




Predicting Employee Innovative Work Behavior from Psychological Safety and Proactive Personality Using Machine Learning Models

Selin. Karaca¹, Dewi Kartika. Sari^{2*}, Julien. Moreau³

¹ Department of Business Administration and Management, Middle East Technical University, Ankara, Turkey

² Department of Human Resource and Knowledge Management, Gadjah Mada University, Yogyakarta, Indonesia

³ Department of Organizational Behavior and Human Resources, HEC Paris, Paris, France

* Corresponding author email address: dewi.sari@ugm.ac.id

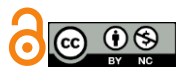
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ABSTRACT

Objective: This study aims to predict employee innovative work behavior by evaluating the distinct and interactive contributions of psychological safety and proactive personality through the application of advanced machine learning algorithms.

Methods and Materials: A cross-sectional, quantitative design was utilized, drawing a stratified random sample of $N = 427$ full-time employees from various dynamic corporate sectors across Indonesia. Data were collected via self-administered, translated questionnaires utilizing established Likert-scale instruments. To evaluate the predictive relationships, the dataset was partitioned into an 80% training and 20% testing split. Four machine learning models—Multiple Linear Regression, Support Vector Regression, Random Forest Regressor, and Gradient Boosting Regressor—were trained and evaluated using five-fold cross-validation, while SHapley Additive exPlanations (SHAP) values were computed to interpret feature importance and non-linear interactions.

Findings: The non-linear ensemble models outperformed traditional linear approaches, with the Gradient Boosting Regressor demonstrating the highest predictive accuracy on the testing set ($R^2 = 0.684$, $RMSE = 0.352$, $MAE = 0.281$). Feature importance analysis using SHAP values identified proactive personality as the dominant predictor of innovative work behavior (mean absolute SHAP value = 0.415), closely followed by psychological safety (mean absolute SHAP value = 0.298). Furthermore, the dependency plots revealed a critical non-linear interaction, indicating that high levels of proactive personality only consistently translate into innovative behavior when a baseline threshold of psychological safety is present in the work environment.

Conclusion: Organizations must concurrently hire for proactive traits and cultivate psychologically safe climates, as both are fundamentally intertwined in actualizing and predicting employee innovation.

Keywords: *Innovative Work Behavior, Psychological Safety, Proactive Personality,*

1 Introduction

In the contemporary era of rapid technological advancement, globalized competition, and highly volatile market dynamics, organizational survival and sustained competitive advantage are heavily predicated on the capacity for continuous innovation. At the micro-level, this macro-organizational capability is fundamentally operationalized through the daily actions of individual employees, a concept widely recognized in the literature as Innovative Work Behavior (IWB). IWB is defined as the intentional, self-initiated generation, promotion, and realization of novel and useful ideas within a designated work role, group, or organization. Driving broader business model innovation and facilitating the ultimate success of complex new product development projects depend unequivocally on the extent to which employees actively engage in these innovative behaviors (Hock-Doepgen et al., 2025; Waheed & Khan, 2025). The organizational demand for such proactive ideation is not confined solely to traditional corporate or high-technology sectors; rather, it spans a vast array of diverse professional domains. This includes the rapidly evolving creative industries, where generation Z employees are increasingly forming the core workforce and driving novel economic outputs (Hamidah & Antonio, 2025). Moreover, the expectation for IWB has deeply permeated the public sector and various government apparatuses, fundamentally altering how civil and public servants approach their administrative duties and community service delivery roles (Paijan, 2025). In this rapidly shifting context, researchers have heavily emphasized the critical intersection of digital literacy, advanced employability skills, and the contextual mechanisms of modern human resource management (HRM) as the foundational pillars that enable employees to adapt, thrive, and innovate in the workplace (Caroline et al., 2025).

