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AI Challenge Awareness and Proactive Innovation Behavior Among Employees in Smart Manufacturing: The Chain Mediation Effects of Harmonious Passion and Approach-Oriented Resources Crafting

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Abstract

Artificial intelligence (AI) technology has become deeply integrated into the smart manufacturing sector, and fostering employees' proactive innovation behavior has become crucial for smart manufacturing enterprises to adapt to the changing times and enhance their core competitiveness. To reveal the formation mechanism of employees' proactive innovation behavior-from cognition to motivation and then to action-under the context of human-AI collaboration, this study, based on Cognitive Evaluation Theory and Resource Dependence Theory, explores the mechanism through which AI challenge awareness influences employees' proactive innovation behavior in the smart manufacturing sector and tests the chained mediating effects of harmonious passion and approach-oriented resource crafting. Through an analysis of survey data from 449 employees in the smart manufacturing sector, the results reveal a significant positive correlation between AI challenges awareness and employees' proactive innovation behavior; employees' harmonious passion and approach-oriented resource crafting play a chained mediating role between the perception of AI challenges and employees' proactive innovation behavior. The findings of this study provide new insights and practical management implications for managers seeking to foster proactive innovation behavior among employees in the smart manufacturing sector within the context of digital and intelligent transformation.

Keywords: *Caffeine Intake; Caffeinated Beverages; Sleep Quality; Pittsburgh Sleep Quality Index; Decision Tree; Students; Cross-Sectional Study*

Introduction

The report of the 20th National Congress of the Communist Party of China emphasizes the central role of innovation in the overall development of modernization. Guided by the innovation-driven development strategy, artificial intelligence (AI) has become a key driving force in advancing China's manufacturing sector from “Made in China” to “Intelligent Manufacturing in China.” For employees in the intelligent manufacturing industry, AI has shifted from a assistive tool to a work partner for both individuals and enterprises[1] , exerting a comprehensive influence on job content and career

development[2]. This transformation further requires employees to evolve from traditional task executors into composite professionals characterized by highly innovative and adaptable compound. At present, intelligent manufacturing industries-represented by new energy vehicles, industrial robots, and semiconductors-is a core national strategic sector facing challenges such as global competition, cost pressures, and shifting market demands. Guiding employees to transform their awareness of AI-related challenges into proactive learning motivation and innovative actions, thereby stimulating their creativity, is not only crucial for high-quality development in intelligent manufacturing but also a vital foundation for achieving the goal of building a strong manufacturing nation.

AI awareness refers to the various reactions or perspectives that employees have towards artificial intelligence (AI) in the workplace[3]. AI impact awareness refers to the understanding of the scope and extent of changes brought about by AI, whose effects include both positive and negative aspects[4].Some scholars have categorized it into AI challenge awareness and AI threat awareness, with the former emphasizing the growth opportunities brought by AI, and the latter highlighting the threats and concerns associated with AI[5].Current research has largely focused on the technical aspects, examining how AI's functional characteristics affect enterprise operational efficiency, financial performance[6], and other related factors. At the employee behavioral level, two main perspectives have emerged:the challenge perspective and the substitution perspective. The perspective of challenges focuses on the positive impacts of AI, arguing that as a resource-aiding tool, AI can enhance the efficiency of employees and promote their growth and development[7-8]. It further suggests that challenging job demands can foster higher levels of work engagement[9], and challenging expectations enhance employees' work autonomy and sense of control through means such as psychological empowerment, thereby strengthening their work confidence[10]. In contrast, the substitution perspective focuses on the adverse consequences of AI, paying attention to issues such as employee anxiety, insecurity, and the tendency to leave the job caused by AI[4].However, Most of the existing studies have focused on a single mediating path. The internal psychological processes and behavioral pathways through which AI challenge awareness is translated into proactive innovation behavior among employees in the intelligent manufacturing sector therefore remain insufficiently understood. To address this gap, this study seeks to systematically explore the roles of harmonious passion as an emotional motivator and approach-oriented resource crafting as a behavioral driver in this transformation process.

