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Modeling Design Method for Intelligent Industrial Robot Based on Perceptual Image

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Abstract:

For intelligent industrial robot for mining user perceptual demand of product modeling design elements, allows the user to intelligent industrial robot product modeling have better perceptual experience, use of eye tracking, skin conductance, heart rate variability with four categories such as brain electrical physiological activities emotional measurement technology, combined with the subjective psychological measurement technology such as semantic difference method, the qualitative and quantitative research combined with each other, put forward a kind of intelligent industrial robot based on perceptual image product modeling design method. The research shows that this method is effective, and the key features of modeling design elements of intelligent industrial robot products based on user's perceptual image are extracted, which provides scientific basis and reference for industrial designers to carry out modeling design of intelligent industrial robot.

***Keywords**: industrial design, modeling design, industrial robots, kansei image, physiological techniques*

I. INTRODUCTION

“Sensibility” refers to the emotional structure underlying human behavior [1]. Sensibility is the most direct feeling of things, is a person in the psychological perception of things, such as “perception”, “impression” or “image”. Sensibility is a subjective perception of a person’s creation, environment, or situation through his senses [2]. Autonomic activities such as neural arousal, subjective adjustment and cognitive evaluation will eventually influence and trigger emotional stimuli. The series of results that result from the interaction between a person and a product is called the “product experience” [3]. The product’s pleasure can move the user more [4]. Emotion is a psychological process of multi-component, multi-dimensional and multi-level integration generated by synthesizing multi-sensory information. Product emotion design is complicated, fuzzy and changeable, which is difficult to control and grasp, making product emotion design and research face great difficulties. The word “Image” comes from psychology. Image is different from the idea of rational thinking. It is the process of thinking activities such as imagination, association, imagination or conjecture. Image emphasizes the content of the state of mind and perception, refers to the impression of things in people’s minds, and is also the most prominent perceptual information conveyed by external objects. Image is a kind of conscious activity. Only when it is interpreted by experience and knowledge can the information after identification be

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converted into another form of information, which can finally be stored and used by the memory system [5]. Perceptual image is a highly condensed deep emotional activities, is the person feeling of things, people's perception of the product form perceptual image products, designers can according to consumers' needs and ideas, to discuss the product should have the perceptual image, image dug up the user's demand and to gain design elements, thus reducing product cognitive differences between designers and consumers, it is the key to product design optimization [6]. It can shorten the development cycle of new products [7]. At present, theoretical system has been formed in this aspect, mainly "kansei engineering" and "emotional design".

Applying kansei engineering technology to conceptual design, a new technique of parallel design and visualization of user cognitive structure is obtained[8-10]; Kansei engineering is applied to all kinds of product innovation to study and obtain the personalized product design method of quantifying subjective needs[11-15]; The application of kansei engineering in automobile design evaluation and other fields has made great achievements, which has made great progress in kansei engineering [16-18]. The research of kansei engineering applies the fuzzy neural network and grey theory to the evaluation of product color image [19-20], Genetic algorithm and neural network are used in perceptual evaluation [21-22], Psychological and physiological indicators were incorporated into kansei engineering methods [23-25]. It also constructs a framework that involves the designer's emotion in the sketches and models in virtual reality to get the immersive experience [26]. A perceptual data modeling method based on language expression and a user-centered product evaluation model are proposed [27-28].

The three-level theory, which emphasizes the product innovation design from the three levels of instinct, behavior and reflection, can arouse the surprise of consumers. Based on biology, neuroscience and psychology, this paper discusses how the emotional system changes the operation of the cognitive system, and Outlines the role of aesthetic products that reflect emotions in the design. The research on emotional design and emotional experience obtained the concept of "Product Emotion", developed emotional measurement tools for Emocards and PrEmo products, constructed the framework of Product experience, and expressed the relationship between evaluation and design project with qualitative and quantitative research methods [29-30]. These results provide theoretical basis and technical support for emotion design research and emotion measurement. The research on the relationship between product attributes and pre-purchase emotion is mainly based on the relationship between the four variables of "purchase criteria", "product attributes", "pre-purchase emotion" and "purchase intention" to study the relationship between the above two variables, confirming that emotional design can significantly improve the usability and emotional quality of products [31-35]. Emotional system research of emotional design mainly carries out data mining on the mapping relationship between emotional needs and user patterns, which provides a more extensive method for the development of new products for the relationship between consumers' emotional needs and products [36-38]. By studying the relationship between physiological signals such as cardiovascular or brain wave changes and emotion, the method applied to discrete emotion analysis and the theory of metaphor structure in emotion design are obtained [39-41]. Aiming at the problem of visual impression emotion, the formation mechanism and emotion design method of shape perception emotion response of design objects are obtained [42-45].

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Through the immersive virtual reality experience and psychophysiological experiment, the problem of emotional participation in design task was studied [46-47].

With the rapid development of artificial intelligence technology and the in-depth exploration of brain science, perceptual design has more entry points in interdisciplinary and cross-disciplinary research. Research in this field covers cognitive science, psychology, ergonomics, informatics, design and brain neuroscience. With the further pursuit of a better life in human society and the continuous enhancement of the realizability of science and technology, the traditional product design concept dominated by “functional utility” or “technology” has turned into the modern product design concept dominated by “user experience” or “emotion” [48].

