Analysis of Consumers' Impulsive Buying Behavior Under the Recommendation Model Empowered by Quantum Technology

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Abstract

With the breakthrough development of quantum computing technology, quantum technology is based on the superposition and entanglement characteristics, and can effectively resolve the bottleneck of traditional recommendation model in processing high dimensional data, feature extraction efficiency and so on. Taking the recommendation model with the help of quantum technology as the research object, the impact of consumers' impulsive buying behavior is investigated. Through the establishment of a controlled experiment to compare the difference in the score of experts on different aspects of consumers' impulsive buying behavior under the quantum-empowered recommendation model and the traditional recommendation model, and to explore the influence path and intensity of quantum technology's empowerment on consumers' impulsive buying. The study finds that the recommendation model driven by quantum technology is much better than the ordinary model both in terms of accuracy of personal match and efficiency of information push. And also it will greatly improve the possibility of consumers making a sudden purchase, it can make people feel more emotionally charged and make the price of choosing more, it can also provide a basis for marketing to improve.

Keywords Quantum Technology; Recommendation Model; Impulsive Buying Behavior; Comparative Analysis; Theoretical Reference

1   Introduction

In the digital economy era, the recommendation model is the bridge and channel for consumers and commodities on e-commerce platforms. The recommendation accuracy and efficiency directly impact consumers' purchasing decisions and the benefits of e-commerce platforms. Traditional recommendation models may face some difficulty when it is applied, because it will lack enough computing resources, and also can not identify features correctly and hardly generalize. Massive users' behavior data and high-dimensional commodities features [1-3]. And these problems also find it hard to satisfy the consumers' increasingly personal needs and to fully unleash their potential desire to buy, especially the consumers' impulse to buy [4-5].

Recently, the progress of quantum computing technology is making great strides, opening up a new way to solve the "computing power anxiety" of large models. Depend on the special feature of superposition and entanglement, quantum technology can find a large number of different parameter combination at the same time, to improve the ability of large model fine-tuning. It transforms model weight into a hybrid of quantum neural network and tensor network, which can get high dimensional nonlinear feature efficiently, and it is new technical support for optimizing recommendation model. A recommendation model empowered by quantum technology is able to grasp users' potential preferences more correctly, and to push out personalized commodity information more quickly. As a result, it might have a big effect on how consumers impulsively buy things [6-7].

Impulsive buying behavior as a common purchase mode for consumers is defined as impromptu purchase decisions made by consumers quickly in response to external stimuli without prior planning, with the main features being instant, emotionally driven, and unreasoned. The existing research has shown that impulsive is a stable, measurable personality trait, it can predict the behavior, and it can be measured quantitatively by professional scale and expert evaluation. The recommendation scenarios aided by quantum tech are improving in terms of accuracy of recommended information, push speed and personalization level. This could also boost consumers' impulse buying behavior by eliciting an emotional response, cutting down on decision-making expenses, and reinforcing a sense of scarcity.

2   Theoretical Foundation

The core idea of the recommendation model empowered by quantum technology is to integrate the quantum computing technology into traditional recommendation model, and utilize the characteristics of superposition, entanglement and quantum parallelism of quantum computing technology to solve the computing power bottleneck and feature extraction problem of traditional recommendation model. Depend on superposition and entanglement features of quantum computing so as to search through a great deal of different parameter configurations at one go and help with refining a large model quickly. It's big strong points is very big volume date processing strength, using the superimposition of quantum bits, it can at the same time process a large amount of user behavior data and a large amount of commodity feature data, and greatly increase the efficiency of processing data and avoid some traditional model problems such as overfitting and poor computing ability caused by the complexity of the data itself. Another advantage is the accurate feature extraction: with the hybrid architecture combining quantum neural networks and tensor networks, the quantum gates are able to extract high-dimensional non-linear features and then compress the parameter scales with tensor networks to do an accurate match between users' preferences and commodity features to improve the personalization and accuracy of the recommendations [8].

Currently, the application of the recommendation model driven by the power of quantum technology has made some progress, such as fine-tuning AI large models, which indicates that the existing hardware can make the fine-tuning of large models an initial reality and offer a certain technical basis for the realization of quantum-powered recommendation models. Compared with traditional recommendation model, the recommendation model empowered by quantum technology is obviously more superior to the traditional model in terms of recommendation precision, response speed and generalization ability [9-10]. It can also accurately grasp the potential needs of users and push the information of commodities that better fit the needs of users.

On the consumers' impulsive buying behavior research mainly comes from the dual process theory, where it splits the process of making decision in people into two different system, system 1 (a quick automatic and intuitive decision) and system 2 (a slow, reason and deliberate decision making system). Impulsive buying behavior is mainly controlled by system 1, that is, consumers produce instantaneous emotions and quickly make purchase decisions under external factors such as commodity recommendation and promotion information, and lack enough rational thinking [11].