Cognitive appraisal theory suggests that when an individual is stimulated by the external environment, their perception and evaluation of external things can influence their intrinsic motivation, and subsequently affect their behavior[11].The resource dependence theory states that individuals have a basic motivation to acquire, protect and maintain their own resources. The core motivation lies in protecting the existing resources and obtaining more of the resources they need[12].Building on the integration of these two theoretical perspectives, this study introduces harmonious passion and approach-oriented resource crafting as a chain of intermediaries to examine the cognition-motivation-behavior pathway through which AI challenge awareness influences proactive innovation behavior among employees in the intelligent manufacturing sector. At present, the work content and career development of knowledge-based employees are highly dependent on AI-related resources. Employees with an awareness of AI challenges will view AI as an opportunity for growth, generating autonomous motivation and forming harmonious passion[13]. Subsequently, these employees tend to proactively invest resources in self-expansion and engage in approach-oriented resource crafting to integrate and optimize work-related resources. Through this process, dependence on external technological resources is reduced, while employees are enabled to transcend existing work paradigms and adapt more effectively to AI-enabled environments, ultimately translating these cognitive and behavioral processes into proactive innovation behavior supported by the organization. By introducing these two mediating variables, this study not only offers a more comprehensive explanation of the transformation mechanism linking AI challenge awareness to employees' proactive innovation behavior, but also extends the literature on the antecedent

mechanisms of proactive innovation behavior. In doing so, it provides both theoretical insights and practical implications for organizations seeking to foster employee-driven innovation.

Theoretical Foundations and Research Hypotheses

AI challenge awareness and proactive innovation behavior

Proactive innovation behavior refers to employees' voluntary and active engagement in innovative initiatives in the workplace, including the generation, introduction, and application of novel and useful ideas within organizational activities, with the aim of improving work efficiency[14]. In the intelligent manufacturing sector, innovative learning ability and an enterprising spirit constitute core competencies, and it is also a professional responsibility for employees to address technical problems through innovative approaches in their work. Some scholars have argued that AI impact awareness, as a form of challenge-related stress, encourages individuals to respond to perceived pressures with more positive attitudes, thereby enhancing proactive innovation behavior[15]. AI impact awareness reflects employees' subjective cognitive and psychological evaluations of the influence of AI, with outcomes that vary depending on individual differences in cognition. In contrast, AI challenge awareness emphasizes employees' positive attitudes and proactive behavioral tendencies toward AI technologies−namely, a constructive appraisal and acceptance of challenging demands, through which employees recognize the opportunities for innovation and growth brought by artificial intelligence and thus take initiative in addressing AI-induced tasks or challenges[5]. This form of awareness places greater emphasis on the positive outcomes of human-AI collaboration, such as improved work efficiency, acquisition of new skills and knowledge, emergence of novel job roles, and expanded career development possibilities. Prior research has shown that awareness of AI and robotics can prompt employees to adapt to technological change through proactive learning and task crafting, thereby enhancing creativity[16]. Accordingly, employees with AI challenge awareness in the intelligent manufacturing sector tend to perceive the application and infiltration of AI in their work environments. Driven by achievement motivation and a career-oriented growth mindset, they develop confidence in their ability to cope with AI-driven change and are willing to respond proactively through innovative behavior, with the expectation of achieving personal value enhancement and developmental growth through AI-enabled transformation.

AI challenge awareness represents a refined extension of the broader constructs of STARA awareness (also referred to as technology impact awareness) and AI awareness. It also constitutes a positive cognitive response to the current trajectory of artificial intelligence development, thereby providing a novel perspective for subsequent research on how positive motivation is transformed into proactive behavior. Although no direct empirical studies have yet examined the relationship between AI challenge awareness and employees in the intelligent manufacturing sector, its linkage with proactive innovation behavior can be reasonably inferred from prior research on AI awareness, STARA awareness, and AI impact awareness. Existing studies have shown that employees' challenge appraisal of STARA awareness can significantly enhance work engagement, strengthen positive motivation in technologically driven and continuously evolving work environments, and ultimately exert a favorable influence on job performance[17]. When employees interpret AI introduced by organizations as a challenge rather than a threat, they are more likely to engage in job crafting proactively, thereby improving service performance[31]. According to JD-R model, when job demands are appraised as challenging stressors, AI awareness can activate employees' intrinsic motivation and promote innovative service behaviors[7].Drawing on cognitive appraisal theory and resource dependence theory, employees in the intelligent manufacturing sector who exhibit AI challenge awareness tend to evaluate AI as an opportunity for personal growth and believe in their own capacity to cope with AI-related challenges, thereby providing a strong cognitive foundation for engaging in innovative behavior. The next aspect is the

change in resources. In the face of the resource dependency shift brought about by AI, employees may perceive a gradual depreciation of their existing experience and skill sets. In response, they are more likely to regard AI as a resource-enabling tool closely integrated with their work, actively engaging in exploration and learning, integrating and reconstructing existing resources while expanding new ones, and thereby forming new patterns of resource dependence. The stimulation of cognitive motivation and adequate resource acquisition provides sufficient capability support for proactive innovation behavior among employees in the intelligent manufacturing sector, ultimately enabling them to initiate innovative actions on a voluntary basis. Therefore, this study proposes the following hypothesis:
H1: AI challenge awareness has a positive effect on employees' proactive innovation behavior in the intelligent manufacturing sector.

