



A Disability-Oriented Analysis Procedure for Leisure Rehabilitation Product Design

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Abstract. The leisure activities of current disabled people are primary static types rather than dynamic types. However, most marketed leisure exercise products seldom consider the requirements of the disabled people especially their slow reactions on hand grasp and eye perception. This situation always makes the disabled people be unable to do normal lifestyle activities. The preliminary investigation showed that certain cerebral palsy people with minor disorders have strong desires to do leisure rehabilitation activities. As such, the objective of this research is to try to focus on the redesign of certain leisure exercise products for the cerebral palsy people and derive specific combination of functions and design guidelines for designer reference. During the development process, an AIO (A: activity; I: interest; O: opinion) questionnaire regarding user feelings, preferences and requirements is designed and distributed the related subjects to explore more precise user requirements. The analytic results are forwarded to the process of conjoint analysis and quality function deployment to help identify some critical design characteristics for the design of leisure rehabilitation products. Several design alternatives are generated based on the proposed design criteria. The generated design alternatives are represented in 3D rendering images with the assistance of computer-assisted software. It is expected that the proposed design process of the leisure rehabilitation product development and recommended design alternatives can provide designers with disability leisure exercise product design guidelines and requirements.

Keywords: Leisure rehabilitation product design · Disability-oriented design · Conjoint analysis · Quality function deployment

1 Introduction

Rehabilitation apparatuses are considered as part of the body for the disabled persons and have been widely used. In general, rehabilitation apparatuses can be classified as personal assisted apparatuses, skill training apparatuses, rectified implements, personal motion apparatuses, personal medical and protective equipments, living rehabilitation apparatuses, living furniture, communication and information assisted apparatuses, tooling, machining and environmental improvement equipments, leisure assisted apparatuses and multipurpose implements [1, 2]. Due to a gradual increase on the disabled people, a variety of rehabilitation apparatuses techniques and development become important to our society. Previous investigation showed that the existing rehabilitation apparatuses

can meet daily requirements of the disabled people, but they expect to have the same living quality as normal people, especially on leisure activity requirements [1]. It appears that a good rehabilitation product design should meet the disabled requirements and can help improve their living quality. Therefore, explore living problems and identify requirements for the disabled are an important issue in rehabilitation technique study. Our preliminary research on the requirements of the disabled people has found that some of them such as cerebral palsy people with minor disorder symptoms will expect to have certain types of leisure rehabilitation products for their daily activities. Unfortunately, there are only very limited leisure rehabilitation products in the market and even do not consider the disabled requirements. It is noted that the cerebral palsy people usually have slow reaction on hand control and eye perception and cannot use regular leisure products for rehabilitation. As such this research will focus on the cerebral palsy demands for recreational sports products and explore the best combination of design guidelines and recommendations based on the requirements of cerebral palsy leisure activity lifestyle.

In product design, the designer must collect many types of information including both product-user requirements and design development in related field. Since the designer has his or her own subjected opinion, the integration of knowledge and experience designers of similar products will greatly improve the quality of product design. Current techniques in product design process indicated that conjoint analysis can be used to help identify the optimum combination of user requirements for specific group [3]; while quality function deployment can be used to effectively link user requirements with design characteristics and determine design criteria [4–6]. In order to explore suitable designs for the requirements of the cerebral palsy people, the objective for this research effort is to apply the concepts of conjoint analysis and quality function deployment in the leisure rehabilitation product design process to develop suitable leisure rehabilitation products for the cerebral palsy people.

2 Development Procedure

During the development procedure, the research considers not only the requirements of rehabilitation functions and user sensation, but also appropriate product form and multi-purpose. The research has three stages of development. The first stage is identification and analysis of cerebral palsy requirements on recreational sports or rehabilitation products, including: (1) data collection on cerebral palsy characteristics, (2) collection of existing regular leisure products and rehabilitation products, and (3) factor analysis for identifying user requirements. The second stage is employment of conjoint analysis and quality function deployment (QFD) technique that will help determine suitable recreational sports or rehabilitation product design criteria for the cerebral palsy people. In the process of conjoint analysis, the research used an AIO (A: activity; I: interest; O: opinion) questionnaire associated with factor analysis to help identify requirements of the cerebral palsy people. Based on the conjoint analysis, the research will determine specific requirements for groups of the cerebral palsy people. The requirements for the first group of the cerebral palsy people are then chosen and forwarded to the process of QFD analysis. According to the evaluation results from the QFD process, some critical design characteristics are identified. As to the third stage,