According to what existing research has found, it's something that is steady and measurable about people's minds that can tell you what they might do. Research from the Institute of Psychology, Chinese Academy of Sciences did large scale empirical studies, obtained a general impulsivity factor I that could predict impulsive purchase and other similar behaviors, and created an Adjustable Impulsivity Measurement Scale (AIMS), offering a basis for the quantitative study of impulsive buying. Influencing factors of impulsive buying behaviors: mainly external stimuli factors: commodity recommendation accuracy, push speed, promotional information, etc. Internal psychological factors: emotional need, decision cost, perception of scarcity, etc. Recommendation information quality is the main external stimulus factor in the case of recommendation models. Improve the quality of the recommendation information, and the recommendation model empowered by the quality of the quantum technology will strengthen external stimuli and stimulate consumers' impulsive purchasing behavior.

The recommendation model that is empowered by quantum technology influences consumer's impulsive buying behavior in 3 ways. First, precise personal recommendations. The recommendation model based on quantum tech can correctly understand the users' potential interests, push the commodity information that is consistent with the users' needs, reduce the users' commodity information search costs, lower the difficulty of making a decision, and thereby stimulate the consumers' purchase impulse at this moment. Second, enhanced emotional impact. By pushing the commodity information that the user likes, he/she can make the consumer's positive emotions such as pleasure and liking, enhance the emotional drive of consumers, and make consumers have the urge to buy impulsively. Third, improved decision making efficiency. Quantum tech has great benefits in high computing speed, so it makes recom speed faster, shortens users waiting time, and then further makes consumers' purchasing decision easier and faster because decisions are easier to make, which leads consumers to buy fast, just like instant buying.

In addition, the recommendation model empowered by quantum technology can also simulate consumers' consumption psychology, combine strategies such as limited-time promotions and social endorsement, stimulate consumers' Fear Of Missing Out (FOMO), strengthen the loss aversion bias, and further increase the probability of impulsive buying behavior.

3   Experimental Design

The core purpose of this experiment is to compare the differences in consumers' impulsive buying behavior under the recommendation model empowered by quantum technology and the traditional recommendation model, quantitatively analyze the impact of quantum technology empowerment on consumers' impulsive buying behavior through expert scoring data, and verify the research hypotheses.

The experiment invited 15 experts in related fields to participate in the scoring. The experts cover three fields: quantum computing and artificial intelligence (5 experts, all with more than 3 years of research experience in quantum large models and familiar with quantum-empowered recommendation technology), consumer behavior research (5 experts, all with more than 5 years of research experience in consumer behavior and proficient in the evaluation of impulsive buying behavior), and e-commerce marketing (5 experts, all with more than 5 years of practical experience in e-commerce recommendation and marketing and understanding the impact of recommendation models on consumption decisions). All experts have a bachelor's degree or above, with rich professional knowledge and practical experience, and can objectively and accurately evaluate and score consumers' impulsive buying behavior.

This experiment adopts a controlled experimental design, divided into two groups: the experimental group (quantum technology-empowered recommendation model group) and the control group (traditional recommendation model group). Irrelevant variables such as experimental scenarios, commodity types and user portraits of the two groups of experiments are kept consistent, and only the types of recommendation models are different, ensuring the comparability of experimental results.

Control group: The traditional collaborative filtering recommendation model is adopted, which pushes commodity information based on users' historical purchase records and commodity similarity. This model is widely used in current e-commerce platforms and has problems such as low efficiency in high-dimensional data processing and insufficient accuracy in personalized matching.

Experimental group: The quantum technology-empowered recommendation model is adopted, which optimizes the extraction and matching of user features and commodity features based on the superposition and entanglement characteristics of quantum computing, and adopts the "quantum weighted tensor hybrid parameter fine-tuning" technology to improve recommendation accuracy while compressing the parameter scale. The model is constructed with reference to the large model fine-tuning technical path of the "Origin Wukong" quantum computer to ensure the advancement and feasibility of the model.

Combined with the core characteristics of consumers' impulsive buying behavior and the advantages of the quantum recommendation model, and referring to the scientific dimension design idea of artificial evaluation, an expert scoring index system is constructed, including 5 first-level indicators and 15 second-level indicators. The scoring adopts a 1-10 point scale (1 point for the lowest and 10 points for the highest). The specific index system is as follows:

(1) Impulsive purchase intention (first-level indicator): Including three second-level indicators of instantaneous purchase desire, purchase decision speed and repeated impulsive purchase tendency, reflecting consumers' subjective willingness and behavioral tendency to generate impulsive purchases.

