented comprehensively in Table 1.

Table 1

Demographic Characteristics of the Study Sample (N=845)

Demographic Variable	Category	Frequency (n)	Percentage (%)
Gender	Female	492	58.22
	Male	345	40.83
	Prefer not to say	8	0.95
Age Group (Years)	18 – 25	312	36.92
	26 – 35	285	33.73
	36 – 45	156	18.46
	46and above	92	10.89
Education	High School or below	134	15.86
	Diploma / Associate	205	24.26
	Bachelor's Degree	385	45.56
	Postgraduate	121	14.32

Following the demographic profiling, descriptive statistics and Pearson bivariate correlations were computed to examine the fundamental relationships between the dependent variable—Somatic Symptom Disorder severity as measured by the PHQ-15—and the independent psychological predictors. The mean score for the PHQ-15 across the entire sample was M=9.45(SD=4.82), indicating a moderate baseline level of somatic burden within the surveyed population. Approximately 22.5%of the sample met the clinical threshold indicative of high somatic symptom severity (PHQ-15 score ≥15). The correlation matrix revealed robust, statistically significant associations in the expected directions. Overall neuroticism and its specific facets, particularly anxiety (r=0.58, p<0.001) and vulnerability (r=0.52, p<0.001), exhibited strong positive correlations with somatic symptom severity. Somatosensory amplification also demonstrated a substantial positive correlation (r=0.61, p<0.001), underscoring the vital role of cognitive appraisal of bodily sensations in somatic distress. Conversely, adaptive dimensions of interoceptive sensitivity, such as self-regulation and body trusting, showed significant negative correlations with the PHQ-15, suggesting a protective mechanism. Table 2 delineates the descriptive statistics and the core correlational matrix for the primary study variables.

Table 2

Descriptive Statistics and Key Correlations with Somatic Symptom Severity (PHQ-15)

Variable	Mean (M)	Std. Dev (SD)	**1**	**2**	**3**	**4**
1. Somatic Symptoms (PHQ-15)	9.45	4.82	1.00			
2. Neuroticism (Total)	86.32	14.55	0.55^{**}	1.00		
3. Somatosensory Amplification	32.18	6.74	0.61^{**}	0.42^{**}	1.00	
4. Interoceptive Awareness	24.50	5.30	-0.38^{**}	-0.29^{**}	-0.15^{*}	1.00

To transition from bivariate associations to complex predictive modeling, three prominent machine learning algorithms—Random Forest, Gradient Boosting, and eXtreme Gradient Boosting (XGBoost)—were trained and evaluated on the 20%hold-out testing set (n=169). The objective was to classify individuals at high risk for Somatic Symptom Disorder based on the aggregated psychological and sensory profiles. Hyperparameter tuning was rigorously conducted using grid search with five-fold cross-validation on the training set to optimize each algorithm. The comparative performance metrics on the unseen test data revealed that all models performed adequately, but the XGBoost algorithm achieved superior predictive capability across all evaluated domains. Specifically, the XGBoost model yielded the highest classification accuracy at 87.57%and an exceptional Area Under the Receiver Operating Characteristic Curve (AUC) of 0.91, indicating robust discriminatory power between individuals with and without significant somatic symptom burden. Gradient Boosting followed closely, while the Random Forest model, though highly precise, exhibited slightly lower recall, suggesting a higher rate of false negatives. The comprehensive performance metrics for all three algorithms are cataloged in Table 3.

Table 3

Machine Learning Model Performance Comparison for Predicting Somatic Symptom Disorder

Model	Accuracy (%)	Precision	Recall	F1-Score	AUC
Random Forest	83.43	0.82	0.79	0.80	0.86
Gradient Boosting	85.20	0.85	0.83	0.84	0.88
XGBoost	87.57	0.88	0.87	0.87	0.91

Because the XGBoost model demonstrated the highest predictive efficacy, it was subsequently subjected to SHapley Additive exPlanations (SHAP) to unpack the “black box” of the algorithm and determine the relative importance and directional impact of each specific psychological facet. The SHAP analysis provided a mathematically rigorous calculation of each feature’s marginal contribution to the model’s predictions. The global explainability results highlighted that Somatosensory Amplification was the single most dominant predictor of Somatic Symptom Disorder, possessing the highest mean absolute SHAP value. Following closely were specific facets of neuroticism rather than the aggregate score; notably, the Anxiety and Vulnerability facets were powerful drivers, substantially increasing the probability of a positive classification for the disorder when their scores were elevated. Interestingly, the MAIA subscale of “Not-Worrying” (the ability to not experience emotional distress with physical discomfort) emerged as a critical negative predictor, meaning that lower scores on this facet heavily contributed to the presence of somatic symptoms. Table 4 ranks the top predictors based on their mean absolute SHAP values, offering a transparent view into the cognitive and sensory architecture driving the machine learning model’s predictive success.