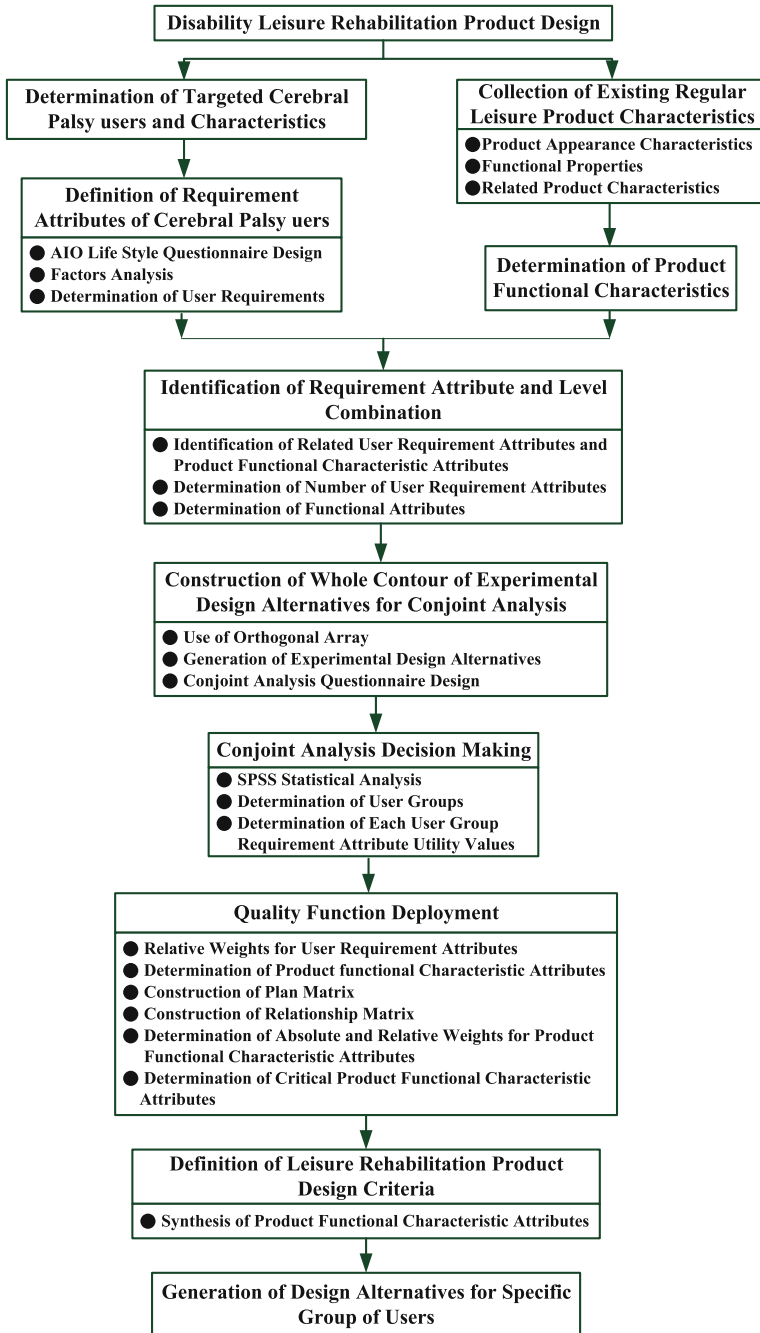


Fig. 1. A conceptual structure showing the procedure for leisure rehabilitation product design

the integrated construction of leisure rehabilitation product design is the major part. The research will develop some conceptual design alternatives for recommendation of the first group of cerebral palsy people. The process used in developing leisure rehabilitation product design alternatives is shown in Fig. 1.