II. FUNDAMENTAL KNOWLEDGE OF METHODS

The accurate measurement of emotion is an important prerequisite for emotional innovation design of products [49]. At present, the emotional factors of consumers are mainly measured by physiological and psychological means [50]. Consumer emotion from the perspective of physiological research of biological neural signals, known as physical measurement, the method with the aid of sensors measuring instrument, as measured by the consumer's brain waves, heart rate, skin sweat, potential physiological indexes such as change, breathing, expression, analysis the emotional state, access to the corresponding emotional information. However, psychometrics are more effective for measuring emotions at the mental or spiritual level. Psychological measurement means to survey people’s current emotional state and psychological feelings in the form of questionnaires, or to obtain emotional information based on the analysis of consumers’ oral reports. The semantic difference method is the most common one. With the continuous progress of information technology, virtual reality technology [51], 3d modeling [52] and internet-based survey technology [53]. It has also been widely used. Davidson’s research shows that the left antebellum and right antebellum are involved in approach-related and avoidance-related expression and experience, respectively, making it possible to explore emotion-specific activity patterns in EEG [54]. Ekman et al. studied subjects’ heart rate, left and right finger temperature, skin resistance, forearm flexural tension and other information during emotions of “anger, fear, sadness, joy, surprise and disgust”, and proposed the separability of discrete emotions [55]. Almost every basic emotion induced has its own specific changes, supporting the idea that different emotions have distinguishable patterns of peripheral physiological active [56]. Eye movement tracking technology has been widely used in many fields. The most widely used method in eye movement experiment is optical recording. Two kinds of modern brain imaging techniques are used to observe the cognitive activity of human brain in neurogenic experiments. One is the measurement of electromagnetic activity in the brain, such as electroencephalogram (EEG), event-related potential (ERP), and magnetoencephalogram (MEG); The other are techniques based on cerebral hemodynamics, namely functional magnetic resonance imaging (fMRI), positron emission tomography (PET), and transcranial doppler ultrasound (TCDS). Electroencephalogram is a special electrophysiological signal. EEG is a non-stationary and nonlinear signal. The amplitude of EEG signal is used to represent the intensity of brain potential, which is closely related to the number of neurons involved in synchronous discharge and their arrangement direction. EEG signals can be divided into four categories according to

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amplitude, namely low amplitude, medium amplitude, high amplitude and very high amplitude. The corresponding ranges are EEG signals less than 25 V, between 25-75 V, between 75-150 V and above 150 V. Electroencephalic signals are classified by frequency and can be divided into fast and slow waves, fast and fast waves, which are faster than the delta waves, and slow waves, which are slower than the delta waves.

From psychology to sociology, a variety of emotional psychological response measurement techniques have been developed, including verbal self-report and non-verbal self-report. Verbal self-report method refers to the method of measuring emotion by means of oral report of the subjects or paired perceptual adjectives combined with rating scale. The paper and pencil test method can be divided into two types, one is the direct questioning method [57], one is written analysis [58]. Multidimensional scaling analysis (MDS) was originally used to study people's mental states, creating a perception space that is linked to user preferences, and MDS becomes more substantial. To determine the area of space, a unit of measurement called stress will be measured. The stress calculation can be expressed by the following formula, where Dij is the average perception difference between object I and j, Dij is the Euclidean distance, xik is the coordinate of object I on the dimension k, and k is the dimension of the perception space selected by the experimenter. After the calculation, each object in Euclidean space USES the point Xi (xi1... , xiK). The point (Xi) I = 1... , the set of N provides a visual representation of approximate patterns between objects.

$$stress = \left[\frac{\sum_i\sum_j (d_{ij} - D_{ij})^2}{\sum_i\sum_j d_{ij}^{\ 2}}\right]^{1/2} \qquad where \quad d_{ij} = \sqrt{\sum_{k=1}^{n}(x_{ik} - x_{jk})^2} \qquad (1)$$

Another advantage of MDS is that it is based on instinctive variability assessment and does not impose any criteria or predefined semantic scales. A technique called "attribute fitting" (PROFIT) enables semantic attributes to be represented by "vector models" in the perceptual space to infer the meaning of the axis [59]. The vector field is realized by dividing the perceptual space into subspaces, and its vector space should be invariant. Each subspace is a vector field obtained through function optimization to minimize the energy function of the following 2N2 design variable:

$$\begin{aligned}
&E\ (V_{ij}) = \alpha E_1(V_{ij}) + \beta E_2(V_{ij}) \\
&E_1 = \sum_{i<j}(P_{MiMj} - P_{cMiMj})^2 \qquad (2) \\
&E_2 = \sum_{i=2}^{M-1}\sum_{j=2}^{M-1}(V_{ij} - V_{(i-1)j})^2 + (V_{ij} - V_{(i+1)j})^2 + (V_{ij} - V_{i(j-1)j})^2 + (V_{ij} - V_{i(j+1)})^2
\end{aligned}$$

Including: N is the product quantity, Mk is perceptual space said in a product k (k=1 to N) of point, PMiMj said is given by the user's preferences between Mi and Mj, PcMiMj is given by the model between Mi and Mj preference, Vij is marked as component (I, j) vector (Vijx, Vijy), as well as the grid of rows and columns. The first term E1 represents the sum of the squared error between the precise preference and the prediction preference, which is calculated as:

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$$P_{cM_iM_j} = \sum_{\Phi} \vec{V}_{ij} \frac{\overrightarrow{M_iM_j}}{M_iM_j} \qquad \textbf{(3)}$$

The second term E2 represents the evaluation of the smoothness of the vector field. In order to use the vector field model as the prediction model, the vector field has been extended to the whole perception space. Since E (Vij) (preference vector field) is constrained below, the vector field needs to satisfy all given preferences as much as possible in order to minimize E for local optimization. Finally, it is worth to note also that the balance between these terms was given by the weighted coefficients α and β. A gradient descendent was used for the minimization of E.

III. METHODS

3.1 Experimental Design

This VR experiment aims to explore subjects' cognitive process in watching industrial robots, analyze their observation process of overall images of the robots such as styles and colors, understand their feelings about designated industrial robots in combination with Perceptual image spaces of the robots, and verify if the product designs of industrial robots satisfy users' Perceptual psychological demands based on the subjects' eye movements, physiological signals, total scores and sequencing of samples. Varying images of industrial robots bring about different physiological and psychological changes. Superior creative industrial robots bring the subjects good Perceptual experiences, including psychological and physiological pleasure and comfort. Preliminary experiments were performed before formal experiments according to the experimental design scheme. At first, the subjects were informed of experimental processes and tasks. They made different physiological and psychological responses to samples of industrial robots observed by wireless experimental equipment under VR conditions to record the signals. Subsequently, they filled up the Perceptual questionnaire form for each sample and questionnaires were collected back. After all 20 subjects completed the test in succession, the experiment came to an end.

