Integration and Improvement of A-Kano and TRIZ in the Design of Rehabilitation Aids for Stroke Patients

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Abstract—**Objective The significant study demonstrates that an important design framework could effectively bridge the gap between critical user psychology and the relevant engineering contradictions by merging the improved A-Kano model with TRIZ to mitigate chronic shortage of rehabilitation resources and the high rate of device abandonment. Methods Moreover, the improved A-Kano model might indicate that fuzzy logic allows for extraction of subtle, high-priority needs often missed by traditional linear weighting. However, psychological need for "concealed appearance" appears most notable. Thus, TRIZ theory may establish that identified needs translate into functional features without compromising performance. Given that contradiction matrix mapped physical conflicts to engineering parameters, segmentation and dynamics principles could resolve them. Results Nevertheless, methodology effectively decouples design conflicts. In light of the findings, optimized component layout may align functionality with nuanced preferences of stroke survivors. Conclusion Furthermore, the findings could provide that the important blueprint demonstrates higher-compliance rehabilitation aids. Moreover, the study might suggest that coupling quantitative need analysis with systematic innovation tools shows value in complex medical product design.**

Keywords—stroke rehabilitation aids; improved A-Kano model; TRIZ theory

I. INTRODUCTION

A. Clinical Background and Rehabilitation Challenges

However, the significant epidemiological evidence could indicate that stroke has become one of the most critical public health challenges of our time, rapidly expanding worldwide. Moreover, the evidence might confirm that prevalence and lifetime risk appear substantial. Thus, genetic risk profiles may dictate probability range between 9.6% and 23.2% for individuals older than 45. Notwithstanding these findings, one in four adults faces threat of stroke[1]. Additionally, death in some cities seems falling. However, actual proportion may increase, especially in developing countries. Given that radical intervention appears absent, stroke-related fatalities could increase dramatically by 2050 [2]. Nevertheless, the important physical symptoms could suggest that bone spasticity and lost motor control, and fatal damage often occurs in patients' self, but not in body. Furthermore, the evidence might indicate that these epidemics come from psychological influences such as depression and anxiety [3]. Moreover, heavy impact may affect families and health systems. Thus, isolation and stigma appear devastating [4]. Therefore, psychosocial aspects could demonstrate that stroke requires more attention, as intensive as physical pathology.

These significant concerns could indicate critical challenges in contemporary healthcare delivery. Moreover, the rapid expansion of patient care demands may suggest that current clinical skill availability has reached historically low levels. Furthermore, this problem appears most prevalent in developing countries where resource constraints are substantial. Given that inadequate education, insufficient leadership, and lack of funding combine with obsolete infrastructure, Htwe demonstrate that these factors can further restrict the access and the quality of health care services. In China, the situation reveals inequitable distribution patterns [5]. However, Wang show worker numbers grow annually while geographic disparities persist[6]. Nevertheless, therapist density remains low compared to developed nations' 50 practitioners per 100,000 people[7]. Additionally, Iran's medical system may face financial constraints alongside structural difficulties. Thus, high costs and limited insurance coverage could prevent long-term inpatient stays[8]. Hospital-to-home rehabilitation might represent not innovation but necessary adaptation. In light of aging populations, this transition appears a survival strategy for pressured medical systems[9]. Notwithstanding these observations, technological production challenges this situation[10].

Unfortunately, the devices currently available cannot maintain that this process may continue effectively, which could lead to an endless cycle of significant resource waste. Moreover, the empirical data might suggest that nearly a third of these assistive devices are discarded by the clinic because of their incompatibility with home life, and without the help of a clinician, patient compliance drops between 50% and 100%. Thus, this industry appears to place patients in a "binary dilemma": either inexpensive, low-tech devices that do not provide much useful feedback, or complex robots that are technically appealing but practically not usable when a stroke survivor attempts to use one hand. Given that such high-end devices are often insensitive to therapy time requirements, patients may experience significant psychological discomfort. However, this "function stacking" could demonstrate that the user is the root of resource waste, and we need a design strategy that goes beyond mechanics to quantify the implicit psychological needs of patients. Nevertheless, the only way this device is actually used and

not abandoned might indicate that these critical psychological factors should be considered [11][12].(Table 1)

Related Equipment	Technology Used	Equipment Advantages	Equipment Disadvantages
Traditional mobility aids	Cane/walking aid/wheelchair	Low price, easy to use, and instant mobile support	The inability to actively rehabilitate may lead to gait abnormalities or postural asymmetry.
Functional electrical stimulation (FES) devices	Low-frequency electrical pulse stimulation	Improves foot drop, strengthens muscles, and is highly portable.	Professional guidance is required for electrode placement; some users may experience skin irritation.
Exoskeleton Rehabilitation Robot	Robot-assisted/Mechanical-driven	Provides high-intensity repetitive training, quantifiable data, and significant gait improvement.	High volume/price, dependent on clinical environment or professional operation, and large individual variability.
Virtual Reality (VR) Rehabilitation System	Immersive gaming/VR technology	Highly engaging, improves patient engagement/compliance, and can be used at home.	Commercial games are not specifically designed for rehabilitation; some patients may experience dizziness.
Brain-computer interface (BCI) devices	EEG signal acquisition and decoding	Restoring mind control, promoting cutting-edge neural remodeling, highly personalized	The technology is extremely difficult, the cost is high, and its clinical application is still in the early stages of exploration.
Daily living aids	Adaptive design (e.g., long-handled brush/sock inserter)	Extremely low cost, immediate increase in independence, and reduced burden on caregivers	It is only for auxiliary, non-therapeutic purposes, has simple functions, and cannot restore the function of damaged limbs.
Remote medical rehabilitation platform	Internet/Data Transmission	Overcoming geographical limitations, increasing training frequency, and facilitating doctor-patient communication.	Lack of physical interaction, requires patients to have technical skills, and involves data privacy.