3 Identification of Leisure Rehabilitation Requirements for the Cerebral Palsy People

In the first stage of development procedure, the research will explore leisure rehabilitation activities of the cerebral palsy people to help identify their suitable leisure rehabilitation requirements [7]. Since a proper linkage between user requirements and design characteristics can get potential benefits on developing better product designs for the cerebral palsy people, the development procedure will include data collection on cerebral palsy characteristics and related leisure exercise or rehabilitation products. To identify the requirements of the cerebral palsy people, the research will use an AIO questionnaire incorporating in the statistical factor analysis [7]. It is noted that obtain essential information about characteristics of the cerebral palsy people will help analyze their preference groups and the corresponding requirements; while the collection of existing regular leisure exercise products and rehabilitation products can identify potential design characteristics for further product development [4].

3.1 Data Collection on Cerebral Palsy Characteristics

Cerebral palsy is a kind of permanent movement disorders because of abnormal brain development that occurs in early childhood. In general, cerebral palsy is not a progressive disorder and cannot be cured, but it can become more severe. The symptoms of cerebral palsy may include poor coordination, stiff muscles, weak muscles and tremors that will lead to multi-development problems on sensation, vision, hearing, speaking, cognition, social emotion and learning, especially control of movement, balance and posture [8]. It is noted that the symptoms of cerebral palsy may vary greatly among individuals and do not cause profound disabilities. Jones et al. [2] further indicated that the associated disorders for the cerebral palsy include intellectual disabilities, sudden physical inability, muscle contraction, abnormal gait, communication disorders, etc. However, certain supportive treatments, medications and surgery may help cerebral palsy people improve their skills and ability of body movement [9]. The ability for the cerebral palsy to live independently varies widely and will depend on the severity of impairment and capability of self-management.

Some people will require personal assistant service for all activities of daily living, but others may only need assistance on specific activities or even do not need any physical assistance [2]. This research will focus on those cerebral palsy people who do not need any physical assistance. Since leisure activities for the cerebral palsy people are noted to have positive effects on physical health and life satisfaction, researchers tried to develop some formal or informal activities to help reduce muscle stress,

increase coping activities, increase companionship, physical relaxation and enjoyment [1, 10]. This research will focus on those cerebral palsy people who do not need any physical assistance.

3.2 Collection of Existing Regular Leisure or Rehabilitation Products

The study showed that electronic games of leisure rehabilitation products can provide the cerebral palsy people with enjoyable fun and direct operational involvement. These activities also have clear rules and objective that encourage the cerebral palsy people to challenge their capability and help them improve their disability. Current marketed electronic leisure products that are available for the cerebral palsy people seldom consider the cerebral palsy requirements, such as slow movement on eyes and hands, weak ability of grip and operation, and use of a wheelchair. Landreth [11] suggested that specific kinds of toys for the play therapy may include pile up, simulated family living, shooting, hammering, boxing, palm type ragdoll, softball playing and transportation type of simulated driving.

3.3 Factor Analysis for Identifying Cerebral Palsy User Requirements

In designing suitable leisure rehabilitation products for the cerebral palsy people, it is important to take physiological functions of human bodies, comfort, pleasure, aesthetics, maintenance and care, and consumers' lifestyles into consideration [12]. As such the research is developed based on user experiences that apply questionnaires, psychographic analysis and statistical factor analysis to identify requirement attributes and explore their preferences on leisure activity products [13]. The research developed an AIO (A: activity; I: interest; O: opinion) lifestyle questionnaire to help identify candidate user requirements [7]. A total of 36 AIO-type questions were designed, which included 16 types of activities, 12 types of interests and 8 types of opinions. This questionnaire is distributed to the selected test subjects of cerebral palsy people. There were 21 effective questionnaire results obtained from 13 male and 8 female people. The results of questionnaire survey were forwarded to the statistical software SPSS for a factor analysis. According to the result of factor analysis, 36 AIO-type questions were pooled to 12 specific requirement attributes and also formed into five factors, as illustrated in Table 1. Based on the semantic contents of 12 requirement attributes corresponding to each factor, the research defined five factors as (1) appearance, (2) adjustment, (3) operation, (4) safety, and (5) feedback. In Table 1, five factors associated with their attributes were identified: (1) appearance (simple form and big size), (2) adjustment (handle enlargement, button enlargement and speed adjustment), (3) operation (simplified and repetitive operation, easy reading and low speedy display), (4) safety (fixed type, and pressure endurance), and (5) feedback (sound and flash light). The identified five factors and associated requirement attributes are then forwarded to the conjoint analysis to determine the requirements of user groups.