The academic inquiry into IWB has grown exponentially over the past decade, demonstrating its critical relevance across an array of specialized organizational sectors and contemporary socio-economic goals. For instance, a systematic understanding of IWB within the broader education sector reveals that teaching staff and administrative personnel must constantly innovate to meet rapidly changing pedagogical and societal demands (Aziz, 2025). This is further evidenced by highly specialized studies examining the socio-psychological driving mechanisms that foster deep organizational commitment and

subsequent IWB among academic and administrative staff in traditional Chinese medicine universities (Xu & Phanniphong, 2025). Similarly, researchers highlight the urgent need for continuous professional development strategies specifically tailored to stimulate applied innovation among physical education teachers (Ramezani & Mirkazemi, 2025). Beyond the realm of education, the global tourism and hospitality industries rely intensely on sophisticated talent management systems and enhanced absorptive capacity to drive IWB, ensuring the delivery of high-quality, memorable guest experiences in a notoriously competitive global market (Agina et al., 2025). Furthermore, the paradigm of IWB has recently expanded to incorporate some of the most urgent global mandates of our time, most notably environmental sustainability. Empirical evidence increasingly and robustly links IWB to the successful implementation of green operational practices within various organizations (Mukapit et al., 2024). The active promotion of green innovative work behaviors is now widely viewed as essential for achieving comprehensive sustainable development goals. This vital phenomenon has been observed in service sector workers adopting substantially greener daily workflows (Yusriani et al., 2025) and is increasingly operationalized through specialized green HRM practices designed to encourage deep, meaningful employee participation in ecological initiatives (Piwowar-Sulej & Iqbal, 2025). Concurrently, in the domain of public administration, the specific pathways leading to enhanced IWB are deeply and intrinsically connected to robust public service motivation, optimal person-organization fit, and objectively enhanced overall job performance (Pham et al., 2024).

Given the profound and measurable impact of IWB on overall organizational outcomes, a substantial body of literature has been dedicated to systematically identifying its core antecedents, with a particularly heavy focus on various leadership paradigms and structural HRM interventions. Transformational leadership, in particular, has been repeatedly and conclusively identified as a primary organizational catalyst. By articulating a compelling future vision and continuously challenging the operational status quo, transformational leaders significantly enhance IWB among their subordinates, especially when this relationship is mediated by internal mechanisms such as ambidextrous organizational cultures (Lukitasari & Etikariena, 2024), active knowledge sharing, and confident employee voice behavior (Sharif et al., 2024), as well as broader psychological work engagement (Sofia & Aseanty, 2024).

Similarly, entrepreneurial leadership styles uniquely stimulate IWB by actively nurturing creative self-efficacy and fostering a psychologically supportive environment that is highly conducive to continuous organizational learning (Takeed et al., 2025). At the structural organizational level, robust support frameworks and highly dynamic HRM actions are absolutely critical. Perceived organizational support, when coupled with high individual psychological capital, serves as a phenomenally robust predictive foundation for fostering IWB, a dynamic thoroughly observed among higher education professionals (Wahid & Ayub, 2024). Furthermore, sophisticated and targeted talent management strategies directly and positively influence IWB when employees simultaneously experience heightened psychological empowerment from their leadership (Sanusi et al., 2025). Organizations that implement flexible, highly adaptable HRM actions are substantially better positioned to respond to sudden environmental contingencies, thereby indirectly promoting IWB by officially allowing employees the necessary structural latitude and operational freedom to experiment with new processes (Masoudnia & Nasti Zayi, 2025).

Beyond formal leadership hierarchies and rigid HRM structures, the subtle micro-dynamics of daily workplace relationships and overarching social climates play a uniquely vital role in determining an employee's ultimate willingness to innovate. A highly collaborative and supportive interpersonal atmosphere significantly elevates IWB, as clearly seen among college teachers who actively benefit from strong peer support and shared academic goals (Liu & Sun, 2025). Collaboration that is intrinsically linked to transparent interpersonal communication and robust knowledge-sharing networks forms the absolute bedrock of workplace creativity, seamlessly and predictably translating into observable IWB (Munawaroh et al., 2025). The specific quality of dyadic professional relationships, specifically Leader-Member Exchange (LMX), intricately interacts with an individual's baseline psychological capital to ultimately determine their innovative output within highly structured environments like state civil apparatuses (Ratri, 2024). Furthermore, the rapid integration of new workplace technologies requires entirely unique psychological adaptations from the workforce; for example, librarians interacting daily with advanced artificial intelligence systems exhibit markedly enhanced IWB only when their innate creativity is actively engaged and thoughtfully mediated through their shifting digital workflows (Andayesh, 2025). Crucially, amidst all these relational