B. Research Gap and Methodological Innovation

Most of the existing product development methods remain at the stage of qualitative analysis or simple linear weighting. For example, while the Analytic Hierarchy Process (AHP) can determine weights, it presumes a linear relationship between user satisfaction and the degree of functionality, making it difficult to reflect users' complex psychological characteristics [13] — patients are extremely sensitive to the absence of certain features (such as safety brakes), yet may be less perceptive to their optimization. The traditional Kano model, although capable of categorizing

needs, is highly subjective and struggles to quantitatively rank demands within the same category [14].

Consequently, we introduce an improved A-Kano model rooted in fuzzy set theory to better map the nuances of user perception. Unlike the linear rigidity of AHP, this nonlinear approach acknowledges that users view the "presence" or "absence" of a function through ambiguous psychological filters, allowing for a more precise depiction of the asymmetry between basic "safety baselines" and the aspirational "experience ceiling." To translate these diagnostic insights into physical reality, the framework is coupled with the TRIZ contradiction matrix. This integration provides a systematic mechanism to convert "fuzzy" psychological data into "precise" engineering parameters, thereby solving the physiological-psychological trade-offs that traditional linear design methodologies struggle to reconcile[15].

II.   INTEGRATING THE IMPROVED A-KANO MODEL WITH TRIZ PRODUCT INNOVATION DESIGN

A. Improved A-Kano Model

Valid though the traditional Kano model is for classification, it remains hampered by inherent subjectivity and a void of quantitative data. Its successor, the A-Kano model, introduces calculation but fails to capture the essential nonlinear link between fulfillment and satisfaction(Table 2). Addressing these deficits, the improved A-Kano model adopted here fuses quantitative rigor with nonlinear relational characteristics. Central to this approach is the fuzzy Kano questionnaire: by permitting users to quantify their reactions to a function's "presence" or "absence" through ranges, the model significantly heightens data accuracy. Thus, the identification of Must-be,Performance, and attractive needs becomes more scientifically robust, offering exact, prioritized guidance for the design phase.

| Evaluation Dimensions	Kano (traditional)	A-Kano	Improved A-Kano
Qualitative analysis	Yes	Yes	Yes
Quantitative analysis	No	Yes	Yes
Demand Classification	Yes	Yes	Yes
Priority sorting	Yes	Yes	Yes
Subjectivity	high	middle	Low
Rigor	Low	middle	high
Applicability	Low	middle	high
Nonlinear relationship	No	No	Yes
Acquisition accuracy	Low	middle	high
Satisfaction Improvement	middle	middle	high
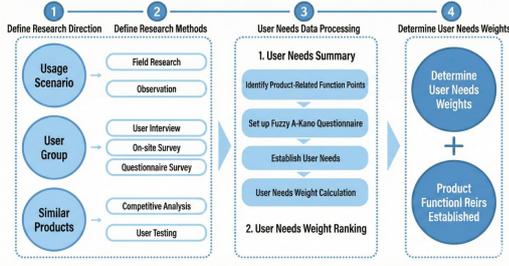
Fig. 1. User requirements analysis step chart

B. User Needs Analysis Based on the Improved A-Kano Model

The improved A-Kano model is concerned with product development. Specifically, we analyze the usage scenario and the user groups for stroke rehabilitation using fuzzy Kano survey survey surveys, weighting the needs. The improved A Kano model are applied to user requirements (Figure 1).

Step 1. Given functional points present in user journey map, we implement a fuzzy KANO survey. We set the questionnaire up as "This function" or "Not this function', and use a 7-point Likert scale to evaluate users on importance and performance of the need(Table 3, Table 4).

TABLE III. FUZZY KANO QUESTIONNAIRE

User needs	Really like	Taken for granted	Doesn't matter	Can tolerate	Don't like
Possess					
Not available					

TABLE IV. SATISFACTION SCORE OF IMPROVED A-KANO QUESTIONNAIRE

Evaluation Level	1	2	3	4	5	6	7
Evaluation Score	0	1	2	3	4	5	6

Step 2: Calculate the user demand satisfaction evaluation value. Semantic evaluation set $F=\{F_1,F_2,\cdots,F_u\}$ *Status indicating the user "has a need"*, $F_D=\{F_{D1},F_{D2},\cdots,F_{Dv}\}$ Indicates a "no demand" status.Among them, $s(F)_i'$ and $s(F_D)_i'$ respectively refer to the respondents $Z_t(t=1,2,3,\cdots,b)$ Corresponding quantitative evaluation vector, And if $\sum_u s(F)_i'=1$, $\sum_v s(F_D)_i'=1$ are satisfied, the corresponding user satisfaction evaluation values are:

$$j_F' = \sum_r \ni_F' \cdot (\breve{v})_F' \quad (1)$$

$$q_F' = \sum_r \ni_F' \cdot (\breve{v}_{\breve{v}})_F' \quad (2)$$

In the formula: g_i' represents the satisfaction score C_i corresponding to the evaluation of user needs, X_i' represents the satisfaction evaluation value when this need is not met, and Y_i' represents the satisfaction evaluation value when this need is met [15].