The Mediating Role of Harmonious Passion

Harmonious passion, as one dimension of the dualistic model of passion, refers to a positive psychological state in which individuals love their work and engage in it wholeheartedly, while maintaining autonomy and flexibility in their work involvement [18-19]. It is a positive and proactive emotion driven by internal motivation, and it is also the process of internalizing external motivation into one's own identity and autonomy. Employees with harmonious passion generally possess rich cognitive and emotional resources that support innovative activities, which in turn shape their work states and generate strong intrinsic motivation[20]. The more employees perceive their work as meaningful and valuable, the more intense their experience of passion becomes.

Based on the job requirements and responsibility specifications of leading enterprises in the intelligent manufacturing sector, employees are required to maintain routine collaborative interactions with AI systems, which in turn necessitates strong capabilities in technology adoption and continuous learning. According to cognitive appraisal theory, AI challenge awareness enables employees to form positive expectations regarding goal attainment and enhances their sense of achievement. When facing AI-related tasks, employees are more likely to generate favorable emotional, motivational, and behavioral responses[21], thereby demonstrating stronger tendencies toward adaptation and acceptance of challenges. As they perceive the opportunities embedded in AI technologies, they engage in proactive learning and continuous resource accumulation to overcome technical difficulties. As task complexity and challenge levels increase, employees derive satisfaction from the process of realizing self-worth in their work[22]. In this process, the external requirement of human-AI collaboration is gradually internalized into their professional identity, and the fulfillment of psychological needs and personal value jointly strengthens harmonious passion[20]. Harmonious passion stems from internalization through autonomy and represents an individual's self-concept, harmonious passion ensures that passion-driven behaviors remain stable and persistent even under conditions of uncertainty and challenge[23].Supported by this stability and persistence, employees are able to continuously invest effort, experiment with new working approaches and integrate diverse resources. When encountering obstacles during the innovation process, they persist in refining and improving their actions, thereby facilitating the emergence of proactive innovation behavior.

Harmonious passion, as a psychological process, not only enhances employees' active engagement in their work but also strengthens their motivation for innovation. Innovative learning and an enterprising spirit constitute core components of the competency model for employees in the intelligent manufacturing sector. Empirical evidence suggests that employees with harmonious passion, driven by intrinsic interest in their work, are able to sustain work vitality, concentration, and dedication over time[24]. When their basic psychological needs at work are satisfied, they tend to attribute meaning to their work and willingly invest themselves in it, thereby forming a motivation pattern characterized by harmonious

passion that fosters more creative behaviors[25].In the context of intelligent manufacturing, where employees are required to maintain high levels of engagement and resilience throughout extended innovation cycles, harmonious passion provides a stable source of autonomous and intrinsic work motivation. It enables employees to allocate emotional and cognitive resources more flexibly and proactively within AI-collaborative work processes, while also increasing their willingness to explore emerging work-related issues and experiment with novel solutions. Accordingly, employees become more inclined to break through existing work paradigms and pursue new approaches, while simultaneously acquiring new knowledge through continuous interaction with AI systems. This process ultimately forms a virtuous cycle of passion, resource accumulation and innovation motivation, laying a solid foundation for employees' innovative work. Therefore, this study proposes the following hypothesis:

H2: Harmonious passion mediates the relationship between AI challenge awareness and employees' proactive innovation behavior.

The Mediating Role of Approach-Oriented Resource Crafting

Within the framework of approach-avoidance theory, approach-oriented resource crafting represents a sub-dimension of job crafting[26]. Resource crafting refers to employees' proactive efforts to develop and acquire new work-related resources, as well as to protect and reconfigure existing resources in the workplace, with the aim of optimizing their work conditions and performance. Resource crafting can be further distinguished into two dimensions: approach-oriented resource crafting and avoidance-oriented resource crafting. Approach-oriented resource crafting comprises three specific behavioral categories, namely work organization, technology adoption, and metacognitive planning[11]. Among these, technology adoption refers to employees' proactive acquisition and utilization of new functional resources to better align their professional competencies and work resources with job demands, as well as their continuous learning of new work methods to address workplace challenges. For employees in the intelligent manufacturing sector, technology adoption is specifically reflected in the proactive exploration, skilled application and deep integration of AI technologies, thereby enabling them to effectively resolve technical problems encountered in the ir work processes.