Table 1. Illustration of requirement attributes associated with factors

Factor Matrix after Data Rotation					
AIO Life Style Requirement Attribute	Factor				
	1	2	3	4	5
36 Simple Form	.899	.207	-.077	.137	-.023
21 Big Size	.885	.180	.019	.052	-.046
34 Handle Enlargement and Bolder	-.126	.828	.041	.293	.012
32 Push Button Enlargement	.352	.756	.096	.142	-.187
8 Speed Adjustment	.448	.626	-.225	-.208	.420
10 Simplified and Repetitive Operation	.379	.094	.829	.118	.180
13 Readability	.160	.067	.783	-.003	.402
12 Low Display Speed	.168	.232	.730	.388	.093
2 Fastener	.302	.186	-.204	.852	.106
4 Pressurization	-.107	-.054	.413	.830	.161
19 Voice Reminder	-.322	.039	.187	.158	.871
20 Flash Light Reminder	.558	.056	.040	.175	.703

4 Employment of Conjoint Analysis and Quality Function Deployment

Followed by the first stage of development procedure, the second stage of this research conducts the procedures of conjoint analysis and quality function deployment. The conjoint analysis will be used to evaluate the requirement factors and attributes and help identify preference attribute combination of group cerebral palsy people. While the analysis of quality function deployment will link the preference requirements of specific group of cerebral palsy people with design characteristics of leisure rehabilitation products that help determine a combination of critical design characteristics for further product development [4, 14].

4.1 Conjoint Analysis for Identifying Group Requirements of Cerebral Palsy People

When dealing with the process of conjoint analysis, dummy variables and utility values corresponding to the identified requirement attributes are defined. The concept of orthogonal array is applied in the experimental design that helps efficiently conduct the measurement [15]. Note that the statistical computer software SPSS V14 is used throughout the proposed research. Considering a minimum size of the orthogonal array in conjoint analysis, the SPSS V14 software helps generate an orthogonal array with a 16 experimental design and will be called as “Card1”, “Card 2”, ... and “Card 16”, respectively. Each experimental design consists of one requirement attribute assigned from each factor that constitutes design characteristics of a leisure rehabilitation

product design alternative. To conduct the experiment, the research designed 16 cards with the size of 10×10 cm cardboards and organized each of combined requirement attributes in the cardboard. The original 21 tested subjects were asked to make a pair-wise preference evaluation of combined requirement attributes among the 16 cardboards. It is noted that the concept of multiple linear regression models will be applied in the measurement of component utility values for the combined requirement attributes of a cardboard. In a multiple linear regression model, the value of preference order associated with values of dummy variables will then be considered as dependent and independent variables, respectively. These component utility values of dummy variables for the 21 tested subjects are then forwarded to the SPSS software for a K-means clustering analysis. In this research, the 21 tested subjects were divided into three groups. The results of each component utility value for the corresponding requirement attribute of three groups are illustrated in Table 2.

Table 2. Group component utility values of requirement attributes

Factor	Level	Requirement Attribute	Group Component Utility Value		
			Group 1	Group 2	Group 3
Appearance Type	1	Simple Form	0	1.188	0
	2	Big Size	0.375	0	1.375
Adjustment Type	1	Handle Enlargement and Bolder	1.361	3.000	1.094
	2	Push Button Enlargement	1.944	4.250	0
	3	Speed Adjustment	0	0	3.297
Operation Type	1	Simplified and Repetitive Operation	1.528	1.813	0
	2	Readability	1.856	0.625	1.556
	3	Low Display Speed	0	0	0.859
Safety Type	1	Fastener	0	0.375	0
	2	Pressurization	0.972	0	0.766
Feedback Type	1	Voice Reminder	0	2.563	1.563
	2	Flash Light Reminder	2.333	0	0