Step 3: Use vector analysis to accurately classify the requirements. Define the vector angle $\rho_i = \tan^{-1}\left(\frac{Y_i}{X_i}\right)$ $(0 \leq \rho_i \leq \pi/2)$ and vector length $r_i = \sqrt{X_i^2 + Y_i^2}$. Based on relevant literature standards, this study sets the classification thresholds $r_0 = 25°$、$\rho_1 = 25°$、$\rho_2 = 75°$. The classification rules are as follows: Indifferent Quality: $r_i \leq r_0$; Must-be Quality: $r_i \geq r_0$ and $\rho_i \leq \rho_1$; Performance Quality: $r_i \geq r_0$ and $\rho_1 \leq \rho_i \leq \rho_2$; Attractive Quality: $r_i \geq r_0$ and $\rho_i \geq \rho_2$[15](Table 5).

TABLE V. FUNCTIONAL REQUIREMENT TYPES OF IMPROVED A-KANO PRODUCTS

Indifferent Quality	Must-be Quality	Performance Quality	Attractive Quality
$r_i \leq r_0$	$r_i \geq r_0$	$r_i \geq r_0$	$r_i \geq r_0$
-	$\rho_i \leq \rho_1$	$\rho_1 \leq \rho \leq \rho_{2_i}$	$\rho_i \leq \rho_2$

Step 4: To determine design priorities, the importance index of each function ξ_i needs to be calculated. This index is directly proportional to customer satisfaction Y_i and inversely proportional to dissatisfaction X_i (that is, the more dissatisfied customers are when it is missing, the more important it is):

$$\xi_i = \sqrt{X_i^2 + (1 - Y_i)^2}, \quad 0 < \xi_i < \sqrt{2} \quad (3)$$

Step 5: Considering that different types of needs have a nonlinear impact on the satisfaction index s_i, this study uses different functions to adjust the satisfaction index:

Performance Quality(Performance):

$$s_i = \frac{\overline{Y_i} - \overline{X_i}}{e - 1} e^{x_i} + \frac{\overline{Y_i} - e\overline{X_i}}{e - 1} \quad (4)$$

Performance Quality(Performance):

$$s_i = (\overline{Y_i} - \overline{X_i}) x_i + \overline{X_i} \quad (5)$$

Must-be Quality (Must-be):

$$s_i = \frac{e(\overline{Y_i} - \overline{X_i})}{e - 1}(- e^{-x_i}) + \frac{e\overline{Y_i} - \overline{X_i}}{e - 1} \quad (6)$$

Step 6: By combining the above indicators, obtain the final Kano importance weight w_i^2 for user needs C_i. This formula indicates that the higher the functional importance index ξ_i and the lower the current satisfaction index s_i, the more urgent it is to improve that function:

$$w_i^2 = \frac{(1 - s_i)\,\xi_i}{\sum_{i=1}^{n} (1 - s_i)\,\xi_i} \qquad (7)$$

C. TRIZ Theoretical Framework

Originally formulated by Altshuller through a meta-analysis of patent data, TRIZ provides a systematic grammar for solving engineering contradictions. In this study, it acts as the translation layer between the psychological needs identified by the A-Kano model and the physical realities of device engineering. We focus specifically on "strong antagonistic relationships"—points where satisfying a user's need creates a conflict in the hardware design. To resolve these impasses, we employ a three-step translation process. Qualitative user feedback is first mapped onto the 39 standard engineering parameters. These are then cross-referenced in a contradiction matrix to highlight the tension between parameters that improve and those that deteriorate. This logical mapping points us toward specific Inventive Principles (such as segmentation or extraction), which guide the actual structural redesign of the rehabilitation device, turning abstract conflicts into tangible functional improvements (Figure 2).
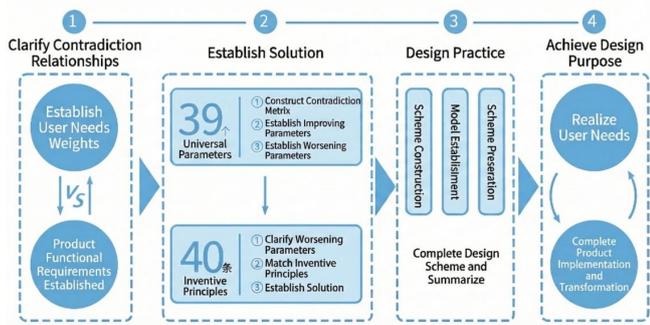

Fig. 2. Product design practice step chart
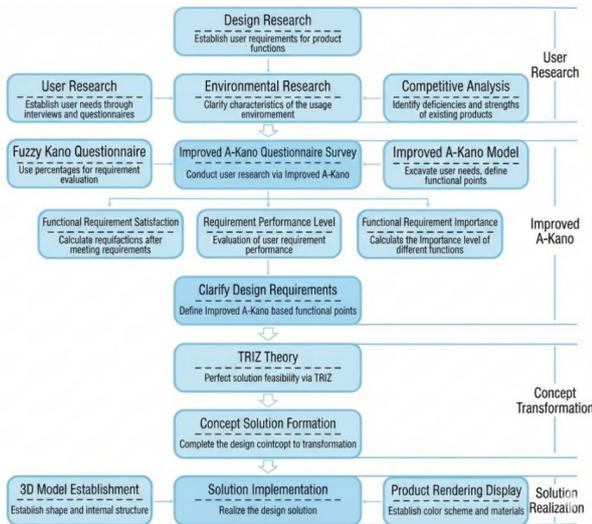
Fig. 3. Design process of rehabilitation aids for stroke patients