3.1.1. Participants

Twenty participants (9 male and 11 female), include designers, researchers and developers of industrial robots, university students, design professionals, psychology professionals, took part in the experiment. The mean age was 23 years old (24for males and 23 for females). All participants reported normal hearing and normal or corrected-to-normal vision.

3.1.2. Apparatus

In this study, ErgoLAB, a man-machine synchronization platform developed by Beijing Shenzhou Jinfa Technology Co., Ltd and including ErgoLAB 3.0 (software for man-machine synchronization), was used in combination with WorldViz VR helmet system, aGlass (VR-based device for tracking eye movements), wearable wireless physiological recording modules such as ErgoLAB PPG/BVP (wireless pulse sensor for blood volume) and ErgoLAB EDA (wireless electrical design sensor), 9 channels of

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wearable wireless EEG measurement system, wireless EEG/ERP/BCI system with dry active electrode, and functional modules for data analysis (including Eyetracking, General, HRV, EDA and Statistic).

3.1.3. Independent variable

Images of industrial robots (three-dimensional models of 8 representative samples + 1 creative sample).

3.1.4. Dependent variables (indicators)

Eye movements (direction, duration and track of eye gaze), physiological signals (indicators for electrical conductance of skin and heart rate variability) and EEG signals.

3.1.5. Stimulus materials

Three-dimensional models of 8 representative samples and 1 creative design sample (use Unity design scenes and develop programs)

3.2 Procedure

3.2.1. The experiment to prepare

Before the experiment begins, the experimenter needs to prepare the required materials for the experiment, including the experimental stimulus materials: 8 representative sample 3d models and 1 innovative design sample 3d model, as well as the table of questions, records and other data to be asked during the experiment. The stimulus material is the 3d model of the sample, which needs to be built in the early stage of the scene in Unity software. In the process of setting up the scene, it is necessary to determine the background environment, including the environment scene, lighting and other environmental factors. Determine model placement and adjust model size; determine the initial position of the perspective, etc., and finally export the program file for use in the virtual reality device. Before the experiment begins, the experimental materials are imported into the virtual reality equipment. The experimenters need to cooperate with professional staff to install and debug the equipment, so as to ensure the normal use of the experimental equipment and the normal stimulation materials.

According to the experimental design, a preliminary experiment is required before the formal experiment begins. Pre-test plays an important role in scientific research projects. The purpose of pre-test is to explore the best experimental conditions, experimental methods, etc., and to test the feasibility of experimental design and operation. Invite two subjects, according to the procedure and method of the formal experiment, first carry out the pre-test. After the completion of the preliminary test, the process of the preliminary test is summarized and counted, and the links and processes of the experimental design are properly modified, then the formal test can be carried out.

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3.2.2. Experimental introduction and baseline collection

Before the experiment began, the subjects were read the prepared experimental instructions, and through explanation and communication, the subjects were given a detailed explanation of the experiment contents and matters needing attention, as well as the operation areas and methods of the experiment. After confirming that the subjects understood the relevant contents of the experiment, they first wore EDA, a wireless skin sensor, and PPG, a wireless blood volume pulse sensor, to collect the ecg and electrodermal baseline.

The baseline should be collected when the subjects are in the resting state, and the duration of baseline collection should be up to three minutes. The baseline was collected to understand the basic ecg and cutaneous electrical levels of each subject. Each person's physical quality is not the same, there are different levels of ecg and galvanic skin, in stimulated also can have different physiological indicators, if need to make sure that there are stimulated in the experiment of physiological indicators, you need to understand the most basic subjects in quiet state of ecg and galvanic skin level, the level is called the baseline. The baseline will be used as an indicator for reference and comparison of experimental data for each subject.

3.2.3. Wear the experimental instrument and calibrate it with eye tracker

After baseline collection, participants were fitted with an infinite EEG device and a virtual reality headset. After checking the electroencephalogram, electrodermic signal and pulse signal, the virtual reality eye movement recorder was calibrated. During the calibration process, the height and pupil distance of the virtual reality helmet were adjusted to achieve the best detection conditions.

3.2.4. Formal experimental process

After the eye tracker calibration is completed, the experiment can officially start. The formal experiment is divided into two stages: the first stage is the independent model observation and scoring stage; the second stage is the model summary observation and comprehensive ordering stage.

Played in a random order of the first stage experiment, 8 representative sample and a model of innovation design sample, each model after the play, let the participants watch 40 seconds, 40 seconds later, prompt subjects based on science and technology feeling this attribute, the industrial robot is score, score for 1 to 7 points, 1 points according to science and technology are the lowest, seven points, said the highest sense of science and technology. After scoring, the subjects were recorded by the subjects and switched to the next model.

In the second stage of the experiment, after viewing 8 representative sample models and 1 innovative design sample model in turn, it was suggested that the subjects would switch to the general model scene, in which the above 9 industrial robots would be displayed at the same time. The subjects were given 2 minutes to freely observe the industrial robots. After observing for 2 minutes, the subjects were instructed

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to gaze at the 9 industrial robots for 5 seconds according to their preference for them from high to low, and the subjects were recorded in a comprehensive order according to their fixation order. In order to ensure accurate recording, the subjects could ask questions briefly during the process.

IV. RESULTS AND ANALYSIS

During the whole experiment, a total of four kinds of original data including eye movement level, skin conductance level, heart rate variability level and EEG level were collected, and subjective questionnaires were also collected. Therefore, in the following data analysis and processing, it is necessary to process and analyze four kinds of physiological data indicators and subjective psychological response indicators.

4.1 Eye movement level indicator

The eye movement tracking module of virtual reality is to install high-precision eye movement tracking elements in the virtual reality glasses. By emitting infrared light, the head and eye movement of an individual can be measured, and the eye movement point, eye movement trajectory, observation time, pupil size and other information of the individual can be recorded and synchronized. By 20 of the subjects to superposition eye movement data, get the final nine samples of industrial robot heat map, the formation of the hot spots, preliminary deduce the participants can focus more focused on the following several parts of the industrial robot: forearm parts, arm elbow connection part and lower part of the big arm and the base of the waist part.