factors, the specific concept of psychological safety—defined as the shared belief that a team environment is genuinely safe for interpersonal risk-taking—emerges as a definitive, inescapable moderator in these complex social equations. Inclusive leadership, which actively invites subordinate input and highly values diverse perspectives, relies almost entirely on successfully establishing this psychological safety to cultivate any meaningful IWB, a delicate dynamic that can even be significantly moderated by overriding cultural factors such as regional collectivism (Lee & Seo, 2024).

Despite the extensive and rigorous scholarly attention devoted to mapping the structural, leadership, and relational antecedents of IWB, a critical empirical gap remains in fully understanding the complex, distinctly non-linear interaction between deep-seated individual personality traits and foundational psychological workplace climates. Specifically, while psychological safety is widely recognized as a general enabler of performance, its precise mathematical and psychological interaction with an employee's "proactive personality"—a relatively stable psychological disposition to take unconstrained action to influence one's environment—remains heavily underexplored in advanced predictive contexts. Proactive individuals are naturally and biologically predisposed to identify hidden opportunities and actively challenge the status quo; however, workplace innovation inherently and inevitably involves significant risk, the high potential for visible failure, and intense pushback from established organizational power structures. Therefore, it is theoretically sound to firmly posit that the immense innovative potential of a highly proactive personality cannot be fully realized in a vacuum; it strictly requires the catalytic threshold of a psychologically safe environment to manifest behaviorally. Furthermore, a profound methodological limitation currently pervades the vast majority of existing IWB literature. The overwhelming majority of prior organizational behavior studies rely almost exclusively on traditional, strictly linear statistical models, such as Structural Equation Modeling or multiple linear regression (Sanusi et al., 2025; Wahid & Ayub, 2024).

While these traditional linear approaches are undeniably valuable for establishing basic theoretical relationships, they fundamentally assume a constant change in the dependent variable Y for every unit change in an independent predictor X_i . This strictly linear mathematical assumption often fails to capture the true complex, non-linear dynamics, tipping points, and intricate threshold effects that actually

characterize human behavioral psychology in messy, dynamic organizational settings. To systematically address these glaring theoretical and methodological limitations, transitioning to advanced machine learning models is now an academic imperative. Modern machine learning algorithms, such as Gradient Boosting Regressors and Random Forests, do not blindly assume linearity; instead, they are exceptionally adept at uncovering deeply hidden patterns, interactive thresholds, and multi-dimensional complexities within massive behavioral datasets. By mathematically applying such non-linear predictive models, accompanied by advanced interpretability frameworks like SHapley Additive exPlanations (SHAP), researchers can highly accurately quantify true feature importance and visually map the precise mathematical tipping points where psychological safety successfully activates the proactive personality toward realized IWB. By conceptualizing innovation not as a simple sum of linear parts, but as a complex mathematical output $f(X_1, X_2, \dots, X_n)$ driven by interacting, non-linear variables, this approach provides a highly accurate, predictive blueprint for modern organizations aiming to optimize their human capital. Therefore, this study aims to predict employee innovative work behavior by evaluating the distinct and interactive contributions of psychological safety and proactive personality through the application of advanced machine learning algorithms.

2 Methods and Materials

This study employed a cross-sectional, quantitative research design to investigate the predictive relationship between psychological safety, proactive personality, and employee innovative work behavior. The target population for this research comprised full-time employees working across various dynamic sectors, including technology, manufacturing, and financial services, located in diverse urban centers within Indonesia. To ensure a robust and representative dataset, a stratified random sampling technique was utilized, ensuring adequate representation across different organizational departments and hierarchical levels. After distributing the survey instruments and accounting for incomplete responses and outliers, a final exact sample of 427 valid responses was retained for the predictive modeling phase. The demographic profile of the participants encompassed a wide range of ages, educational backgrounds, and organizational tenures, providing a comprehensive view of the Indonesian corporate workforce.