When employees in the intelligent manufacturing sector engage in a challenge appraisal of AI, they are more likely to proactively adjust their work practices by acquiring and integrating additional resources. Although no empirical study has directly examined the relationship between AI challenge awareness and approach-oriented resource crafting, this linkage can be theoretically inferred. Given that AI challenge awareness is conceptually rooted in AI awareness, and that AI awareness itself extends from prior research on STARA awareness. Relevant theoretical and empirical foundations can be drawn from the existing literature. Previous studies have shown that STARA awareness can positively influence job crafting through the mechanism of performance pressure, and performance pressure further drives work reshaping through the chain-mediated effect of employees receiving assistance or providing assistance[27]. In this sense, employees with AI challenge awareness are fundamentally motivated by the acquisition and control of critical resources. They therefore tend to actively learn from and capitalize on opportunities brought by AI, with the aim of strengthening their own capability base and building the resources necessary for innovative work.

When employees interpret STARA awareness as a challenge, they are more likely to perceive AI as an opportunity for resource enhancement and value creation. This cognitive appraisal is associated with positive emotional responses, which encourage employees to more actively acquire new skills, absorb new knowledge and accumulate new resources, thereby facilitating continuous and proactive capability development [21].

According to resource dependence theory, approach-oriented resource crafting provides the necessary resource foundation for translating AI-related cognitive appraisals into innovative behavior. In human-machine collaborative work contexts, employees in the intelligent manufacturing sector must adapt to shifts in resource structures driven by AI technologies. This requires them to actively acquire new functional and composite resources within AI-enabled collaboration, thereby better aligning their skills, capabilities and work resources with evolving job demands. Empirical research has shown that job crafting can enhance work performance by increasing access to work resources and strengthening work engagement[28]. Similarly, constructive controversy has been found to influence employees' innovative behavior through the mediating role of job crafting[29]. Through the continuous acquisition and application of new resources, employees in intelligent manufacturing can reduce their dependence on external AI systems while simultaneously strengthening their own problem-solving and innovation capabilities, thereby establishing a solid foundation for the emergence of innovative behavior. Therefore, this study proposes the following hypothesis:

H3: AI challenge awareness has a positive indirect effect on employees' proactive innovation behavior in the intelligent manufacturing sector through approach-oriented resource crafting.

The Chain Mediating Role of Harmonious Passion and Approach-Oriented Resource Crafting

Harmonious passion originates from the internalization of external motivation and represents a highly autonomous form of work passion[13]. It not only provides employees with a sense of psychological safety that supports engagement in resource crafting, but also supplies sustained emotional energy that drives innovative behavior. Research has shown that employees with high levels of harmonious passion develop a genuine affection for their work and exhibit strong autonomous intrinsic motivation. Job crafting emphasizes employee proactivity，employees driven by intrinsic motivation are more likely to actively adjust their work tasks and relational boundaries in order to acquire the knowledge and capabilities required to meet job demands[30-31].Approach-oriented resource crafting is one type of job crafting, Therefore, there is a connection between harmonious passion and approach-oriented resource crafting.

According to cognitive appraisal theory and resource dependence theory, once employees internalize AI challenge awareness into harmonious passion, this passion provides a strong psychological impetus for engaging in approach-oriented resource crafting. In the intelligent manufacturing context, which is characterized by rapid technological iteration and continuously evolving work environments, employees' work passion and their capacity for resource crafting play a critical role in enabling adaptation to the development of intelligent manufacturing. During the process of engaging in innovative behavior, harmonious passion enhances employees' perceived autonomy in the workplace. This heightened sense of autonomy facilitates more proactive adaptation to innovative tasks, strengthens employees' confidence in their ability to cope with AI-related challenges, and reinforces their belief in innovation. Such positive cognitions can encourage employees to invest greater positive emotion and stronger motivation into innovative work, enabling them to creatively address a wide range of work-related problems and ultimately promoting the emergence of innovative behavior[32].Empirical research has further demonstrated that work resources, by cultivating employees' harmonious passion rooted in intrinsic interest, enable them to actively and joyfully engage in their work, thereby enhancing their work engagement and facilitates the transformation of work resources into favorable work states[33], providing essential resource support for the realization of proactive innovation behavior.