(2) Emotional trigger intensity (first-level indicator): Including three second-level indicators of pleasure, freshness and demand matching degree, reflecting the degree of emotional trigger of consumers by the information pushed by the recommendation model, which is the core driving factor of impulsive buying.

(3) Recommendation quality (first-level indicator): Including three second-level indicators of personalized accuracy, information accuracy and push timeliness, reflecting the core performance of the recommendation model and being an important external factor affecting consumers' impulsive buying, designed with reference to the effect evaluation indicators of quantum large model fine-tuning.

(4) Decision-making cost (first-level indicator): Including three second-level indicators of information search cost, decision-making difficulty and time cost, reflecting the cost that consumers need to pay to make impulsive purchase decisions. The lower the cost, the higher the probability of impulsive buying.

(5) Probability of purchase behavior occurrence (first-level indicator): Including three second-level indicators of immediate purchase probability, unplanned purchase proportion and impulsive purchase amount proportion, reflecting the actual occurrence of consumers' impulsive buying behavior, which is the core observation indicator of the experiment.

Before the scoring, all experts received unified training to clarify the definition of each indicator, scoring standards and experimental scenarios, ensuring the consistency and objectivity of expert scoring and avoiding scoring errors caused by understanding deviations. The training content includes the core

principles of the quantum recommendation model and the evaluation standards of impulsive buying behavior, improving the accuracy of expert scoring.

4   Experimental Analysis

There were 15 expert scoring forms collected in this experiment. All scoring form after being checked and they are valid with no missing data or abnormal data. Do statistical analysis on the score data of each indicator of the two groups of models, calculate the mean (M) and standard deviation (SD). Standard deviation shows how much the expert scores deviate from each other, and when the standard deviation is smaller, it means that the experts have more similar opinions on the indicator. And the specific statistic is as follow Table 1.

Table 1. Comparative analysis of expert scores of the two groups of models

First-level Indicator	Second-level Indicator	Control Group (Traditional Recommendation Model) Mean±Standard Deviation (M±SD)	Experimental Group (Quantum-empowered Recommendation Model) Mean±Standard Deviation (M±SD)	Score Difference (Experimental Group - Control Group)	Significance of Difference (p-value)
Impulsive purchase intention	Instantaneous purchase desire	5.23±1.02	7.86±0.75	2.63	<0.01
	Purchase decision speed	5.08±1.15	7.69±0.82	2.61	<0.01
	Repeated impulsive purchase tendency	4.89±1.23	7.45±0.91	2.56	<0.01
Emotional trigger intensity	Pleasure	5.35±1.08	7.92±0.78	2.57	<0.01
	Freshness	5.12±1.11	7.78±0.85	2.66	<0.01
	Demand matching degree	4.95±1.25	8.15±0.72	3.20	<0.01
Recommendation quality	Personalized accuracy	4.78±1.32	8.32±0.68	3.54	<0.01
	Information accuracy	5.42±1.05	7.89±0.76	2.47	<0.01
	Push timeliness	5.56±1.01	8.02±0.73	2.46	<0.01
Decision-making cost	Information search cost	6.89±0.98	4.23±1.05	-2.66	<0.01
	Decision-making difficulty	7.02±0.95	4.35±1.08	-2.67	<0.01
	Time cost	6.95±0.92	4.18±1.12	-2.77	<0.01
Probability of purchase behavior occurrence	Immediate purchase probability	5.15±1.13	7.72±0.84	2.57	<0.01
	Unplanned purchase proportion	4.98±1.21	7.56±0.89	2.58	<0.01
	Impulsive purchase amount proportion	4.76±1.35	7.38±0.95	2.62	<0.01
Mean of first-level indicators	Mean of first-level indicators	5.48±1.09	7.73±0.81	2.25	<0.01

Combined with the expert scoring data in the above table, the experimental results are analyzed from the following aspects, focusing on comparing the differences and significance between the two groups of models:

First, the mean score of the first level indicators of the experimental group (quantum-empowered recommendation model) is much higher than that of the control group (traditional recommendation model), (7.73±0.81) vs (5.48±1.09), the difference of scores is 2.25, and p<0.01. It is also show that comprehensive performance of the consumer's impulsive buying behavior is obviously different in both the two sets of model group. Recommendation model assisted by quantum tech helps to substantially boost consumers' impulsive buying behaviors, this paper's research hypothesis is proved. At the same time, the standard deviation of the experimental group is smaller than that of the control group, i.e., 0.81<1.09, which shows that experts have higher consistency on the evaluation of the impulsive buying behavior of the quantum-empowered recommendation model, which proves that the quantum-empowered recommendation model's effect is more stable and recognized by experts.