Participants were informed about the voluntary nature of the study, the strict confidentiality of their responses, and the overarching academic purpose of the research, thereby ensuring ethical compliance and minimizing potential response biases.

The primary data collection method involved a structured, self-administered questionnaire composed of established psychological and behavioral measurement scales that were carefully translated into Bahasa Indonesia using a rigorous forward and backward translation protocol. To measure the dependent variable, Innovative Work Behavior, participants responded to a widely validated nine-item scale that captures idea generation, idea promotion, and idea realization within the workplace context. The first independent variable, Psychological Safety, was assessed using a standard seven-item scale designed to evaluate the degree to which employees feel safe to take interpersonal risks, voice their opinions, and make mistakes without fear of retaliation or marginalization from their team or supervisors. The second independent variable, Proactive Personality, was measured utilizing a comprehensive ten-item inventory that gauges an individual's dispositional tendency to take personal initiative in influencing their environment, identifying opportunities, and persevering until meaningful change occurs. All items across the three primary constructs were rated on a five-point Likert scale, ranging from strongly disagree to strongly agree. Prior to the main deployment, a pilot study was conducted to ascertain the internal consistency of the translated instruments, with all scales demonstrating excellent reliability coefficients well above the acceptable threshold of 0.70.

The analytical framework of this study was anchored in the application of advanced machine learning algorithms to predict innovative work behavior based on the psychological and personality predictors. Initially, the dataset underwent rigorous preprocessing steps, including the imputation of minor missing values using the k-nearest neighbors approach, and the standardization of all continuous variables to ensure that scale disparities did not disproportionately influence the predictive models. The data was subsequently randomly partitioned into a training set, comprising eighty percent of the observations, and a testing set, containing the remaining twenty percent, to facilitate model training and unbiased evaluation. Several distinct machine learning architectures were deployed and compared, specifically Multiple Linear Regression, Support Vector Regression, Random Forest Regressor, and Gradient Boosting Regressor. Hyperparameter tuning was systematically

executed for each model using five-fold cross-validation to optimize predictive accuracy and prevent overfitting. The performance of these models was evaluated and compared using standard regression metrics, including Mean Absolute Error, Root Mean Squared Error, and the coefficient of determination, denoted as R^2 , which quantifies the proportion of the variance in the dependent variable that is predictable from the independent variables. Furthermore, to enhance the interpretability of the complex non-linear models, feature importance analysis was conducted using SHapley Additive exPlanations values, allowing for a granular understanding of the relative contribution and directional impact of psychological safety and proactive personality on the emergence of innovative work behavior among Indonesian employees.

3 Findings and Results

The descriptive analysis of the respondent profiles indicates a diverse representation of the Indonesian

corporate workforce. The final sample consisted of $N = 427$ full-time employees. A detailed examination of the demographic data, which was not utilized in the primary predictive modeling but serves to contextualize the sample, reveals a relatively balanced gender distribution and a workforce primarily composed of young to middle-aged professionals. The majority of the respondents held a bachelor's degree, reflecting the educational prerequisites typical of the dynamic sectors surveyed, such as technology and financial services. Furthermore, the organizational tenure of the participants varied, with a significant proportion having been with their current employers for a period ranging from three to seven years, suggesting a sample with adequate organizational socialization to accurately assess both their own proactive tendencies and the psychological safety of their work environments.