4.2 Construction of a House of Quality of QFD

The 9 tested subjects of Group 1 were asked to make a quality function deployment survey to measure the relationships between customer requirement and design characteristic attributes, respectively. To develop a house of quality (HOQ) of quality function deployment, the research made an investigation on identifying suitable leisure rehabilitation design characteristic attributes. The investigation involved the cerebral palsy people, tested subjects, school mentors and supervisors, parents of tested subjects, and current leisure recreational products. The research summarized 12 design characteristic attributes that are thought to be related to the customer requirement attributes. The 12 design characteristic attributes are (1) error reminder, (2) character

size, (3) clear indication, (4) control area size, (5) targeted control size, (6) user dominant role, (7) simplified operation process, (8) material selection, (9) sticky fastener, (10) avoid redundant decoration, (11) avoid sharp angles, and (12) simple manual operation. After customer requirement attributes and design characteristic attributes having been defined, the research performed the process of quality function deployment analysis. Since this research will primarily deal with the generation of design alternatives, the development of quality function deployment only considers the core part of the relationship matrix. The general steps for developing a simplified house of quality in quality function deployment are stated as follows [4–6]:

- Step 1. List customer requirement attributes and place them on left side of the house.
- Step 2. List design characteristic attributes and place them on top of the house.
- Step 3. Determine relative weights for customer requirement attributes.
To evaluate customer requirement attributes, the concept of analytic hierarchy process (AHP) [16] is used. In implementing pairwise comparisons between two customer requirement attributes, a questionnaire survey based on a measurement scale with points 1–9 and their reciprocals is distributed to the tested subjects. The points of 1–9 represent the strength of relative importance of a customer requirement attribute compared with the other customer requirement attribute. The values of 1–9 represent equal, weak, ..., and extreme importance between customer requirement attributes. Note that geometric means are calculated to pool evaluation values of all tested subjects. By the summation of the geometric means of all customer requirement attributes, a normalization process is also calculated to obtain relative weights for each customer requirement attribute. The relative weight value of each customer requirement attribute is expressed as a percentage.
- Step 4. Evaluate close relationships between customer requirement attributes and design characteristic attributes to form a relationship matrix.
The relationship matrix evaluates the strength of the linkages between customer requirement attributes and design characteristic attributes. Each matrix cell indicates a relationship that represents the impact strength of a design characteristic attribute on a corresponding customer requirement attribute. The strength relationship is assessed with a rating scale of 0, 1, 2, 3, 4, and 5 to represent none, very weak, weak, medium, strong, and very strong, respectively. The measured data from all tested subjects are averaged and filled in the corresponding cells of the relationship matrix.
- Step 5. Calculate the absolute weight for each design characteristic attribute.
To calculate the absolute weight for each design characteristic attribute, simply do the summation of the value by multiplying the relative weight value of each customer requirement attribute with the corresponding relationship matrix cell value of a design characteristic attribute. The summation denotes the contribution of that design characteristic attribute to the overall customer satisfaction.

Step 6. Normalize the absolute weights of design characteristic attributes to be relative weights.

The relative weight value for each design characteristic attribute is calculated as the absolute weight value of a customer requirement attribute divided by the summation of all absolute weight values of customer requirement attributes. Each relative weight value of the design characteristic attribute is expressed as a percentage.

Step 7. Determine certain critical design characteristic attributes for further product development.

The relative weights of design characteristic attributes are ranked according to their relative priorities. It means that a higher rank corresponds to a more important design characteristic attribute and needs to pay more attention to product development.

Figure 2 illustrated the construction of a partial house of quality in quality function deployment for the group 1 survey. The result of quality function deployment analysis showed in Fig. 1 revealed that the design characteristic attributes of “targeted control size”, “user dominant role”, “control area size”, and “error reminder” can be considered as critical design characteristics for further improvement in product design.