D. Design Process Based on the Integrated Model

We structured the research framework around a cyclical "demand-contradiction-solution" feedback loop. The process commences with the aggregation of raw user data—derived from field studies and expert interviews—which is initially categorized via fuzzy clustering. To convert this qualitative data into actionable priorities, we employ the improved A-Kano model (Equations 1-7); this quantitative filtering allows us to isolate high-impact "core needs" from the noise of general requirements. These priorities then serve as the anchor for a technical feasibility analysis, where we utilize the TRIZ contradiction matrix to map the specific engineering conflicts that hinder implementation. By applying TRIZ's 40 inventive principles to these identified friction points, we derive a multi-dimensional solution that addresses functionality, form, and technology. The result is a coherent methodology that systematically translates vague, implicit user desires into precise engineering specifications.

III. NEEDS ANALYSIS AND SOLUTION GENERATION

A. User Needs Identification and Classification

Based on research data concerning the environment, users, and competitor products, this section explores the functional needs of rehabilitation aids for stroke patients, as shown in Figure 3. Needs are categorized according to different characteristics, and their weights are calculated; the design direction is then clarified based on the importance of each need. By conducting observational research on the target users and considering factors such as usage scenarios, usage methods, and product functions, numerous pain points were identified. Taking both explicit and implicit needs into account, the needs were classified into four aspects: safety, practicality, aesthetics, and innovation. A summary of functional needs was developed, forming a functional requirements framework for rehabilitation aids for stroke patients as shown in Table 6.

TABLE VI. LIST OF FUNCTIONAL REQUIREMENTS FOR REHABILITATION AIDS FOR STROKE PATIENTS

Safety	X_1	Fall prevention and emergency braking	The equipment can detect imbalance tendencies and automatically brake or support to prevent secondary injuries.
	X_9	Spasticity detection and relief intervention	Monitor muscle spasms and provide immediate physical relief such as vibration or heat.
	X_{12}	Fatigue monitoring and alerts	Real-time monitoring of muscle fatigue levels; a rest reminder is issued when a threshold is reached.
Utility	X_3	Adaptive difficulty adjustment	Automatically adjust training resistance or difficulty based on the patient's current exercise capacity.
	X_5	Remote monitoring and guidance	Supports doctors or family members to remotely view training data and provide voice guidance.
	X_6	Lightweight, easy to wear and comfortable	The lightweight design makes it easy to put on and take off, and it feels comfortable to wear for extended periods without any pressure.
	X_8	Modular and multi-functional expansion	It has an interface that allows for the replacement of different training module accessories according to the rehabilitation stage.
	X_{10}	Personalized plan memory	Automatically record and load rehabilitation training parameter settings for specific users.
Aesthetics	X_7	Concealed appearance	The design de-emphasizes medical aspects, making it not only discreet and difficult to detect, but also protecting privacy.
	X_{14}	color scheme	The color scheme aligns with modern fashion aesthetics .

Innovation	X_2	Real-time biofeedback and data visualization	Physiological data such as electromyography and force are converted into intuitive visual feedback in real time.
	X_4	Gamification and Contextual Interactive Training	Combining virtual reality or screen interaction to provide fun, scenario-based rehabilitation games
	X_{11}	Social and peer motivation	Establish community functions to allow patients to help, communicate, and encourage each other.
	X_{13}	Intent recognition assistance	Using sensors to capture subtle motion intentions and actively assist in completing actions.

B. Improvement of A-Kano Requirement Analysis

Based on Table 5, the types of A-Kano product functional requirements were refined, and a total of 370 fuzzy Kano questionnaires on functional requirements were designed and distributed. The respondents mainly consisted of stroke patients, family members of stroke patients, and others. After excluding invalid questionnaires, 303 valid responses were obtained, resulting in a valid response rate of 81.89%. Although the sample size was limited due to the particular characteristics of the stroke patient group, according to relevant studies in fuzzy mathematics and design psychology, when focusing on user needs exploration in a specific vertical field (stroke rehabilitation), the sample size meets the convergence requirements for model calculations. It is sufficient to reflect the core needs and preference distribution of the target user group, and the data is statistically significant.

After collecting the survey results, based on steps 3 to 4 of the improved A-Kano calculation method, questionnaire data analysis was conducted to obtain the satisfaction values of functional requirements and their corresponding user requirement attributes, as shown in Table 7.