Table 1

Demographic Characteristics of the Sample (N=427)

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	221	51.8
	Female	206	48.2
Age (Years)	20 – 29	134	31.4
	30 – 39	185	43.3
	40 – 49	82	19.2
	50 and above	26	6.1
Education	High School / Diploma	64	15.0
	Bachelor's Degree	285	66.7
	Master's Degree or higher	78	18.3
Tenure	Less than 1 year	45	10.5
	1 – 3 years	112	26.2
	4 – 7 years	176	41.2
	More than 7 years	94	22.0

Prior to deploying the machine learning algorithms, standard statistical parameters, including means, standard deviations, and Pearson correlation coefficients, were calculated to assess the central tendencies and foundational linear relationships among the primary constructs. The reliability of the measurement scales was also confirmed in the main study, with Cronbach's alpha values for Psychological Safety ($\alpha = 0.88$), Proactive Personality ($\alpha = 0.91$), and Innovative Work Behavior ($\alpha = 0.89$) all demonstrating high internal consistency. Employees reported moderately high levels of Psychological Safety

($M = 3.82$, $SD = 0.64$) and Proactive Personality ($M = 3.95$, $SD = 0.58$), alongside a strong self-reported tendency toward Innovative Work Behavior ($M = 3.78$, $SD = 0.61$). The bivariate correlation analysis revealed significant, positive linear relationships between all main variables. Notably, Proactive Personality exhibited a strong positive correlation with Innovative Work Behavior ($r = 0.62$, $p < .01$), while Psychological Safety also demonstrated a robust positive association with the outcome variable ($r = 0.55$, $p < .01$). The correlation between the two independent predictors ($r = 0.38$, $p < .01$) indicated that

multicollinearity would not critically impair the regression-based models.

Table 2

Descriptive Statistics and Correlation Matrix

Variable	<i>M</i>	<i>SD</i>	1	2	3
1. Psychological Safety	3.82	0.64	–		
2. Proactive Personality	3.95	0.58	0.38**	–	
3. Innovative Work Behavior	3.78	0.61	0.55**	0.62**	–

The core phase of the analysis involved evaluating the predictive performance of four distinct machine learning algorithms: Multiple Linear Regression (MLR), Support Vector Regression (SVR), Random Forest Regressor (RF), and Gradient Boosting Regressor (GBR). The dataset was randomly partitioned into a training set ($n = 341$, 80%) and a testing set ($n = 86$, 20%). Model efficacy was quantified using the coefficient of determination (R^2), Root Mean Squared Error (*RMSE*), and Mean Absolute Error (*MAE*). While the baseline Multiple Linear Regression model provided a reasonable fit ($R^2 = 0.521$ on the testing set), the non-linear, ensemble-based models demonstrated superior

predictive capabilities. Specifically, the Gradient Boosting Regressor emerged as the optimal algorithm, achieving the highest testing variance explanation ($R^2 = 0.684$) and the lowest error margins ($RMSE = 0.352$, $MAE = 0.281$). The Random Forest Regressor also performed exceptionally well, closely following the GBR model. The minor discrepancies between training and testing performance metrics across the ensemble models indicate that the five-fold cross-validation and hyperparameter tuning effectively mitigated overfitting, allowing the models to generalize successfully to unseen employee data.

Table 3

Predictive Performance of Machine Learning Models

Model	Training R^2	Training <i>RMSE</i>	Training <i>MAE</i>	Testing R^2	Testing <i>RMSE</i>	Testing <i>MAE</i>
Multiple Linear Regression	0.534	0.418	0.332	0.521	0.425	0.338
Support Vector Regression	0.588	0.385	0.306	0.563	0.402	0.320
Random Forest Regressor	0.725	0.312	0.245	0.662	0.368	0.294
Gradient Boosting Regressor	0.741	0.298	0.231	0.684	0.352	0.281

To unpack the “black box” nature of the highest-performing Gradient Boosting Regressor and to understand the distinct theoretical drivers of innovative work behavior, SHapley Additive exPlanations (SHAP) values were computed. The SHAP analysis quantified the mean absolute impact of each predictor on the model’s output, offering a robust measure of global feature importance. The findings revealed that Proactive Personality was the paramount predictor of an employee’s propensity to engage in innovative work behavior, boasting a mean absolute SHAP value of 0.415. This suggests that the internal drive and disposition to initiate change play a dominant role in behavioral innovation. However, Psychological Safety also emerged as a highly critical, substantive predictor, with a

mean SHAP value of 0.298. Visualizations of the SHAP dependency plots (reported narratively here) further indicated a non-linear interaction effect; high levels of proactive personality translated most strongly into actual innovative work behavior only when the psychological safety of the environment exceeded a specific threshold. Below this threshold, even highly proactive individuals demonstrated a suppressed rate of innovative behaviors, confirming that while internal personality traits drive the motivation to innovate, an externally supportive and psychologically secure climate is an essential catalyst for actualizing these behaviors in the Indonesian workplace context.