Table 4

SHAP Explainability: Top Predictors Ranked by Mean Absolute SHAP Value

Rank	Predictor Feature	Mean | ***SHAP*** |Value	Direction of Impact	Role
1	Somatosensory Amplification	+1.42	Positive	Risk Factor
2	Anxiety (Neuroticism Facet)	+1.18	Positive	Risk Factor
3	Vulnerability (Neuroticism Facet)	+0.95	Positive	Risk Factor
4	Not-Worrying (Interoception)	−0.88	Negative	Protective Factor
5	Body Trusting (Interoception)	−0.62	Negative	Protective Factor

4. Discussion and Conclusion

The present study aimed to elucidate the complex, non-linear predictive architecture of Somatic Symptom Disorder by deploying advanced, explainable machine learning techniques to analyze the relative contributions of neuroticism facets, somatosensory amplification, and interoceptive sensitivity. By utilizing an eXtreme Gradient Boosting (XGBoost) algorithm coupled with SHapley

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Additive exPlanations (SHAP), the analysis successfully transitioned beyond traditional linear modeling to uncover the granular cognitive and sensory drivers of somatic distress. The findings revealed that the XGBoost model achieved exceptional predictive efficacy, with an accuracy of 87.57%and an Area Under the Curve (AUC) of 0.91, robustly differentiating individuals with high somatic symptom burdens from those with subclinical presentations. Most importantly, the SHAP analysis illuminated that rather than broad personality domains, specific cognitive-perceptual styles—namely, somatosensory amplification, the anxiety and vulnerability facets of neuroticism, and deficits in adaptive interoceptive awareness (specifically the "Not-Worrying" and "Body Trusting" dimensions)—were the paramount predictors of Somatic Symptom Disorder severity.

The emergence of somatosensory amplification as the single most powerful positive predictor of Somatic Symptom Disorder aligns with foundational psychopathological theories emphasizing the hyper-vigilant cognitive appraisal of bodily states. The SHAP global explainability metrics demonstrated a profound, directional impact where elevated tendencies to perceive normal somatic sensations as intense and noxious drastically increased the probability of somatic distress. This corroborates the conceptualization of somatosensory amplification as a critical magnifying mechanism that bridges benign physiological fluctuations and severe health anxiety (Köteles & Witthöft, 2017). When individuals habitually amplify internal "noise," they are significantly more susceptible to interpreting these sensations through a catastrophic lens. This perceptual distortion is frequently exacerbated by underlying psychosocial stressors and emotional dysregulation. Previous research has demonstrated that traits like alexithymia serve to link perceived psychosocial stress to somatic symptoms primarily through the conduit of somatosensory amplification (Nakao & Takeuchi, 2018). Furthermore, the amplification of somatic signals is not solely a cognitive error but is deeply intertwined with interpersonal functioning and historical emotional attachments. Studies have shown that attachment insecurity and related interpersonal problems significantly mediate the severity of somatosensory amplification, suggesting that relational distress often manifests as a heightened sensitivity to physical discomfort (Kealy et al., 2021).

Beyond somatosensory amplification, the machine learning model highlighted the critical necessity of deconstructing the broad trait of neuroticism into its constituent facets. While overall neuroticism has long been associated with somatic complaints, the SHAP analysis identified the specific facets of Anxiety, Vulnerability, and Depression as the primary drivers of somatic symptom severity. This finding supports recent qualitative and quantitative shifts in personality psychology that advocate for examining the distinct psychological and somatic dimensions of neuroticism to better capture its multidimensional etiology (Ahmadabadi, 2025). The prominent role of anxiety and vulnerability in our model suggests that the concomitant cognitive processes inherent to these traits—such as chronic worry and persistent rumination—are the actual catalysts that translate a generalized negative affect into localized somatic complaints (Denovan et al., 2018). This relationship is further complicated by self-regulatory beliefs. The interplay between high neuroticism (specifically its anxiety facet) and low self-efficacy has been shown to drastically increase pain catastrophizing, a cognitive distortion that directly fuels the chronicity of Somatic Symptom Disorder (Sayed Alitabar & Goli, 2023). By identifying these specific facets, our model clarifies that it is the anticipatory dread and perceived inability to cope with stressors, rather than mere emotional volatility, that predisposes individuals to somatic symptom amplification.

Conversely, the multidimensional assessment of interoceptive sensitivity revealed critical protective factors against the development of Somatic Symptom Disorder. The SHAP analysis identified the "Not-Worrying" subscale—defined as the ability to not experience severe emotional distress when experiencing physical discomfort—as the strongest negative predictor of somatic burden. Lower scores on this adaptive interoceptive facet strongly predicted a positive classification for the disorder. Similarly, "Body Trusting," or the experience of one's body as safe and trustworthy, emerged as a vital buffer. These findings underscore the profound impact of interoceptive awareness on mitigating pain catastrophizing and correcting maladaptive illness perceptions (Hooshmandi et al., 2023; Hooshmandi et al., 2024). Individuals with Somatic Symptom Disorder consistently exhibit deficits in interoceptive accuracy, particularly when their cognitive processing is hijacked by emotional interference (Lee et al., 2024). The ability to sit with physical discomfort without immediately assigning catastrophic clinical meaning to it is a hallmark of adaptive interoception. The literature heavily supports this, noting that getting comfortable with physical discomfort through targeted interoceptive exposure is highly efficacious in treating both physical and mental health conditions characterized by somatic hyper-focus (Farris et al., 2025).