	User Requirements Relative Weight (100%)	Error reminder	Character size	Clear Indication	Control Area Size	Targeted Control Size	User Dominant Role	Simplified Operation process	Material Selection	Sticky Fastener	Avoid Redundant Decoration	Avoid Sharp Angles	Simple Manual Operation
Simple Form	4.35	2.6	3.0	2.7	3.6	4.6	3.2	3.0	2.4	3.0	3.6	3.0	2.0
Big Size	4.35	3.0	3.8	2.0	3.6	4.6	4.0	3.6	2.0	3.4	3.4	3.3	3.0
Handle Enlargement and Bolder	16.5	3.5	2.2	2.0	4.4	4.5	4.2	2.8	2.4	3.0	2.2	3.0	2.0
Push Button Enlargement	22.1	3.2	2.8	1.7	3.4	4.2	4.2	3.2	3.0	4.4	3.2	3.6	3.5
Speed Adjustment	1.72	3.0	2.8	4.0	2.6	4.2	2.7	2.6	2.2	4.4	3.2	2.6	2.1
Simplified and Repetitive Operation	3.88	3.4	3.2	4.0	2.6	4.0	3.6	1.8	2.2	3.0	3.0	3.6	2.2
Readability	1.87	3.8	3.4	4.2	2.8	4.0	2.7	1.6	2.4	3.4	3.8	2.0	2.1
Low Display Speed	15.8	2.6	2.4	4.2	2.8	4.4	3.4	1.6	2.4	3.4	3.0	2.6	3.0
Fastener	0.92	2.0	3.6	3.0	3.6	4.8	4.2	3.2	2.4	2.4	2.6	2.3	3.0
Pressurization	13.1	4.0	3.4	2.3	4.0	4.8	2.8	3.6	2.6	1.4	2.4	2.6	3.5
Voice Reminder	7.73	2.6	2.0	2.5	2.6	2.2	3.0	2.0	2.6	2.0	2.6	2.0	2.0
Flash Light Reminder	7.73	3.0	2.4	3.4	3.4	3.0	3.6	3.2	3.2	2.0	4.0	2.3	3.2
Design Characteristics Absolute Weight	317	271	266	345	414	363	276	261	305	294	289	284	
Design Characteristics Relative Weight (100%)	8.6	7.4	7.2	9.4	11.2	9.9	7.5	7.1	8.3	8.0	7.8	7.7	
Design Characteristics Ranking	4	10	11	3	1	2	9	12	5	6	7	8	

Fig. 2. Construction of QFD’ house of quality for Group 1

5 Generation of Conceptual Design Alternatives

The analysis of quality function deployment for group 1 of the tested subjects shown in Fig. 2 provides designers with clear design criteria for developing design concepts. This research proposed three concepts of design alternatives. These design alternatives will be focused on activities of upper and lower extremity, and eye movement rehabilitation exercise. They are (1) fight rodents game, (2) pedal touch panel, and (3) memory pair-off matching game.

The concept of fight rodent game design is based on the large scale of regular fight rodent game that reduces the size to fit the personal use. When playing the game, the user pushes the central red ON/OFF button. One of the surrounding 12 different colored rodents will rise up randomly in a relatively and reasonably time that allow the cerebral palsy people to use the wooden hammer to press it and get the score. The cumulative score will be displayed on a rectangular panel to encourage the user to make an effort to obtain a good score. Figure 3 illustrates the proposed design alternative of fight rodent game. The pedal touch panel is designed for the lower limb rehabilitation purpose. Basically, the front panel has six or more large circles. When the power is on, the user can apply the foot touching to any circle area and the circle area will emit the light and sound of music. Each time of pedal touch action will emit different color of light and sound of music that will make the user to continue his or her rehabilitation without showing boredom. Figure 4 illustrates the proposed design alternative of pedal touch panel. As to the memory pair-off matching game, it belongs to a kind of card play. The game can be available for single, couple, or multiple persons of play. The figure images of the cards are designed based on the concepts of both 12 Chinese animal signs and 12 constellation signs. Each card is doubled in pairs that make the total box of 48 cards. As to the play rules, it is similar to the game of memory matching in the Internet. However,



Fig. 3. A fight rodent game design alternative

people prefer electronic products. The research proposed a design procedure that involving conjoint analysis and quality function deployment to determine requirements of the cerebral palsy people. In the conjoint analysis, factors of user requirements including appearance, adjustment, operation, safety and feedback are identified. Based on the linkage between user requirement attributes and design characteristic attributes in the analysis of quality function deployment, the priority of design characteristic attributes are determined to be the design criteria. Three conceptual design alternatives, “fight rodent game”, “pedal touch panel”, and “memory pair-off matching game” are presented for further product development. It is expected that this research effort is directed toward the development of the procedures and will enhance the efficiency of design on leisure rehabilitation products to help the disabled persons or even social vulnerable groups in medical rehabilitation and living care.

Acknowledgements. The authors are grateful to the Fujian University Humanities and Social Science Research Base-Product Design Innovation Research Center, China for supporting this research.

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