AI challenge awareness first activates employees' harmonious passion, which in turn motivates them to voluntarily and proactively invest greater time and energy in their work. This heightened passion encourages employees to actively acquire AI-related skills and knowledge, obtain external resources

necessary for innovation, and thereby drive employees to carry out approach-oriented resource crafting. They will restructure and integrate their existing resources to provide an emotional cognition and resource foundation for innovative behaviors, promoting the emergence of proactive innovative behaviors. Accordingly, this study proposes that harmonious passion and approach-oriented resource crafting play a chain mediating role in the relationship between AI challenge awareness and proactive innovation behavior, forming an internal pathway of AI challenge awareness→harmonious passion→approach-oriented resource crafting→proactive innovation behavior.Therefore, this study proposes the following hypothesis:

H4: Harmonious passion and approach-oriented resource crafting play a chain mediating role between AI challenge awareness and employees' proactive innovation behavior in the intelligent manufacturing sector.

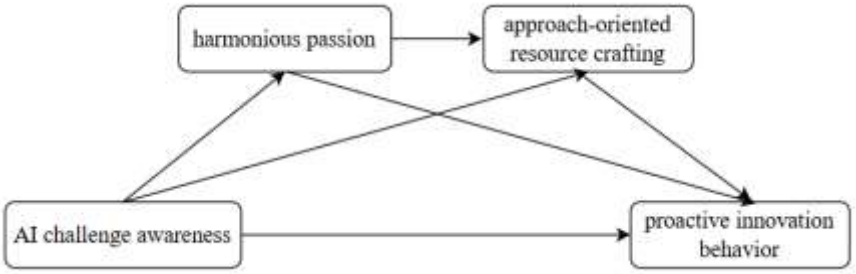

Fig.1 Research model

Research Design

Research Samples

The sample for this study was collected online through the Wenjuanxing platform, targeting employees in the intelligent manufacturing industry across multiple regions. A total of 587 questionnaires were distributed, and after excluding invalid responses, 449 valid questionnaires were retained, The effective response rate was 76.5%.The demographic characteristics of the individual sample (N=449) are as follows. In terms of gender, 25.4% were male and 74.6% were female. Regarding age, 68.2% were aged 18-25, 28.7% were aged 26-35, and 3.1% were aged 36-45 or above. In terms of educational attainment, 4.5% held a junior college degree, 81.5% held a bachelor's degree, and 14.0% held a master's degree or above. With respect to tenure, 73.1% had less than 2 years of work experience, 19.8% had 2-5 years, 5.8% had 6-10 years, and 1.3% had more than 10 years. Regarding organizational type, 24.5% of respondents worked in state-owned enterprises, 42.5% in private enterprises, 10.7% in foreign-invested or foreign-chinese joint ventures, and 22.3% in other types of organizations. In terms of job category, 12.5% were engaged in R&D roles, 12.2% in production roles, 35% in marketing roles, 26.7% in administrative roles, and 13.6% in other positions.

Measuring Tools

The scales used in this study were adapted from mature systems in various research fields, and their reliability and validity have been widely demonstrated in prior studies. All measures were assessed using a 5-point Likert scale, ranging from 1 (“strongly disagree”) to 5 (“strongly agree”).

AI Challenge Awareness. This study adopted the challenge dimension of the Challenge-Obstructive Appraisal Scale developed by Searle and Auton (2015)[34], consisting of four items (such as “The uncertainty in my work brought about by AI helps me learn a great deal”).Given that research on AI challenge awareness is still in its early stages, a mature measurement scale specifically designed for this construct has not yet been established. However, existing studies have conceptualized AI awareness

as a challenge-related stressor with potential motivational effects on employees. Employees may perceive AI as an opportunity for self-improvement, view AI technologies as enabling tools, and be willing to invest additional effort and resources to cope with related challenges, thereby demonstrating more proactive behaviors[36]. Through active problem-solving and adaptation to technological change, employees can enhance their capabilities and achieve improvements in both work efficiency and innovative capacity through collaboration with AI[5].When AI is appraised as a challenge, it has been shown to elicit higher levels of work engagement and organizational commitment[17], and to increase the likelihood of positive emotional experiences and corresponding creative behaviors[35]. These findings regarding the positive effects of challenge appraisal of AI are consistent with the concept of AI challenge awareness in this study, employees with higher AI challenge awareness are more likely to recognize the opportunities and challenges associated with AI and are willing to respond proactively in pursuit of greater personal achievement and organizational development. Accordingly, the challenge dimension of the Challenge-Obstructive Appraisal Scale was adopted as the measurement instrument. The Cronbach's α coefficient for this scale in this study was 0.812.