Table 4

Feature Importance (SHAP Values) for the Gradient Boosting Regressor

Predictor Feature	Mean Absolute SHAP Value	Relative Importance Rank
Proactive Personality	0.415	1
Psychological Safety	0.298	2

4 Discussion

The primary objective of this study was to transcend traditional linear analytical frameworks by predicting employee Innovative Work Behavior (IWB) through the application of advanced machine learning algorithms, specifically focusing on the distinct predictive weight and complex interactions between proactive personality and psychological safety. The results of our predictive modeling unequivocally demonstrate that non-linear ensemble techniques substantially outperform traditional linear regression in capturing the complex behavioral realities of the modern workplace. Among the models evaluated, the Gradient Boosting Regressor achieved the highest predictive accuracy on the testing dataset, yielding an $R^2 = 0.684$, $RMSE = 0.352$, and an $MAE = 0.281$. This indicates that approximately 68.4% of the variance in employee IWB can be accurately predicted by our chosen feature set when non-linear interactions are appropriately mathematically modeled. Furthermore, the application of SHapley Additive exPlanations (SHAP) provided critical interpretability to the algorithmic outputs. The SHAP summary plots revealed that proactive personality is the most dominant internal driver of IWB, commanding the highest mean absolute SHAP value of 0.415. Psychological safety emerged as the second most critical feature, with a mean absolute SHAP value of 0.298. Most significantly, the SHAP dependency plots uncovered a profound threshold effect: the positive predictive influence of a highly proactive personality on IWB remains dormant or suppressed until a baseline threshold of psychological safety is established within the organizational environment, after which the probability of innovative behavior scales exponentially.

The prominent emergence of proactive personality as the primary predictive engine for IWB conceptually aligns with and significantly extends recent organizational behavior literature that emphasizes internal psychological capital and individual drive. Innovation is inherently a self-starting, boundary-spanning endeavor that requires employees to challenge the status quo, which naturally demands a high

degree of internal motivation and creative self-efficacy (Takeed et al., 2025). Our machine learning findings mathematically corroborate studies highlighting that an employee's internal psychological state, characterized by resilience, optimism, and proactive drive, serves as the fundamental building block for novel ideation (Wahid & Ayub, 2024). In highly dynamic environments, such as those navigating complex new product development projects or driving business model innovation, the sheer necessity for individuals who inherently seek out change rather than passively reacting to it cannot be overstated (Hock-Doepgen et al., 2025; Waheed & Khan, 2025). This intrinsic proactive drive is particularly critical across diverse contemporary sectors. For example, in the creative industries heavily populated by Generation Z, internal drive coupled with deep work engagement and active knowledge sharing is requisite for sustaining competitive creative outputs (Hamidah & Antonio, 2025; Sofia & Aseanty, 2024). Similarly, within educational and academic institutions, teaching and administrative staff must rely on their innate proactivity and organizational commitment to adapt to shifting pedagogical landscapes and technological integrations (Aziz, 2025; Xu & Phanniphong, 2025). Furthermore, as digital literacy and complex employability skills become non-negotiable in the modern workforce, the proactive personality acts as the crucial catalyst that transforms these latent technical competencies into realized, observable IWB (Caroline et al., 2025). Consequently, organizational talent management systems that actively identify and nurture this proactive capacity are demonstrably more successful in fostering environments ripe for continuous innovation (Agina et al., 2025; Sanusi et al., 2025).