TABLE I STATISTICAL TABLE OF THE AVERAGE NUMBER OF FIXATION IN THE AREA OF INTEREST BY SAMPLE

AOI AVG / Samples	AOI-1	AOI-2	AOI-3
Sample1	28.05	26.15	30.95
Sample2	34.40	6.93	32.65
Sample3	42.00	20.14	28.71
Sample4	25.05	23.75	26.08
Sample5	35.00	36.00	15.67
Sample6	38.00	34.00	38.00
Sample7	15.51	37.03	30.40
Sample8	14.17	26.67	45.67
Sample9	20.29	24.64	30.43
Sum	252.47	235.31	278.56

To further study quantitatively the degree of each part of the industrial robot attention in image, and can be divided Interest Areas (Areas of Interest, AOI) for research, three forms part of the industrial robot respectively corresponding AOI area 1, 2, 3, AOI AOI and count by focusing your number to each part of statistical analysis of importance of each sample fixation counts statistics as shown in TABLE I.

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Analysis of the above table data, to understand the AOI 3 represents the lower part of the big arm and the base of the waist a corresponding observed average number and total most times, combined with the fifth chapter of numerical analysis result of type I, that is to say, in the most high-profile three subjects for industrial robot morphological characteristics, wrist, arm connecting the elbow part and lower part of the big arm and base of the middle seat, big arm connects with the base of the lower lumbar area is the most overlooked by the participants, in the design of industrial robots need to focus on design.

The fixation point and the gaze path of each subject when viewing the sample can be obtained through the line of sight scan, as shown in Fig 1. The Numbers in the circle of each fixation point represent the order in which the subject views the picture.

The visualization tool of colony diagram can dynamically superimpose the fixation points of a group of subjects on the selected stimulus material for synchronous playback, so as to analyze the changes of fixation points of all subjects. After colony figure playback, you can see 20 subjects in the process of watching the fixation point falls in the middle of the picture area was the first, and then start from static to the first observation points, the fixation point moves to the robot wrist part, followed by the forearm and elbow, arm, waist, base, is a top-down view process as a whole.

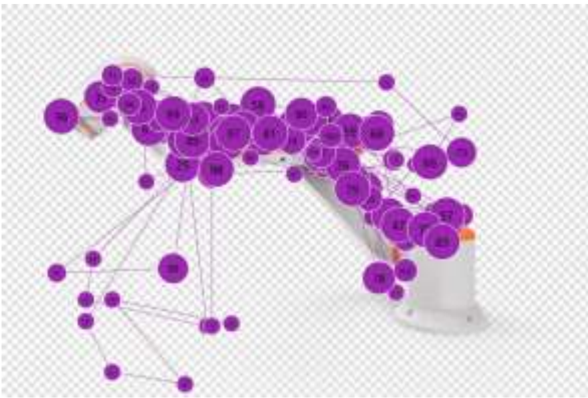

Fig. 1. Line of sight scan path diagram

Comprehensive the above analysis, the morphological characteristics of the industrial robot can be obtained in the key of important influence on the user's cognitive characteristics is the wrist, elbow joint parts and the waist and the base area, the waist and base site to look at the most respected, most times, the lower part is the user first observed area, the elbow part fixation point, is the user to observe more attention in the area, also verified the quantification analysis of type I second impact base first, forearm, elbow third analysis results.

The main indexes of eye movement tracking experiment include fixation time, fixation times, saccadas, etc. In this experiment, two indexes of average fixation time and average fixation times were selected to analyze eye movement. Average fixation time refers to the average fixation time in a certain area of interest (AOI). The larger the average fixation time, the more complex the content in the area of interest,

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the richer the details. Average fixation number refers to the number of fixation points in a certain interest area (AOI), that is, the number of fixation points in the interest area.

The AOI area is divided into 9 cases on the screen by using the tool of polyline or box. Each AOI area is covered on each case and the color should be distinguished. A total of 9 AOI areas are drawn according to the number of cases. After drawing in AOI region, eye movement hotspot map, AOI division diagram and scanning path map of each sample need to be collected. First, the experimental data were analyzed and summarized based on the data derived from the eye movement hotspot map.

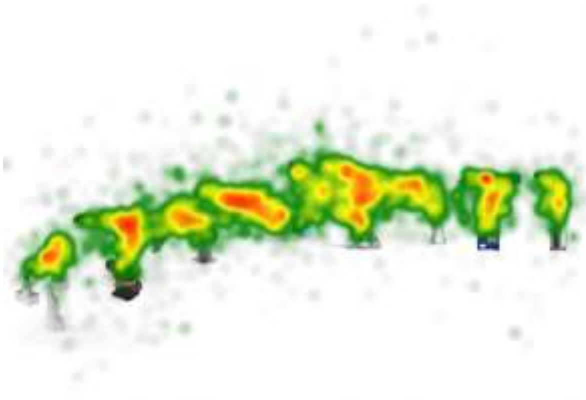

Fig. 2. Eye movement hot spot

Fig 2 is the scene hotspot diagram of the total model of eye movement experiment. In order to facilitate the observation of the model samples, the transparency of the hot spot map area was reduced to 80%, so that the sample model could be observed without affecting the visual effect of the hot spot map. From the heat map, it can be intuitively observed that the fourth model on the left, that is, the red color in the region of sample 9 is large and dark, so it can be known that sample 9 has certain advantages over the other 8 samples in terms of the time or number of observations, indicating that the subjects are more inclined to watch sample 9.

Fig. 3. A schematic map of the division of interest (AOI)

Fig 3 shows the interest area (AOI) divided by the scene of the total eye movement experiment model. The interest area is divided by model monomers, and the 9 sample model pictures are divided into 9

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rectangular interest areas. After dividing the interest area, the data can be quantified to obtain the data of average fixation time and average fixation times.