Harmonious Passion. This study adopted the harmonious passion dimension of the Dualistic Model of Passion Scale developed by Vallerand et al. (2003)[23], consisting of seven items including “My work allows me to experience a variety of feelings and experiences” with a Cronbach's α coefficient of 0.825.

Approach-Oriented Resource Crafting. This study adopted the scale developed by Bruning and Campion (2018)[26], which includes three dimensions-work organization, adoption and metacognition, with a total of 14 items including “I keep my work processes clearly organized”.In this study, the Cronbach's α coefficient for this scale was 0.905.

Proactive Innovation Behavior. This study adopted the Proactive Innovation Behavior Scale developed by Morrison and Phelps (1999)[36], consisting of 10 items such as “I often attempt to adopt improved procedures to accomplish my work”. In this study, the Cronbach's α coefficient for this scale was 0.888.

In addition, this study included gender, age, educational attainment, tenure, organizational type, and job category as control variables.

Analysis of Empirical Results

Homologous Analysis of Variance

To control for potential common method bias, this study adopted an anonymous questionnaire design and conducted a statistical test based on the “controlling for an unmeasured latent method factor”approach proposed by Xiong et al. (2012)[37]. Specifically, a comparison was made between a baseline model without a method factor (M1) and a model M2 with a method factor. The differences in model fit indices were as follows: ΔIFI=0.022, ΔTLI=0.021, ΔCFI=0.022, ΔRMSEA=−0.006,ΔSRMR=−0.0071.The differences between these indices are all less than 0.03, indicating that the inclusion of the method factor did not lead to a meaningful improvement in model fit. Therefore, no significant common method bias was detected in this study.

Discriminating Validity of Variables and Model Fitting Test

This study employed AMOS 26.0 to assess model fit and discriminant validity among variables using key indices, including χ^2, df, χ^2/df, TLI, CFI, and RMSEA. The results of the confirmatory factor

analysis are presented in Table I.The four-factor model demonstrated a superior fit compared with alternative models (χ^2/df=1.845<3, TLI=0.929>0.90, CFI=0.934>0.90, RMSEA=0.043<0.08). All fit indices fell within acceptable thresholds, indicating that the constructs in the hypothesized four-factor model exhibit good discriminant validity.

Table I. Confirmatory Factor Analysis Results

	χ^2	df	χ^2/df	TLI	CFI	RMSEA	$\Delta\chi^2$
4-Factor：AI、HX、CS、CX	1022.114	554	1.845	0.929	0.934	0.043	
3-Factor 1 AI＋HX、CS、CX	1064.495	557	1.911	0.923	0.928	0.045	42.381***
3-Factor 2 AI、CS、HX＋CX	1130.168	557	2.029	0.913	0.919	0.048	108.054***
2-Factor AI＋CS、HX＋CX	1210.608	559	2.166	0.902	0.908	0.051	188.494***
Singer-Factor AI＋HX＋CS＋CX	1355.477	560	2.420	0.880	0.887	0.056	333.363***

Note: AI=AI challenge awareness; CX=proactive innovation behavior; HX=harmonious passion; CS=approach-oriented resource crafting; + indicates that two factors are combined into one variable.

Descriptive Statistics and Relevant Analysis Results

Table II presents the means, standard deviations, and correlation coefficients of the main variables in this study.It shows AI challenge awareness was significantly and positively correlated with proactive innovation behavior (r=0.710, p<0.01), harmonious passion (r=0.743, p<0.01), and approach-oriented resource crafting (r=0.748, p<0.01).Harmonious passion was also significantly and positively correlated with approach-oriented resource crafting (r=0.716, p＜0.01) and proactive innovation behavior (r=0.743, p＜0.01). In addition, approach-oriented resource crafting was significantly and positively correlated with proactive innovation behavior (r=0.780, p＜0.01). These correlation results provide preliminary empirical support for the proposed hypotheses.