TABLE VII. TYPES OF FUNCTIONAL NEEDS OF REHABILITATION AIDS FOR STROKE PATIENTS

Serial Number	Functional elements	$\bar{x}$	$\bar{y}$	Attribute Classification
X_1	Fall prevention and emergency braking	0.75	0.82	Performance Quality
X_2	Real-time biofeedback and data visualization	0.24	0.65	Attractive Quality
X_3	Adaptive difficulty adjustment	0.48	0.58	Performance Quality
X_4	Gamification and Contextual Interactive Training	0.18	0.52	Attractive Quality
X_5	Remote monitoring and guidance	0.42	0.49	Performance Quality
X_6	Lightweight, easy to wear and comfortable	0.32	0.68	Performance Quality
X_7	Concealed appearance	0.25	0.28	Performance Quality
X_8	Modular and multi-functional expansion	0.38	0.42	Performance Quality
X_9	Spasticity detection and relief intervention	0.71	0.78	Performance Quality
X_{10}	Personalized plan memory	0.41	0.45	Performance Quality
X_{11}	Social and peer motivation	0.15	0.38	Attractive Quality
X_{12}	Fatigue monitoring and alerts	0.62	0.55	Performance Quality
X_{13}	Intent recognition	0.21	0.61	Attractive

| X_{14} | assistance Stylish color scheme | 0.22 | 0.24 | Quality Indifferent Quality |

Classify the satisfaction of functional requirements according to the intervals of vector S, and draw a classification diagram of the functional requirements for rehabilitation aids for stroke patients, as shown in Figure 4.
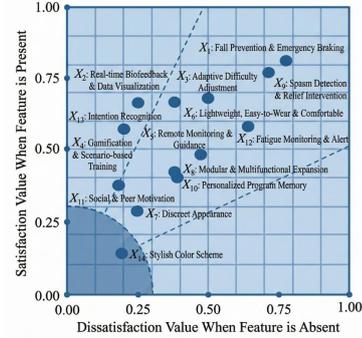
Fig. 4. Classification of Functional Needs of Rehabilitation Aids for Stroke Patients

As shown in Figure 4, performance and attractive needs include: intention recognition assistance, fall prevention and emergency braking, adaptive difficulty adjustment, gamified and scenario-based interactive training, spasm detection and soothing intervention, among others. These needs have clearly high attention and satisfaction levels and should be given priority in design analysis. Meanwhile, the analysis results show that fashionable color schemes are classified as indifferent needs, indicating that users do not pursue a "fashionable" decorative quality in rehabilitation aids. However, concealed appearance is identified as a high-priority performance need. This reveals a key user insight: stroke patients do not seek to express their individuality through "fashionable colors," but rather have an urgent need to mask signs of disability through "de-medicalized" and discreet design. Therefore, subsequent design strategies will focus on "morphological concealment" rather than merely "color decoration."

Based on the improved A-Kano calculation steps 5 − 7, the relevant data for must-be, performance, and attractive needs were calculated. The index of functional requirement importance is represented by , user satisfaction value by , and Kano importance by , as shown in Table 8.

TABLE VIII. IMPROVEMENT OF FUNCTIONAL NEEDS OF STROKE PATIENTS' REHABILITATION AIDS: A-KANO IMPORTANCE

Serial Number	Functional elements	ξ_i	S_i	w_i^2	Sort
X_7	Concealed appearance	0.762	0.258	0.1261	1
X_{11}	Social and peer motivation	0.638	0.139	0.1223	2
X_8	Modular and multi-functional expansion	0.693	0.395	0.0935	3
X_{10}	Personalized	0.686	0.426	0.0877	4

X_4	plan memory Gamification and Contextual Interactive Training	0.513	0.255	0.0851	5
X_5	Remote monitoring and guidance	0.661	0.449	0.0811	6
X_{12}	Fatigue monitoring and alerts	0.766	0.577	0.0723	7
X_{13}	Intent recognition assistance	0.443	0.310	0.0681	8
X_3	Adaptive difficulty adjustment	0.638	0.528	0.0671	9
X_2	Real-time biofeedback and data visualization	0.424	0.302	0.0660	10
X_6	Lightweight, easy to wear and comfortable	0.453	0.435	0.0570	11
X_9	Spasticity detection and relief intervention	0.743	0.760	0.0398	12
X_1	Fall prevention and emergency braking	0.771	0.803	0.0339	13

C. Contradiction Identification and TRIZ Application

The quantitative ranking results derived from the improved A-Kano model may suggest that TRIZ theory could provide systematic solutions to the critical engineering contradictions encountered during the implementation of these core requirements. Moreover, the initial step involves constructing a comprehensive function contradiction matrix that appears to be based on the significant interrelationships among the identified needs, and this matrix may enable accurate identification of the physical and technical conflicts that could emerge in the design process. Furthermore, the specific engineering problems are converted into the standardized TRIZ contradiction parameters to build a conflict problem model. Thus, invention principles recommended by the contradiction matrix are used to derive design strategies tailored to stroke rehabilitation assistive devices[16].

1) Construction of the Function Contradiction Matrix and Conflict Identification

Table 8's importance ranking might indicate 13 key requirements warrant cross-analysis, including "spasm detection and alleviation intervention," "lightweight, easy to wear, and comfort," "intention recognition assistance," and "modular and multifunctional expansion." Given that logical constraints among functional elements in engineering implementation require systematic examination, a contradiction matrix of functional requirements for stroke rehabilitation assistive devices is constructed in Table 9. Matrix analysis shows design faces two groups of "strong negative correlation" contradictions. Nevertheless, structural-level physical contradictions could epitomize friction between the imperative for "fall mitigation and emergency braking" and requisites of being "lightweight, ergonomic, and aesthetically unobtrusive," and to accommodate stroke survivor's demand for high-rigidity bracing against falls, the conventional architectures frequently resort to lamination of metallic frameworks.