TABLE 2 and TABLE 3 show the statistical table of average fixation times in the interest area and the statistical table of average fixation time in the interest area respectively. From these two tables, we can see the average number of eye movement points in each interest area and the average duration of each gaze. From the above data, it can be concluded that the fixation times of 20 subjects to 9 industrial robots are 9 > samples, 4 > samples, 7 > samples and 3 samples. It can be known that compared with the other 8 samples, the innovative design sample 9 is more able to attract the attention of the subjects and arouse their interest in watching. From average fixation time table, you can see the sample average fixation time on 6th September, but compared with sample 1 ranked the first, the average fixation time difference is only 0.11 seconds, in consideration of the top 3 sample 1 and sample 2 samples, sample 5, 4 in a fixed position in the scene at the end, 1, 2 and the location of the center, there are subjects gaze into the scene and pause after finish sorting interference, interference effects can be in the later experiment by changing the model of location.

TABLE II STATISTICAL TABLE OF AVERAGE GAZE TIMES IN INTEREST ZONES

TESTED NUMBER	**SAMPLE1**	**SAMPLE2**	**SAMPLE3**	**SAMPLE4**	**SAMPLE5**	**SAMPLE6**	**SAMPLE7**	**SAMPLE8**	**SAMPLE 9**	**AVG**
001	26.00	49.00	51.00	79.00	25.00	45.00	47.00	52.00	74.00	45.83
002	23.00	34.00	44.00	94.00	48.00	47.00	45.00	41.00	97.00	48.33
003	39.00	52.00	38.00	39.00	22.00	26.00	68.00	49.00	44.00	36.00
004	25.00	70.00	48.00	41.00	7.00	46.00	41.00	29.00	81.00	39.50
005	14.00	22.00	56.00	81.00	21.00	36.00	51.00	41.00	80.00	38.33
006	3.00	22.00	8.00	9.00	66.00	2.00	134.00	68.00	19.00	18.33
007	23.00	69.00	87.00	47.00	4.00	7.00	5.00	0.00	9.00	39.50
008	8.00	30.00	16.00	53.00	14.00	24.00	39.00	23.00	53.00	24.17
009	5.00	15.00	42.00	66.00	22.00	20.00	22.00	22.00	50.00	28.33
010	21.00	24.00	40.00	49.00	58.00	13.00	54.00	37.00	67.00	34.17
011	18.00	45.00	43.00	54.00	33.00	22.00	60.00	37.00	68.00	35.83
012	8.00	17.00	57.00	68.00	23.00	48.00	66.00	55.00	94.00	36.83
013	21.00	38.00	56.00	43.00	11.00	35.00	45.00	44.00	47.00	34.00
014	21.00	69.00	52.00	61.00	6.00	30.00	11.00	13.00	39.00	39.83
015	2.00	9.00	30.00	33.00	13.00	39.00	59.00	41.00	76.00	21.00
016	0.00	3.00	40.00	57.00	5.00	40.00	27.00	32.00	89.00	24.17
017	18.00	32.00	31.00	49.00	33.00	39.00	56.00	60.00	70.00	33.67
018	20.00	39.00	38.00	71.00	3.00	52.00	36.00	46.00	83.00	37.17
019	18.44	40.33	43.33	56.56	25.44	28.11	50.22	36.11	56.33	35.37
020	14.33	30.67	43.00	53.89	20.56	35.33	46.00	40.56	70.33	32.96
AVG	16.39	35.50	43.17	55.22	23.00	31.72	48.11	38.33	63.33	39.42

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TABLE III STATISTICAL TABLE OF AVERAGE FIXATION TIME IN INTEREST ZONES

Tested number	Sample1	Sample2	Sample3	Sample4	Sample5	Sample6	Sample7	Sample8	Sample9	AVG
001	0.27	0.20	0.17	0.17	0.30	0.14	0.17	0.17	0.15	0.18
002	0.19	0.21	0.27	0.22	0.29	0.20	0.23	0.19	0.28	0.23
003	0.25	0.24	0.18	0.14	0.20	0.17	0.13	0.21	0.15	0.17
004	0.26	0.22	0.17	0.17	0.29	0.17	0.23	0.22	0.19	0.21
005	0.26	0.18	0.20	0.21	0.13	0.19	0.16	0.16	0.19	0.17
006	0.65	0.25	0.25	0.36	0.21	0.11	0.32	0.25	0.18	0.24
007	0.13	0.14	0.13	0.15	0.07	0.07	0.07	0.20	0.10	0.09
008	0.24	0.56	0.30	0.31	0.20	0.20	0.20	0.22	0.42	0.26
009	0.28	0.27	0.22	0.28	0.32	0.33	0.23	0.25	0.23	0.27
010	0.34	0.27	0.20	0.32	0.24	0.29	0.20	0.21	0.21	0.25
011	0.24	0.16	0.15	0.15	0.28	0.19	0.14	0.15	0.16	0.18
012	0.33	0.11	0.16	0.17	0.15	0.19	0.20	0.19	0.14	0.17
013	0.32	0.21	0.20	0.15	0.25	0.18	0.21	0.16	0.16	0.18
014	0.38	0.34	0.29	0.27	0.26	0.22	0.33	0.24	0.27	0.27
015	0.99	0.18	0.16	0.13	0.21	0.21	0.16	0.16	0.16	0.17
016	0.33	0.40	0.25	0.25	0.19	0.30	0.27	0.27	0.32	0.26
017	0.27	0.18	0.15	0.16	0.30	0.16	0.19	0.18	0.16	0.19
018	0.16	0.14	0.12	0.16	0.16	0.19	0.18	0.16	0.14	0.16
019	0.28	0.25	0.21	0.23	0.22	0.18	0.19	0.21	0.21	0.20
020	0.37	0.22	0.19	0.19	0.23	0.21	0.21	0.19	0.19	0.20
AVG	0.33	0.24	0.20	0.21	0.22	0.20	0.20	0.20	0.20	0.22

The data generally showed that the innovative design sample model had rich details, which could attract the attention of the subjects, who were interested in the innovative design sample model. According to the knowledge of eye movement psychology and cognitive psychology, the longer the subjects observe a certain area, the more interested they are in this area. More details of this area need to be identified and felt by the subjects. According to the experimental results, the subjects are more interested in samples 9 and samples 4.