Table II. Means, Standard Deviations, and Correlation Coefficients

	M	SD	1	2	3	4
1.AI challenge awareness	4.11	0.62	1			
2.harmonious passion	4.04	0.58	.743**	1		
3.approach-oriented resource crafting	4.14	0.52	.748**	.716**	1	
4.proactive innovation behavior	3.99	0.59	.710**	.743**	.780**	1

Note: **p < 0.01

Hypothesis Testing

Hierarchical regression analysis was conducted using SPSS 27.0 to test the proposed hypotheses, along with a multicollinearity diagnostic test，the results are presented in Table III.As shown in Model 2, AI challenge awareness had a significant positive effect on harmonious passion (β=0.745, p<0.001). In Model 4, AI challenge awareness significantly and positively predicted approach-oriented resource crafting (β=0.485, p<0.001), while harmonious passion also had a significant positive effect on approach-oriented resource crafting (β=0.356, p<0.001).In Model 6, when AI challenge awareness, harmonious

passion, and approach-oriented resource crafting were simultaneously entered as predictors of proactive innovation behavior, all three variables exerted significant positive effects on proactive innovation behavior (β=0.135, p<0.01; β=0.317, p<0.001; β=0.447, p<0.001, respectively).The variance inflation factor (VIF) values from the multicollinearity test were all below 3, indicating that multicollinearity was not a serious concern in the model.

Table III. Hierarchical Regression Analysis and Multicollinearity Test (N=449)

Variable	HX		CS		CX		VIF
	Model 1	Model 2	Model 3	Model 4	Model5	Model 6	
Gender	0.037	0.025	0.05	0.029	0.032	-0.004	1.093
Age	0.093	0.063	0.061	0.009	0.094	0.032	1.485
Education	-0.02	-0.056	-0.011	-0.028	-0.029	-0.024	1.068
Year	-0.108	-0.042	-0.039	0.043	-0.08	-0.016	1.494
organizational type	-0.051	0.024	-0.085	-0.018	-0.08	-0.012	1.12
job category	-0.044	-0.015	-0.024	0.011	-0.096	-0.066*	1.165
AI		0.745***		0.485***		0.135**	2.897
HX				0.356***		0.317***	2.6
CS						0.447***	2.632
R^2	0.015	0.559	0.013	0.620	0.027	0.691	
F	1.157	79.818	0.992	89.746	2.023	109.124	

Note: ***p<0.001，**p<0.01，*p<0.05

To further examine the sequential mediating effects of harmonious passion and approach-oriented resource crafting, this study employed PROCESS 4.0 and conducted a bootstrapped mediation analysis using 5000 resamples with a 95% bias-corrected confidence interval. The results are presented in Table IV.First, the direct effect of AI challenge awareness on proactive innovation behavior was 0.1292, with a 95% confidence interval of [0.0444, 0.214], which did not include zero, indicating a significant direct relationship between the two variables; thus, Hypothesis 1 was supported.Second, for Path 1 (AI challenge awareness→harmonious passion→proactive innovation behavior), the indirect effect was 0.2257, with a 95% confidence interval of [0.1501, 0.326], which excluded zero, indicating a significant mediating effect of harmonious passion; thus, Hypothesis 2 was supported.Third, for Path 2 (AI challenge awareness → approach-oriented resource crafting → proactive innovation behavior), the indirect effect was 0.2070, with a 95% confidence interval of [0.1257, 0.2758], which did not include zero, confirming the significant mediating role of approach-oriented resource crafting; thus, Hypothesis 3 was supported.Fourth, for Path 3 (AI challenge awareness→harmonious passion→approach-oriented resource crafting→proactive innovation behavior), the indirect effect was 0.1130, with a 95% confidence interval of [0.0673, 0.1533], which did not include zero, indicating a significant sequential mediating effect of harmonious passion and approach-oriented resource crafting; thus, Hypothesis 4 was supported.

Table IV. The Pathway and Effect Decomposition of AI challenge awareness on proactive innovation behavior

Path	Effect	Boot SE	Boot 95% CI	相对效应占比
Total effect	0.6748	0.032	[0.6119,0.7377]	
Direct effect	0.1292	0.0431	[0.0444,0.214]	19.15%
Indirect effect	0.5457	0.0477	[0.448,0.6354]	80.87%
Path 1：AI→HX→CX	0.2257	0.0444	[0.1501,0.326]	33.45%
Path 2：AI→CS→CX	0.2070	0.0383	[0.1257,0.2758]	30.68%
Path 3：AI→HX→CS→CX	0.1130	0.0222	[0.0673,0.1533]	16.75%

Discussion

Research Conclusions

Grounded in cognitive appraisal theory and resource dependence theory, this study systematically examined the mechanism through which AI challenge awareness influences employees' proactive innovation behavior in the intelligent manufacturing sector, and empirically tested the sequential mediating roles of harmonious passion and approach-oriented resource crafting. The results supported all proposed hypotheses.