In light of these engineering constraints, this trajectory invariably precipitates a bulky, ponderous form factor that appears strictly antithetical to user's aspiration for a "zero-burden" and "de-medicalized" visual identity. Additionally, technical contradictions at system level may refer to conflict between "intention recognition assistance" and "modular and multifunctional expansion." Notwithstanding the critical importance of precision, high-precision intention recognition could rely on integrated skin-contact EMG sensor arrays and the complex signal transmission wiring that might significantly increase system coupling. Thus, modular assembly and disassembly become difficult. However, this may raise threshold for operation and maintenance by elderly users.

2) Conflict Description and Transformation to TRIZ Universal Parameters

For the above core contradictions, this study may suggest that these contradictions could be mapped to the 39 standard engineering parameters of TRIZ, constructing the standardized conflict problem model (see Table 10): Moreover, structural optimization might indicate improving product support performance, which is defined as an improvement in No.27 Reliability. The resulting increase in physical burden is defined as a worsening of No.2 Weight of stationary object. Furthermore, intelligent expansion may show the essence of intention recognition functionality requires the device to dynamically adjust to individual patients' EMG signal thresholds. However, the device could switch control logic at different stages of recovery (such as spastic and recovery phases). This aligns with the TRIZ definition of "system adaptability to changes in external conditions" and is therefore mapped to an improvement in No.35 Adaptability and versatility. Given that sensor arrays are used, the increased complexity arising from sensor arrays corresponds to a worsening of No.36 Device complexity[17]. In light of the significant user interaction experience requirements, the system might indicate delivering real-time feedback information while reducing the cognitive load. Nevertheless, it is necessary to address the contradiction between No.33 Operability and No.24 Loss of information.

TABLE IX.   CONTRADICTORY MATRIX OF REHABILITATION AIDS FOR STROKE PATIENTS

Functional	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}

element number												
X_1					Sn	Sn	n	p				
X_2			p	Sp	p			p			p	p
X_3		p		p			p	Sp	p			
X_4		Sp	p						Sp			
X_5			p					p				
X_6	Sn					Sp	p					n
X_7	Sn				Sp		n					n
X_8	n		p		p		n					n
X_9	p	p									p	p
X_{10}				Sp	p							p
X_{11}				Sp								
X_{12}		p	p					p				
X_{13}		p				n	n	Sn	p	p		

*Note:p=positive n=negative Sp=Strong positive Sn=Strong negative

TABLE X. CONFLICT OF FUNCTIONS IN REHABILITATION AIDS FOR STROKE PATIENTS

Achieve the goal	Functions involved	Parameters to be improved (Feature to improve)	The consequently worsening feature.	Contradiction type
Structural optimization	Fall prevention and emergency braking Lightweight X_1, easy to wear, and comfortable X_6	No. 27 Reliability	No. 2 Weight of stationary object	physical contradiction
Intelligent Expansion	Intent recognition assistance Modular X_{13} and multi-functional expansion X_8	No. 35 Adaptability/Versatility	No. 36 Device Complexity	Technical contradictions
Concealed design	Concealed appearance X_7, fall prevention, and emergency braking X_1	No. 8 Volume of stationary object	No. 14 Strength	physical contradiction
Rehabilitation efficacy	Spasm Detection and Relief Intervention Lightweight X_9, easy to wear, and comfortable X_6	No. 33 Ease of operation	No.10 Force	Technical contradictions

TABLE XI. OPTIMIZATION OF REHABILITATION AIDS DESIGN FOR STROKE PATIENTS

Optimization direction	Improve parameters	Deterioration parameters	39 general technologies	Solution
Intelligent Expansion	No. 35 Adaptability and versatility	The complexity of device No. 36	No.1 Segmentation Principle No. 15 Principle of Dynamic Characteristics	Split-type kinetic module: The high-precision sensor is separated from the main structure and can be attached as needed. Active spasm compensation: Utilizing pneumatic/magnetorheological technology, it becomes softer when intention is detected and stiffer when spasm occurs. Magnetic split structure: The core power unit is detachable, and only a lightweight frame is worn for daily use.
Structural optimization	No. 27 Reliability	No. 2 Weight of a stationary object	No.1 Segmentation Principle No. 40 Principles of Composite Materials	Carbon fiber + liquid silicone: The main body is made of carbon fiber reinforced nylon to ensure strength, and the inner lining is made of silicone to improve skin-friendliness. Multimodal light language system: Replaces complex data with breathing light color (green/red) to intuitively reflect status.
Interactive experience	No. 33 Operability	No. 24 Information Loss	No. 23 Feedback Principle No. 26 The Principle of Replication	Tactile vibration warning: When a premonitory convulsion is detected, a linear motor vibration is used to provide a direct alert, reducing cognitive load.

3) Design Strategy Development Based on Inventive Principles

Based on the established conflict parameters, recommended inventive principles are obtained from the TRIZ contradiction matrix, and are then used in combination with the clinical characteristics of stroke rehabilitation to develop specific design strategies(Table 11):

Structural Solution Based on Principle No.1 Segmentation and Principle No.40 Composite Materials: To resolve the conflict between reliability and weight, the design strategy approaches from both "physical segmentation" and "scenario segmentation." The innovative "magnetic modular architecture" is proposed, which separates the heavy core power unit from the basic wearable frame. At home during rest, patients wear only the lightweight frame; during training, the power module is magnetically attached, allowing on-demand loading. In terms of materials, continuous carbon fiber-reinforced nylon is used in place of aluminum alloy, combined with a medical-grade liquid silicone liner. This ensures No.27 reliability while greatly reducing No.2 weight, thus achieving both rigid support and skin-friendly comfort.