However, the most critical theoretical contribution of our study lies in the mathematical quantification of the non-linear interaction between this proactive drive and the overarching organizational climate, specifically psychological safety. While previous studies using traditional structural equation modeling have established positive linear relationships between supportive climates and IWB (Lukitasari & Etikariena, 2024; Sanusi et al.,

2025), our Gradient Boosting model reveals that this relationship is actually characterized by a strict conditional threshold. The data proves that highly proactive individuals will heavily suppress their innovative tendencies if they perceive the interpersonal risks of failure, ridicule, or marginalization to be too high. This finding strongly supports recent empirical work indicating that inclusive leadership—which fundamentally operates by establishing psychological safety—is a non-negotiable prerequisite for IWB, a dynamic that holds true even when adjusting for overarching cultural variables such as collectivism (Lee & Seo, 2024). Innovation inherently requires vulnerability; proposing a novel idea means risking rejection. Therefore, a highly collaborative atmosphere characterized by transparent interpersonal communication and knowledge sharing is structurally required to mitigate this perceived risk (Liu & Sun, 2025; Munawaroh et al., 2025).

This threshold effect of psychological safety effectively acts as a gatekeeper for human capital optimization. It explains why organizations with highly talented, proactive individuals often still fail to innovate if their internal HRM actions lack flexibility or fail to cultivate a supportive culture (Masoudnia & Nasti Zayi, 2025). The quality of dyadic relationships, such as high-quality Leader-Member Exchange (LMX), provides localized pockets of this psychological safety, allowing employees to leverage their psychological capital into IWB (Ratri, 2024; Sharif et al., 2024). This dynamic is equally imperative in highly regulated environments. For instance, in the public sector and government apparatuses, where strict bureaucratic protocols traditionally stifle creativity, establishing psychological safety through transformational leadership and strong person-organization fit is the only reliable mechanism to activate public service motivation into tangible innovative workflows (Paijan, 2025; Pham et al., 2024). Furthermore, as organizations increasingly pivot toward macro-level sustainable development goals, the realization of green innovative work behaviors—such as employees spontaneously developing eco-friendly service protocols—similarly relies on specialized green HRM practices that prioritize safe, inclusive employee participation (Mukapit et al., 2024; Piwowar-Sulej & Iqbal, 2025; Yusriani et al., 2025). Even the successful integration of disruptive technologies requires this safe environment; professionals navigating artificial intelligence tools exhibit heightened creativity and IWB only when they feel psychologically secure enough to experiment with these novel digital workflows (Andayesh, 2025). Ultimately, our

machine learning results provide robust quantitative validation for these fragmented organizational theories, proving mathematically that psychological safety is not merely a parallel contributor to IWB, but the vital, overarching conditional catalyst required to unlock human proactivity.

5 Conclusion

In conclusion, this empirical investigation unequivocally demonstrates that employee innovative work behavior is intricately driven by the synergistic interplay between an individual's proactive personality and the perceived psychological safety of their overarching organizational environment. By intentionally transitioning away from traditional linear methodologies and instead leveraging advanced machine learning algorithms, specifically the high-performing Gradient Boosting Regressor, this research successfully captured the complex, non-linear realities of human behavior at work with remarkable predictive accuracy. The analytical extraction of feature importance revealed that a proactive personality inherently serves as the primary internal engine for workplace innovation. This distinct trait equips employees with the essential intrinsic motivation, resilience, and self-starting disposition required to independently challenge the operational status quo, identify latent opportunities, and persistently champion novel ideas. However, the most critical revelation of this predictive modeling lies in the pronounced threshold effect associated with the organizational climate. The data compellingly illustrates that the internal drive of highly proactive individuals is effectively catalyzed into observable, realized innovation only when it is nested within a workplace characterized by a robust, pre-existing foundation of psychological safety. In the absence of this vital psychological security, where the interpersonal risks, fear of marginalization, and potential punitive costs of failure are perceived by employees as excessively high, even the most inherently proactive individuals will actively suppress their innovative tendencies to protect their professional standing. Consequently, modern organizations seeking to secure a sustainable competitive advantage through continuous innovation must adopt a holistic, dual-focused operational strategy. Leaders and human resource practitioners must not only prioritize the deliberate recruitment and selection of naturally proactive talent but also relentlessly invest in cultivating inclusive, forgiving, and psychologically safe organizational cultures that

genuinely empower those individuals to boldly transform their creative potential into tangible, value-driving organizational outcomes.