4.2 Skin conductance level indicator

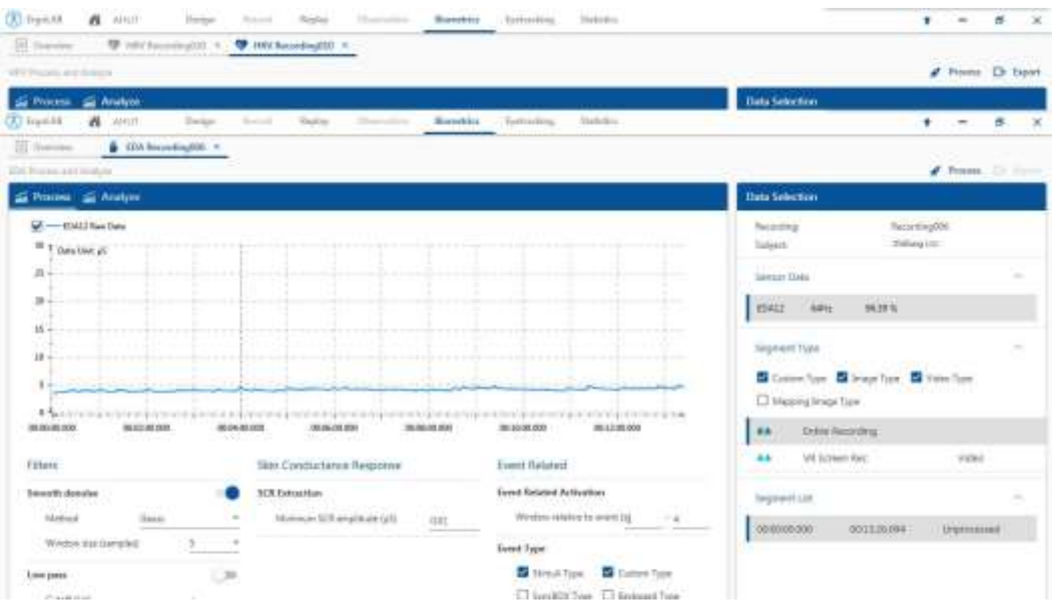

Fig. 4 Electrical index curve of an experimenter

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Skin conductance can be used to evaluate people's image activity, arousal level, emotional response level and other indicators, is one of the important means of studying human emotions, measuring emotional response time, intensity and frequency. Dermal electrometry is the change of skin conductance brought about by the change of sweat gland activity under different emotional or reaction conditions. By measuring the change of sweat gland secretion, we can understand the state change of sweat gland activity, skin vessel contraction and relaxation, and obtain the result of skin electrometry. For the measurement of skin electrical responses, the most significant results were measured at the palms of the hands and the soles of the feet. In this study, sensors were measured at the fingers. The skin electrical index curve of a subject is shown in Fig 4 First, filter Settings were used to smooth denoise and low pass the EDG data, and SCR extraction was conducted through the case of SCR conductance response. See figure 5.

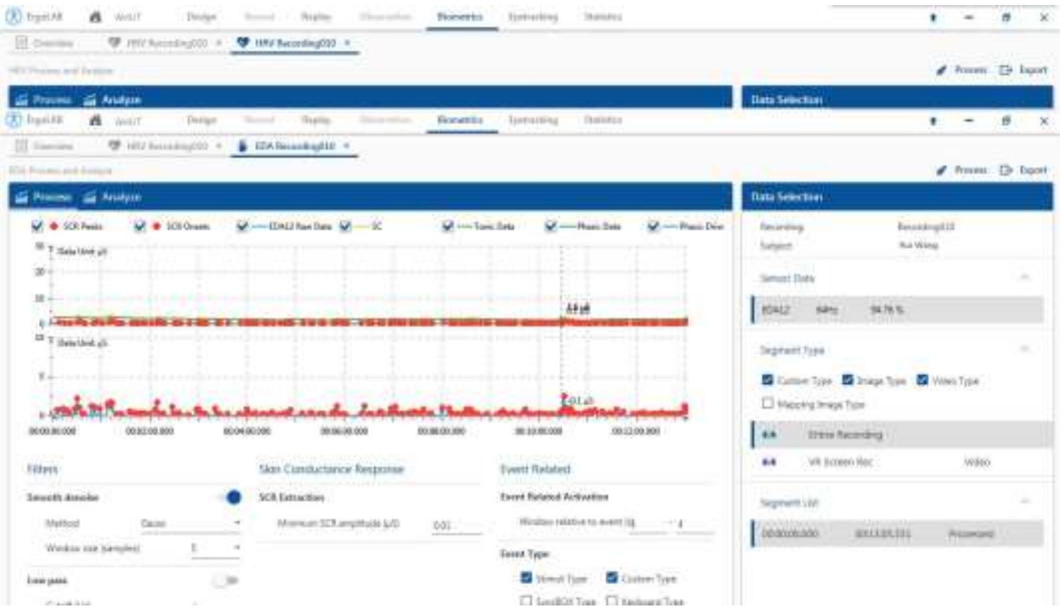

Fig. 5. EDA data noise reduction parameters

Through preliminary data noise reduction and qualitative parameter processing, the baseline time domain analysis results of skin conductance were obtained as shown in TABLE IV and the time domain analysis results after skin conductance stimulation as shown in TABLE V.