Intelligent Solution Based on Principle No.15 Dynamics: To address the conflict between adaptability and complexity, the solution introduces an "rigid-flexible

coupled" adaptive drive logic. Pneumatic artificial muscles or magnetorheological dampers are used as actuators, allowing the assistive device to remain in a low-resistance, flexible following state (high adaptability) when no movement intention is detected. Once signals of spasm or a fall are captured, the system instantly hardens and locks (high reliability). This dynamic adjustment mechanism avoids complex mechanical transmission structures and effectively resolves system conflicts.

Interaction Solution Based on Principle No.23 Feedback and Principle No.26 Copying: To address interaction conflicts, a "multimodal light-language system" is designed. Intuitive breathing light color changes (green/red) replace complex digital display screens, translating obscure EMG data into visual signals that are easy for patients to understand; combined with linear motor tactile vibration alerts, visual information is transformed into tactile feedback, effectively reducing the cognitive processing burden for elderly patients and enhancing the immersive experience of rehabilitation training.

D. Final Design Scheme Presentation (Using Hand Rehabilitation Aids as an Example)

1) Design Concept and Functional Architecture of Stroke Rehabilitation Aids

We have learnt that this improved A-Kano model is an essential design, which is delicate in both "safety" and "rehabilitation efficiency." We propose "adaptive progressive rehabilitation," wherein the device has an active control on its intervention, and assists in the patient's physiological shifts during flaccid, spastic and recovery steps. We formulate this design in theory in the manner of TRIZ principles of dynamics, and remove rigid braces, by making the device able to "assist when necessary" to stimulate residual muscle strength.

Structurally the solution consists of three layers: perception, control and execution. The perception layer captures intention and spasm signals. The perceptual layer captures fingertip and forearm sensor with the help of the fingertip. This signals is fed to the control layer where the algorithm logic (calculated with the A-kano weight) determines rehabilitation difficulty. Finally, execution drives the movement using pneumatic muscles or servo motors to ensure smooth force delivery. With this modular design, we are able to fulfill "segmentation principle" by avoiding system coupling and achieve high performance in complex home settings.

2) Core Module Design and Concrete Realization of Invention Principles

Central to this design scheme is the TRIZ segmentation principle, materialized here as a "master control core and detachable bracket" configuration. Integrated on the forearm's dorsal side is the main module—containing power, processing, and communication units—while the rehabilitation brackets for fingers and wrists exist as independent entities, snapping into place via magnetic interfaces[10]. It is this segmentation that solves the puzzle of modular expansion: users may start with a basic anti-fall support and, as recovery progresses, install high-precision fingertip modules. The result is a significant drop in initial

wearing weight, a change that profoundly improves lightness and comfort scores.

Safety is engineered through the "pre-trigger damping mechanism," a feature inspired by the principles of preemptive prevention and dynamic characteristics. The moment sensors capture abnormally high-frequency limb shaking, the control system reacts: it preemptively alters pneumatic pressure to flip the device from "assist" to "damping protection" mode instantly. Through this fusion of physical warning and dynamic torque adjustment, the design intervenes effectively during sudden onset episodes. Finally, applying Principle 40, the material selection balances strength and weight. By pairing a 3D-printed nylon carbon fiber chassis with breathable silicone liners, the scheme achieves extreme lightness without sacrificing durability, successfully resolving the technical standoff between "support force" and "wearing load."[16]

3) Interaction Process and User Experience Design in Rehabilitation Scenarios

In order to solve a cognitive load issue of stroke patients, the scheme adopts the "multi-modal feedback" for interaction design.For online feedback, the product does not use a complex digital display and it just maps the image using a circular LED strip, green indicates movement goal, yellow indicates fatigue warning and red indicates spasm protection triggered. The non-textual visualization also reduces the cognitive load of the patient and serves as a communication gateway. A child or therapist could immediately see how tired or stiff the patient is by color changes without interruption of the training, providing a timely and inspiring intervention.This non-textual intuitive interaction technique allows reduced operational burden for elderly patients and reflects humanistic care in nursing.

During rehabilitation training, auxiliary devices connect to home smart terminals using Bluetooth (BT) for remote monitoring and game interaction.For grip strength training, the dynamic torque of the auxiliary devices changes with the game plot[18].Therefore, the rehabilitation training is more interesting[19] .After the training, a training progress curve is automatically generated according to the personalized plan.This full-chain design from physical assistance to psychological motivation turns into an attractive feature of A-Kano coordinate system, and TRIZ logical reasoning is used to trace the design touch points, which becomes more promising for product market change(Figure 5).

Fig. 5. Display of the appearance of rehabilitation aids for stroke patients

IV. DISCUSSION ON REHABILITATION AIDS

A. Satisfaction and the Coupling Mechanism of Technical Implementation

Modeling, One can transfer model data from the "users'

vague hearts" to "engineered exact solutions".

Example The A-Kano model can model "demand decoder" from stroke patients' "stamp safety and dignity" requirements to "dissatisfaction coefficients", or using TRIZ theory as "technical encoder", converting high-weight psychological needs to mechanical language.

Example (Linear Response of performance) For "lightweight, easy-to-wear, comfortable" specification, the technical encoding leverages TRIZ No.1 segmentation principle. From physical relationship of power module and support to a "demand driven adsorption" relationship, each percentage point of weight decrease in technical implementation results in a linear gain in user satisfaction, both physically and psychologically satisfied users achieve the same physical and psychological benefits.