First, AI challenge awareness exerts a positive effect on employees' proactive innovation behavior in the intelligent manufacturing sector. The stronger employees perceive AI-induced challenges, the more likely they are to break through the status quo, explore new resources and work methods, and proactively engage in innovative activities.

Second, harmonious passion mediates the relationship between AI challenge awareness and proactive innovation behavior. When employees appraise AI as a challenge, they tend to adopt a positive and enthusiastic attitude toward AI-related demands, invest more time and energy in innovative activities, and thereby establish sufficient psychological and motivational foundations for the emergence of innovative behavior.

Third, approach-oriented resource crafting mediates the relationship between AI challenge awareness and proactive innovation behavior. This finding is consistent with prior research indicating that AI challenge appraisal influences employee performance through job crafting[38]. When employees perceive AI-related challenges, they tend to reintegrate and reconstruct existing as well as newly acquired resources to cope with these demands, which enhances their willingness to initiate innovative activities while adapting to the requirements of a new technological era.

Fourth, harmonious passion and approach-oriented resource crafting play a chain mediating role between AI challenge awareness and proactive innovation behavior. When employees form a challenge appraisal of AI, they first activate their intrinsic motivational drive and approach their work with a positive and enthusiastic attitude, thereby developing harmonious passion. Driven by harmonious passion, employees engage more actively in approach-oriented resource crafting by integrating and expanding work-related resources, strengthening their ability to cope with AI-related challenges, and ultimately fostering more proactive innovation behavior.

Theoretical Contributions

First, this study extends the application of cognitive appraisal theory and resource dependence theory to the context of human-AI collaboration. By integrating these two theoretical frameworks into this emerging context, the present research reveals how AI challenge awareness shapes employees' psychological states and innovative behaviors through the dual mechanisms of harmonious passion and approach-oriented resource crafting, thereby offering a novel perspective for understanding how continuous advances in AI influence employees' proactive innovation behavior.

Second, this study uncovers the chain mediating mechanism of harmonious passion and approach-oriented resource crafting. It reveals the sequential effect of these two constructs within the cognition-motivation-behavior pathway, highlighting the emotional-motivational function of harmonious passion and the behavioral implementation effect of approach-oriented resource crafting in the process through which AI challenge awareness influences employees' proactive innovation behavior.

This finding not only enriches the theoretical understanding of harmonious passion and approach-oriented resource crafting, but also explicates the internal mechanism through which artificial intelligence affects employees' proactive innovation behavior via corresponding psychological and behavioral pathways. The results provide practical managerial implications for organizational leaders and lay a foundation for future research on the psychological and motivational mechanisms underlying human-machine collaboration.

Managerial Implications

First, organizations should guide employees to develop a challenge-oriented appraisal of AI awareness. Intelligent manufacturing enterprises can achieve this through AI-related training programs and the sharing of best practices and success stories, strengthening employees' perceptions of AI as an opportunity for growth and capability enhancement in human-AI collaboration, while reducing negative psychological perceptions of AI. Such efforts lay a solid cognitive base for employees' innovative behavior.

Second, organizations should attend to the fulfillment of employees' psychological needs. In AI-enabled collaborative work contexts, enterprises can enhance employees' work autonomy and cultivate a supportive innovation climate, satisfying their needs for development and achievement. This not only strengthens employees' sense of intrinsic value but also facilitates the formation of harmonious passion, providing a stable and sustained intrinsic motivational force for employee innovation.

Third, organizations should continuously improve and optimize their AI-related resource systems. Intelligent manufacturing enterprises should provide employees with sufficient and diverse resource support, as well as an open and collaborative environment for resource sharing, so as to facilitate approach-oriented resource crafting. Such support enables employees to proactively acquire and integrate AI-related resources, increases their ability to optimize resource configurations, and ultimately provides a solid resource foundation for proactive innovation behavior.

Limitations and Prospects

This study has several limitations that should be addressed in future research.First, the industry scope is relatively narrow, as the sample is limited to employees in the intelligent manufacturing sector, therefore the generalizability of the findings to other industries requires further verification.Second, the empirical analysis relied exclusively on questionnaire survey data. Future research could integrate multiple data collection methods to improve the accuracy and reliability of the conclusions.Third, this study does not account for potential industry heterogeneity. Given the varying degrees of digitalization and AI application intensity across industries, future studies could conduct multi-group comparisons to further examine these differences and address this limitation.

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