TABLE IV TIME DOMAIN ANALYSIS OF THE SKIN CONDUCTANCE BASELINE

TESTED NUMBER	MEAN(MS)	MAX(MS)
001	3.82	4.44
002	4.37	4.95
003	2.24	2.98
004	6.33	8.42

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005	6.36	6.86
006	3.99	4.74
007	1.09	1.32
008	1.45	1.61
009	1.02	1.40
010	2.85	3.98
011	7.72	9.00
012	0.96	1.06
013	1.52	1.97
014	15.17	16.27
015	1.31	1.48
016	4.67	5.79
017	6.40	7.31
018	3.10	3.22
019	2.75	2.97
020	4.07	4.99
AVG	4.06	4.74

TABLE V TIME DOMAIN ANALYSIS RESULTS AFTER ELECTRICAL STIMULATION OF SKIN

Tested number	Mean(μS)	Max(μS)
001	4.02	4.54
002	8.94	10.39
003	4.06	4.77
004	14.83	17.18
005	8.83	10.08
006	9.81	11.82
007	1.95	3.34
008	5.31	6.54
009	4.96	6.90
010	10.68	12.63

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011	9.40	11.06
012	2.26	2.57
013	3.00	4.77
014	12.75	14.91
015	5.35	5.89
016	1.65	1.91
017	6.28	8.11
018	3.22	3.89
019	3.37	3.84
020	3.84	4.50
AVG	6.23	7.48

Electrodermal response and sympathetic excitation showed a positive correlation, that is, sympathetic excitation, the body is in the excited state, at this point the human sweat gland secretion activity becomes active, the skin electrical indicators will increase the trend. It can be seen from the above analysis results that, compared with the baseline resting state of the subjects, the Mean (Mean S) and maximum (Max S) of the subjects' skin electricity level generally increased during the experiment, so it can be considered that the subjects' bodies were in an excited state when viewing the experimental materials.

4.3 EEG level indicator

The research needs to record the electrode before setting the reference electrode. EEG signals are usually recorded using the unipolar lead method, which USES a common reference electrode and multiple recording electrodes. The recording of eye electrical signals is often done by the bipolar lead-in method, which records the relative potential difference between two points. The recording of ERP data basically adopts the global unified 10-20 international electroencephalography standard lead system, In this paper, a 19-channel EEG recording system is applied as shown.

Subjects watch a different sample model of industrial robot Visual evoked brain potentials (Visual evoked potential, the VEP) collected through the experiment, data sampling time for 900 ms, stimulus for deviation before 100 ms to 800 ms after deviation stimulation, and then apply the EEG recording system and software Matlab7.0 evoked brain potentials for further data processing, using SPSS21.0 software for statistical analysis. The processing parameters of EEG data are as follows.

Electroencephalogram derivative: 19
Reference electrode: whole-brain average
Filter setting: 1HZ-30HZ
For data Amplitude in Bands [µv]

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Selection and number of subjects : Subjects included the designers, researchers and developers of industrial robots, university students, design professionals, and psychology professionals. A total of 20 subjects were included in the experiment. Studies have shown that a-wave occurs when a person is "at ease", "relaxed", comfortable or feeling happy; In contrast, a-waves are suppressed when uncomfortable or stressed. At the same time, when people focus on something and feel particularly happy, wave a is also suppressed, and there are depression waves. Therefore, by measuring the changes in the composition of the brain waves, it was possible to analyze whether 20 subjects felt comfortable and happy or uncomfortable under the stimulus of 9 samples of industrial robots. The analysis of the influence of stimulation on brain waves is mainly based on the mean values of different amplitude-especially α wave and β wave, as shown in TABLE VI. θ waves have a frequency of 4 ~ 7Hz and an amplitude of 20 ~ 150μv. θ waves are more obvious in the occipital and parietal lobes, and appear in adults when they are sleepy. The δ wave frequency is 1 ~ 3Hz and the amplitude is 20 ~ 200μv. δ waves often occur in the frontal region. Normal adults have almost no δ waves when they are a wake, but they appear during sleep. The electroencephalogram (EEG) of normal adult is mainly composed of α wave, with slow wave activity of β and a small amount of low amplitude θ wave, but no obvious δ wave.

TABLE VI AVERAGE OF THE AMPLITUDES OF EACH SAMPLE

AMPLITUDE MEAN VALUE / SAMPLE	AWAVE	BWAVE	ΔWAVE	ΘWAVE
Sample 1	121.44	172.51	317.11	162.12
Sample 2	92.16	151.43	193.35	110.09
Sample 3	100.38	156.12	186.53	111.74
Sample 4	102.76	158.35	218.14	127.59
Sample 5	97.02	149.65	207.85	118.84
Sample 6	93.10	144.63	203.74	110.18
Sample 7	81.92	134.46	162.50	100.94
Sample 8	92.75	143.86	187.75	107.64
Sample 9	92.24	155.53	166.86	101.57

As the sample change, at the early stage of α wave amplitude is relatively high, and β wave amplitude decreased significantly, showed that the participants in the condition of relatively relaxed, cheerful, and later to 9 samples of this period of observation period, α wave was suppressed, β wave began to recover, shows that the subjects gradually into a state of concentration observation, in the sample during the observation of 9, α waves can be suppressed, little change, β wave rapid rebound, showed that the

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participants are stimulated larger under centralized state. It can be seen from this that sample 9, that is, the innovative design sample, gives obvious excitement to the subjects.

4.4 Statistics and analysis of questionnaire data

In formal experiment of two stages, the main subjects for the two problems of questioning, respectively was conducted for 9 samples of different single sense of science and technology, and the model of in nine samples total summary to present in the scene of samples by the degree of be fond of according to its comprehensive model to sort the results by the main subjects to record, and after the experiment data statistics and analysis. The scores of single sample and sample ordering are shown in TABLE VII and TABLEVIII.

TABLE VII SAMPLE SCORE TABLE

Sample number / Tested number	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9
001	5	4	4	6	5	3	5	4	6
002	3	3	6	6	5	2	5	2	5
003	3	4	5	6	6	2	5	3	7
004	5	4	3	6	4	3	5	5	6
005	3	4	7	5	6	4	5	2	6
006	4	3	3	6	4	4	4	2	3
007	3	1	6	6	4	2	6	3	5
008	4	3	5	7	4	2	6	1	7
009	4	2	3	4	5	2	3	1	5
010	1	3	4	1	5	1	2	1	5
011	3	2	1	6	5	4	6	3	4
012	4	5	4	6	4	4	6	5	6
013	1	2	4	3	5	2	6	3	5
014	5	4	6	5	6	4	5	3	7
015	5	2	3	6	5	3	4	3	5
016	4	3	6	5	5	3	5	2	7
017	5	4	4	6	5	2	6	5	5
018	6	2	6	5	4	3	5	4	7
019	3	2	5	6	3	2	4	3	7
020	2	2	5	4	6	6	4	3	7
AVG	3.65	2.95	4.5	5.25	4.8	2.9	4.85	2.9	5.75