The transdiagnostic relevance of these sensory and cognitive mechanisms provides a broader context for our findings. The interplay between internal bodily signals and emotional regulation is a fundamental aspect of human psychology, observed across varying clinical and non-clinical populations. For instance, strong interoceptive abilities are crucial for emotional state regulation during stress and recovery in healthy adolescents, indicating that interoceptive competence is a foundational developmental milestone (Braet & Braet, 2024). When this interoceptive integration fails, it often leads to diverse psychopathological manifestations. Deficits in interoceptive capabilities are deeply embedded in the pathophysiology of severe eating disorders, such as Avoidant/Restrictive Food Intake Disorder and Anorexia Nervosa, where the perception of hunger and satiety signals is profoundly distorted (Datta & Lock, 2023). Even in subclinical populations, maladaptive interoceptive awareness acts as a primary mediator for behaviors like emotional eating, heavily influencing how emotional distress is misattributed to physical appetite (Bullock & Goldbacher, 2023). By positioning Somatic Symptom Disorder within this broader literature, our explainable machine learning model confirms that the disorder is fundamentally an pathology of sensory integration and cognitive appraisal, where the failure to accurately interpret and tolerate internal signals leads to a cascading cycle of somatic amplification and neurotic distress.

Despite the robust predictive capabilities of the machine learning algorithms and the novel insights provided by the SHAP analysis, several limitations must be acknowledged when interpreting the results of this study. First, the cross-sectional nature of the research design precludes the establishment of definitive causal relationships between the psychological predictors and Somatic Symptom Disorder. While the predictive model strongly suggests that somatosensory amplification and specific neuroticism facets drive somatic distress, it is equally plausible that the chronic experience of unexplained physical symptoms exacerbates anxiety, heightens vulnerability, and further degrades interoceptive trust, creating a bidirectional feedback loop. Second, the reliance on self-report psychometric instruments introduces the potential for common method bias and socially desirable responding. Individuals with severe somatic symptom burdens may lack the objective self-awareness required to accurately report their levels of somatosensory amplification or interoceptive deficits, potentially skewing the data. Finally, while the sample was adequately powered and diverse, it was drawn entirely from the Malaysian population using convenience and snowball sampling. This geographical and methodological constraint may limit the cross-cultural generalizability of the findings, as cultural idioms of distress significantly influence how physical symptoms are perceived, reported, and conceptualized in different societies.

To address these limitations and build upon the current findings, future research should prioritize longitudinal and prospective study designs. Tracking cohorts over extended periods would allow researchers to determine the temporal precedence of sensory amplification and interoceptive deficits in the onset of somatic symptom disorders, thereby clarifying causality. Furthermore, future investigations should integrate objective, physiological biomarkers of interoception and autonomic nervous system functioning—such as heart rate variability, electroencephalography (EEG), and functional magnetic resonance imaging (fMRI)—to complement self-report data. Combining behavioral tasks of interoceptive accuracy, such as heartbeat tracking or respiratory resistance paradigms, with the subjective measures used in this study would provide a much more comprehensive and empirically rigid assessment of sensory processing. Additionally, implementing Ecological Momentary Assessment (EMA) via smartphone applications could capture real-time, real-world fluctuations in physical symptoms, anxiety, and bodily awareness, overcoming the recall bias inherent in retrospective questionnaires and providing a massive, high-resolution dataset ideally suited for the ongoing refinement of machine learning predictive models.

The clinical implications derived from this explainable machine learning analysis offer highly actionable insights for the treatment and management of Somatic Symptom Disorder. The identification of somatosensory amplification and the "Not-Worrying" interoceptive facet as primary drivers suggests that therapeutic interventions must move beyond general anxiety reduction and directly target sensory appraisal mechanisms. Cognitive Behavioral Therapy (CBT) protocols should be explicitly tailored to challenge the catastrophic misinterpretation of benign physical sensations, utilizing psychoeducation to normalize somatic "noise." More critically, the results strongly advocate for the integration of interoceptive exposure therapies into standard

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clinical practice. By systematically and safely exposing patients to feared physical sensations (e.g., induced hyperventilation, spinning to cause dizziness, or physical exertion), clinicians can help patients build tolerance to physiological discomfort, effectively increasing their "Not-Worrying" capacity and rebuilding "Body Trusting." Furthermore, mindfulness-based somatic therapies that focus on non-judgmental present-moment awareness of the body can directly dismantle the somatosensory amplification process. Finally, utilizing individualized SHAP profiles in clinical settings could pave the way for precision psychiatry; clinicians could assess a patient's specific predictive feature map and design a bespoke treatment plan that directly targets their unique vulnerabilities, whether that be a specific anxiety facet, a deficit in bodily trust, or overwhelming sensory amplification.

Authors' Contributions

Authors contributed equally to this article.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethics Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

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