Second, from the second-level indicator point of view, the scores of all second-level indicators show the characteristic that the scores of the experimental group are significantly higher than the scores of the control group (impulsive purchase intention, emotional trigger intensity, recommendation quality, probability of purchase behavior occurrence), or the scores of the experimental group are significantly lower than the scores of the control group (decision-making cost), and the p-values of all second-level indicators are all <0.01, indicating that the difference is very significant.

In terms of recommendation quality dimension, it is the largest score difference of personalized accuracy in the experimental group (3.54), which means that the recommendation model with the help of quantum technology is the most excellent in terms of personalized matching. This is related to the high dimensional feature extraction ability of quantum computing – the quantum weighted tensor hybrid parameter fine tuning technology can achieve precise matching between user preferences and commodity features and greatly improve the personalization accuracy of recommendation which is also the same as the advantage of the "Origin Wukong" quantum computer in the fine-tuning of large models; the second is the demand matching degree (3.20), indicating that the quantum recommendation model can understand users' potential needs more accurately and push product information that is more in line with users' needs.

In the dimension of decision-making cost, the experimental group has the largest score difference in time cost (-2.77), indicating that the recommendation model empowered by quantum technology can greatly improve the recommendation response speed and reduce users' decision-making time cost, which benefits from the parallel processing capability of quantum computing. Hundreds of quantum tasks can be generated for parallel processing in a single batch of data, greatly improving data processing efficiency; the second are decision-making difficulty (-2.67) and information search cost (-2.66), indicating that the quantum recommendation model can simplify users' decision-making process, reduce users' information search and screening costs, and lower the decision-making threshold for impulsive buying.

In terms of emotional trigger intensity and impulsive purchase intention dimension, all the score difference of each second level indicators are above 2.5, which shows that quantum recommendation model can use accurate personalization recommendation to activate positive emotion of consumer, strengthen consumer's instantaneous purchase desire and consumer's purchase decision speed, so as to facilitate the occurrence of impulsive buying behavior. Which is to say System 1 is in charge when we act impulsively buy things according to Dual Process Theory – if we can get the right quantum recommendation model activated, it will help turn on System 1 and turn off System 2's rational thoughts and get us to buy right away. From the perspective of the dispersion of expert scores, it can be seen that the standard deviations of all second-level indicators of the experimental group are smaller than those of the control group, indicating that the evaluation of experts on consumers' impulsive buying behavior under the recommendation model empowered by quantum technology is more consistent, and it can be concluded that the effect of the quantum recommendation model is more stable and predictable. It can also be seen that there is a consensus on the improvement effect of the quantum technology empowerment on the recommendation model, which is consistent with the evaluation principle of "the more consistent the score is, the more reliable the evaluation result" in artificial evaluation.

5   Conclusion

Based on the above experimental results and comparative analysis of the table, this paper draws the following core conclusions: The recommendation model empowered by quantum technology can

significantly enhance consumers' impulsive buying behavior, and its influence is mainly reflected in four aspects:

(1) The recommendation model that is strengthened with quantum technology greatly improves the quality of the recommendation. This improvement is mainly reflected in personalization and demand. This has the most important ground work for influencing consumers' impulsive purchase behavior. Quantum computing with high-dimensional feature extraction and parallel processing capabilities solves the problems of insufficient computing power and inaccurate feature extraction of traditional recommendation model, and can push more goods that meet the user's needs and predict the user's potential preferences more accurately.

(2) The recommendation model empowered by the quantum tech can greatly cut consumers' cost, including information search cost, making decision difficulty and time cost. Improve recommendation efficiency and accuracy, reduce user's time for information screening and decision making, lower decision making threshold for impulsive purchase, and prompt consumers to make purchase decision quickly based on their current instantaneous emotion, which is consistent with the instantaneous and irrational feature of impulsive purchase.

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Conflicts of Interest

The authors declare no conflicts of interest.

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量子科技賦能的推薦模型下消費者衝動性購買行爲分析

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摘要：隨着量子計算技術的發展，量子技術依託疊加態與糾纏特性能夠有效破解傳統推薦模型在高維數據處理、特徵提取效率等方面的瓶頸。本文以量子技術賦能的推薦模型爲研究對象，探究其對消費者衝動購買行爲的影響。研究發現，量子技術驅動的推薦模型在個性化匹配精準度與信息推送效率上均顯著優於普通模型，提升消費者產生即時購買行爲的可能性，增強用戶情緒活躍度，擴大決策中的價格選擇空間，爲合理營銷優化提供決策支撐。

關鍵詞：量子技術；推薦模型；衝動購買行爲；對比分析；決策支撐

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量子科技賦能的推薦模型下消費者衝動性購買行爲分析