Example(Over-Expectation Awakening) for attractive demand of assistive device.The technical coding leverages the No.15 dynamic characteristics principle. The medical device switches the pneumatic artificial muscles at millisecond-scale "spasm-damping" mode switching. The intuitive embodiment of "perception-response" beats the cold perception of the assistive devices. The technological "emotional awakening" can trigger the charm zone of the Kano model and turn users"seemingly compliance" into "active trust".

B. Design Strategies for Rehabilitation Products

1) Cognitive Interaction: Sensory Dimensionality Reduction Strategy Based on No.26 Duplication Principle

In order to tackle the common problem of a low cognitive speed of stroke patients, we take advantage of TRIZ No.26 duplication principle, which asserts "using simple cheap copies to replace complex expensive originals". In interaction design, we reduce dimension of "complex electromyographic values" to "intuitive color light language" by creating a low brain load mapping of "green light is safety and compliance" and "red light is spasm and danger", and the patients can train intuitively without considering higher-level reasoning. Such sensory substitution reduces the "digital divide" of the elderly, as a fundamental property of inclusive design.

By simplifying complex data into intuitive signals, the design addresses the need for "digital inclusion" and barrier-free interfaces, which have been proven to be key determinants of satisfaction in elderly healthcare technology[20].

2) Cognitive Social Integration: Implicit Design Strategy Based on "De-Stigmatization"

Rehabilitation assistive devices can be used to provide functional compensation and social image reconstruction.According to Goffman's stigma theory, products that exhibit exposed metal mechanical structures in traditional assistive device devices are often visualized as the "disabled identity" of users. Based on the original assumption of users for concealment of products in Kano model analysis, this work suggests a "de-medicalization" design. TRIZ principle 40 "composite materials" are proposed, lightweight materials such as carbon fiber and skin friendly fabrics are introduced and assistive equipment are seen as "sports equipment" rather than "medical devices." Specialized material is utilized to cover up appearance, "aid - disability" is attached and is guaranteed to bring the patient's self-esteem in family or community social interactions, while rehabilitation is successfully monitored in terms of psychology. By going from 'medical device' to 'sports equipment,' the design essentially eliminates the social stigma of disability. By doing so, the patient is able to reconstruct the social identity of a patient, and can also use the aid in a community environment, which allows better social integration.

C. Limitations

Although we have constructed a joint design model and proof of concept, two limitations remain. The first concerns sample representativeness. We utilized 303 valid questionnaires; while this meets the convergence requirements for the fuzzy Kano model, the respondents were primarily urban patients in the recovery phase. Consequently, the derived demand weights reflect specific subgroup preferences rather than the entire population.

The second limitation concerns the verification level. This study focuses on the 'design-definition' and 'compliance-validation' phases rather than physical clinical trials. However, as noted by Portz , high abandonment rates—often due to poor user experience—are a primary barrier to home rehabilitation success[12]. By validating the design through the improved A-Kano model, we prioritized psychological acceptance to address this issue. Thus, although physical clinical data is pending, the established high-compliance design logic serves as a critical proxy for potential rehabilitation efficacy. Future work will proceed to longitudinal clinical trials with high-fidelity prototypes to quantify the physiological benefits of this compliance-driven design.

V. RESEARCH SUMMARY

We have addressed the tradeoff between supply and demand ofstroke rehabilitation and the industry-wide challenge of highabandonment rate of current home-use assistive devices. Our proposed design involves a novel design paradigm by integrating an improved A-Kano model with TRIZ theory. We have achieved great results at three perspectives: theoretical, engineering, and social.

From a methodological perspective, we have established a mechanism to achieve accurate "psychological-physical" mapping. By introducing an improved A-KANO model, we overcome subjective limitations of qualitative analysis by quantifying unambiguous needs of stroke patients at different rehabilitation stages identifying "spasticity detection and relief intervention" and "intention recognition assistance" as the essential pain points. As well as providing an objective mathematical anchor to design choices, by incorporating the TRIZ contradiction matrix, it further transmits implicit psychological needs of "sense of safety" or "feel of dignity" into general engineering parameter conflicts, confirming the scientific merit of combining psychological models and engineering theory for medical product development. On the engineering side, we

developed a novel structural architecture, "full-cycle adaptability," to address the fundamental physical contradiction of "rigid support" versus "lightweight comfort." By working on the TRIZZ segmentation and dynamic characteristics principle, we develop a "magnetic modular framework" for enhancing and maintaining "adaptive damping". Our novel design technique is superior to the static and unchanging functionality of traditional assistive device. Dynamic transitions from strong protection in the flaccid step to demand-based assistance during the recovery step can be easily adopted. Our results show offers a solution to the "double paradox" between advanced functional integration and ease of home use, thereby achieving both good rehabilitation outcomes and a better user experience.

On the social level, we established a human-centered design code focusing on "de-medicalization" of modern assistive medical devices. We show that the ultimate goal of assistive robot design is not to replace or compensate physical function, but to facilitate a return of a patient to his or her social function. Our design uses carbon fiber composites and a " soft-language" interactive system with low cognitive load, and overcomes the stigma associated with medical device. Our approach transforms assistive technology into "emotional empowerment media" that can help reduce home rehabilitation compliance and provide a practical model of what the industry.

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