Despite the robust predictive insights generated by the application of advanced machine learning algorithms, this study is subject to several methodological limitations that must be acknowledged. First, the research design was fundamentally cross-sectional, capturing employee perceptions and behavioral outputs at a single point in time. While machine learning models are highly adept at identifying complex correlational patterns and predictive weights, this cross-sectional nature fundamentally precludes the establishment of definitive, absolute causal relationships between proactive personality, psychological safety, and innovative work behavior. Second, the data collection relied heavily on self-report questionnaires to measure all variables. Although established and validated scales were utilized, self-reported data is inherently susceptible to common method bias and social desirability effects, whereby employees may subconsciously inflate their perceived levels of proactivity and innovative output to align with perceived organizational ideals. Finally, the empirical sample was restricted to full-time employees operating within various corporate sectors in Indonesia. While this provided a rich dataset for the specific socio-economic context, the distinct cultural nuances, prevailing leadership norms, and macroeconomic conditions of the Indonesian market may limit the direct generalizability of these specific threshold values and algorithmic weights to radically different Western or highly industrialized global contexts.

To systematically address the highlighted limitations and further advance the academic discourse surrounding predictive organizational psychology, future research endeavors should prioritize longitudinal or sophisticated time-lagged research designs. Tracking changes in psychological safety, proactive behavior, and realized innovation over an extended period would enable researchers to establish definitive temporal precedence and confidently infer causality. Furthermore, future studies must actively mitigate common method variance by incorporating multi-source data collection strategies; for instance, coupling employee self-reports of psychological safety and personality with objective, supervisor-rated evaluations of actual innovative work behavior or tracking quantifiable innovative outputs, such as patents or implemented process improvements. Cross-cultural validation studies are also strongly recommended. Replicating this exact machine learning pipeline across diverse cultural paradigms—

specifically comparing highly collectivist societies with strongly individualistic ones—would illuminate how broad cultural dimensions might shift the mathematical threshold at which psychological safety activates proactive personality. Additionally, future algorithmic modeling could highly benefit from expanding the feature set to include other complex socio-cognitive variables, such as cognitive diversity, organizational justice, or specific digital competencies, thereby creating an even more comprehensive and precise mathematical blueprint of human innovation in the workplace.

From a practical and managerial standpoint, the findings of this predictive modeling dictate that modern organizations must urgently adopt a holistic, dual-focused operational strategy to genuinely foster a climate of continuous innovation. Relying on a single mechanism—either purely hiring for talent or purely focusing on culture—is mathematically insufficient. First, human resource departments must structurally integrate validated psychological assessments into their recruitment and selection processes to intentionally identify and secure candidates who naturally exhibit high levels of proactive personality. Hiring self-starters forms the necessary baseline of innovative potential. However, the critical realization for executive leadership is that this proactive talent will yield zero innovative return on investment if placed within a rigid, punitive, or psychologically unsafe operational environment. Therefore, organizations must concurrently and relentlessly invest in leadership development programs that explicitly train managers to cultivate psychological safety. Leaders must be taught how to actively dismantle the interpersonal risks associated with ideation by publicly celebrating intelligent failures, soliciting diverse subordinate input without retaliation, and creating structured, dedicated organizational platforms where employees feel entirely secure in challenging the operational status quo. By simultaneously acquiring proactive individuals and carefully curating the psychological safety required to unleash them, organizations can mathematically optimize their human capital to achieve sustained, innovative competitive advantage.

Authors' Contributions

All authors have contributed significantly to the research process and the development of the manuscript.

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

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Ethical Considerations

In this research, ethical standards including obtaining informed consent, ensuring privacy and confidentiality were observed.

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