TABLE VIII SAMPLE RANKING SCORE TABLE

Sample number / Tested number	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9
001	6	7	5	1	4	9	3	8	2
002	7	6	4	2	3	8	5	9	1
003	6	8	4	1	5	7	3	9	2
004	4	9	8	1	2	6	5	7	3
005	7	8	2	6	3	4	5	9	1
006	7	8	5	1	6	4	2	9	3
007	7	9	1	5	2	6	4	8	3

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008	7	8	3	1	6	5	4	9	2
009	3	8	4	1	6	5	7	9	2
010	7	5	4	8	3	2	6	9	1
011	9	8	7	3	5	6	1	4	3
012	8	7	4	3	5	6	1	9	2
013	4	7	3	6	2	8	5	9	1
014	5	9	7	1	4	8	2	6	3
015	6	8	2	3	5	7	4	9	1
016	9	7	5	2	6	4	1	8	3
017	5	8	2	4	6	7	3	9	1
018	5	7	3	2	6	8	4	9	1
019	7	9	3	6	2	5	4	8	1
020	9	6	7	1	3	4	5	8	2
AVG	6.4	7.6	4.15	2.9	4.2	5.95	3.7	8.25	1.9

From the top of the separate sample rating scale can be seen that the highest average score is 9 samples, namely the innovation design samples, and you can see, each participant is given the score, sample 9 scores are relatively high in this sample, can be fully proved in the 9 samples, innovative design samples of science and technology feeling is the strongest.

As can be seen from the top of the sample sort assessment, each participant in the nine samples model according to his be fond of the process of sorting, all the sample 9: innovation design samples in the top three, and on average, the highest ranked show innovative design samples for unanimous subjects, prove that innovative design solutions to meet the preset targets.

Through the above cross-eyed dynamic index and heart rate variability index, and skin conductance index data statistical analysis, statistics and questionnaire data analysis, can draw the following conclusions: through the subjective questionnaire survey with physiological data acquisition analysis method, the experimental stimulus samples of 8 representative samples of industrial robots and 1 industrial robots in samples of innovation design, innovative design samples of industrial robots can better stimulate subjects, more for the participants.

V. DISCUSSION

Kansei experiments for measuring eye movement typically incorporates 2D images and forms such as web pages and photos as stimuli. However, the difference between the effects of abstract and product forms on people's Kansei evaluations requires further investigation. We maintain that the form elements reported by Fann, Chuang, and Hsu [60] by affecting the Kansei evaluations of people in 2D image experiments also influence the Kansei evaluation of 3D forms. In this study, we use 3D modeling technology to transform 8 experimental samples from 2D to 3D, and then combine them with innovative experimental samples of 3D modeling to form a group of comparable experimental samples, and then carry out the experimental study. The results show that the experimental results are more reliable.

Identifying the emotion-related product attributes (perceived by consumers) is a challenging task in the field of emotional design. Conventionally, this process relies profoundly on the researchers who conduct the Kansei experiments and select the product attributes such as color, form, and texture for Kansei studies.

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However, in that way, other product attributes that also play a vital role in product-emotion associations may be neglected. More importantly, the identification of product attributes should be based on user emotions. A product configuration analysis method for an emotional design using a personal construct theory is introduced by Yuexiang Huang et al. [61]. In this paper, the Kansei experiments include a large number of real users so that the experimental results can reflect the emotional needs of users better.

Tomomi Nomura and Yasue Mitsukura [62] found what kinds of emotions users have while watching TV commercials in the presence of words (lines, a jingle, a sound logo, and on-screen words) that were later remembered, by using the EEG and questionnaires. In their experiment on TV commercials, the EEG measurement and questionnaires were conducted. However, this research simulates the real scene in the VR environment, combines the EDA, EMG, HRV, Eye Movement, EEG, and subjective questionnaires to carry out the experiments. Besides, it gives users an immersive experience while testing the subjective and objective emotional response data of users. Through the analysis and research, it finally draws mutually validated and accurate experimental results, which provides scientific support for further research in this field.

VI. CONCLUSION AND FUTURE RESEARCH

In the modeling design of intelligent industrial robot products, it is relatively one-sided to design solely by relying on the perceptual thinking and creativity of industrial designers, or to over-emphasize the intervention of data quantization research in the field of emotional cognition. Paper intelligent industrial robot as the research object, on the above two aspects, the effective combination of research, through semantic differential method and eye movement under the condition of VR, galvanic skin, such as heart and brain electrical synchronous physiological signal acquisition experiment, to explore a kind of product shape design for industrial robot provides the approach to the study of artistic creativity and scientific support. Through 3 d modeling and simulation, with the help of virtual reality (VR) technology, using semantic differential method and eye movement, galvanic skin, heart rate and brain electrical synchronous physiological signal acquisition experiments of emotional evaluation method of measurement, intelligent industrial robot to achieve the optimal solution of the perceptual design, set up a kind of intelligent industrial robot based on perceptual image product modeling design method.

Emotional design research direction, involving design, aesthetics, psychology, sociology, statistics, management, mechanics, computer science and technology and other multidisciplinary, multi-field theoretical intersection and large-span combination research. Paper while the perceptual design aspects some beneficial exploration, has obtained certain research results, but because of its own knowledge theoretical level, the limitations of experimental conditions, etc, it also has some shortcomings, such as the entire study mainly static product image characteristics and the perceptual image, for people in the process of the industrial robot operating interactive behavior and emotional experience a lack of research, needs further research in the future work and combined with practical work to improve and perfect. In addition, this paper only studies a small part of the research direction of perceptual design, which needs to be further studied in the breadth and depth of the research direction. Along with the rapid development of neuroscience, nervous people learn, aesthetics, and many other branches in neuroscience have been booming, how the technology and its research in neuroscience, such as emotional psychological activities associated with the neural mechanisms and design creative activity combined with research, will become the perceptual design trend in the future research direction.

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