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EXPLORING THE DIFFERENCES BETWEEN USERS' AND DESIGNERS' PERCEPTIONS OF APP INTERFACE DESIGN: A CASE STUDY OF ILLUMINATION DIMMING AND CONTROL APPLICATION

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ABSTRACT

This paper presents a case study of comparing users' and designers' perceptions towards user interface (UI) designs of six smart household illumination and control apps. It is intended to provide users' insights into app UI design during an interaction design project. The study consisted of three phases. (1) Familiarization: prototypes of six apps were demonstrated to each participant; (2) Eliciting participants' overall preferences by ranking; and (3) Eliciting participants' idiosyncratic perceptions using the Repertory Grid Technique (RGT). A multidimensional scaling (MDS) analysis of preference ranking indicated that designers and users differed in overall perceptions towards to the six UIs. The specifics of inter-group perceptual differences were examined by comparing the RGT-elicited perceptions, as well as exploring the relationships between UI design features, designers' and users' subjective evaluation, and their overall preferences. This case study illustrates the application of the explorative use of the RGT method as an inspirational tool during the design process.

INTRODUCTION

Smart household lighting systems are the illumination solutions that apply intelligence concepts to household environment lighting and make illumination and dimming interactively controllable by users, and/or adaptive based on conditions such as occupancy [1]. It has become an emerging market. Many commercial and concept products have been proposed, e.g., Philips Hue, GE Link Smart LED and Belkin WeMo Smart LED lighting. These smart household lighting solutions are usually multifunctional, and could be intentionally controlled through their accompanying mobile applications (apps). Current products and concepts are mainly technology-pushed solutions, targeted at tech-savvy users who look for novelty and technical specifications. Existing literature on smart household lighting system designs also mainly focuses on technological solutions and implementations, e.g., [2-5].

When the smart household lighting market becomes mainstream and shifts to ordinary layperson users, the holistic user experience, e.g., usability and affective aspects of designs would surpass or at least become equally important to the concerns about a product's functions [6, 7]. User interface (UI) design is a central issue for the usability of a software product [8]. Designing a usable and pleasurable UI for lighting control apps would be essential to ensure layperson users' acceptance of smart household lighting systems.

Designers vs Users' Concepts of Product

Designing usable UIs for multifunctional smart lighting system requires understanding of users' conceptual models (UCMs) [9]. Previous studies show that designers often failed to predict the users' desires and preferences accurately [10], as designers' mental models about a product differ from the users' [11]. Krippendorf [9] explains this is due to designers employing professional sense-making instead of ordinary sense-making that users use.

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Several empirical studies confirmed these cognitive and conceptual differences between designers and users. For example, Filippi and Barattin [12] applied the function-behavior-structure framework and protocol analysis to compare designers and users' cognitive processes behind designing. Chamorro-Koc, Popovic, and Emmison [13] used drawing, retrospective protocol analysis and interviewing to compare designers and users' concepts of everyday products. Béguin [14] used intermediate design solutions as a means to facilitate learning between designers and users. These findings are not directly related to the topics of smart household lighting, thus could only be referred as general guidelines. Users' conceptual models as well as their preferences for smart lighting control apps are not well studied yet.

Another concern with these studies into designers-users difference is that these are based on scientific research paradigms. They are rigorous, but also costly and time-consuming, requiring a substantial amount of research efforts. Therefore these methods are rarely implemented in real design projects.

Repertory Grid Technique as Explorative Tools to Elicit People's Insights about Design

User-centered principles, e.g., understanding users' needs and including users in designing process, have been well accepted by design practitioners [15]. But the applications of such user-centered methods by design practitioners in their real design projects are often limited [16], due to the pressure of competition, short-term focus and critical resources.

In order to efficiently incorporate users' insights in practical design projects, we adopt selective user involvement [17] and treat users mainly as information sources. Techniques and tools for probing users' insights should be easy to implement under a tight design and development schedule. Because of the differences between designers and users' concepts of a product, the methods should able to highlight the conceptual differences between designers and users, so that design practitioners could better understand their prospective user.

There are many methods and techniques developed to gain insights into the user's needs and preferences [18-21]. We found the repertory grid technique (RGT) could be an appropriate candidate. Compared with other methods, it could capture users' insights in a relatively simpler way, though it has received less attention in relevant literature of product design and development [22].

RGT was initially developed and applied in clinical psychology, it was later adapted to explore user insights, particularly the idiosyncratic nature of perceptions and evaluation of product attributes [21, 23]. It has been applied to both physical products [24, 25] and software products [26-28]. It has also been used to compare conceptual differences between two or more groups [25], thus is suitable to explore the differences between designers' and users' perceptions towards UI designs.

The remainder of this paper presents a case study of applying RGT and other rapid user study techniques to compare designers' and users' perceptions towards app UI designs in a practical design project of a smart household illumination product. Relationships between designers' and users' subjective perceptions and UI design features are explored.

METHODS

Case Study of Apps Design

The study was based on a practical project of designing a mobile app that controls household environment illumination and dimming. In a competitive analysis, designers systematically reviewed existing smart lighting apps available in Apple's App store and Google Play store. Six UI design alternatives were proposed, Figure 1 and Table 1. This study only tested the function of adjusting the color and brightness of lighting.

Figure 1. SIX UI ALTERNATIVES OF LIGHTING CONTROL APPS

These UIs were different in several dimensions. The UIs ①-④ simply use colors to indicate lighting effects and UIs ⑤ and ⑥ use rendered images as a preview of intended effects. The UIs ①②④⑥ have separate controls for hue and brightness, while UIs ③ and ⑤ adjust the hue and brightness at the same time. The mode of control could either be operated continuously using a virtual knob (UIs ①②⑥) and/or sliding bar (UIs ②④⑥), or discretely by clicking a range of predefined settings (UIs ③⑤). Among these designs, the design alternative of ⑥ "scene" was chosen by the client for further development. The chief designer claimed the operation of ⑥ "scene" UI was intuitive and followed the principle of WYSIWYG ("what you see is what you get"). But designers were not confident whether the users think in the same way.

Table 1. DESCRIPTION OF SIX UIS

No.	Name	Description
①	Hue Circle	Control the color and brightness by adjusting the circle
②	Color Wheel	Rotate the color wheel and slide the brightness bar to change color and brightness
③	Color Palette	Tap a color square to choose a predefined color setting
④	Hue Panel	Choose a color from a hue space and adjust the brightness using the brightness bar
⑤	Hue Images	Choose a predefined lighting setting from a range of rendered images
⑥	Scene	Adjust lighting using hue wheel and brightness bar, and the intended effect is shown in a scene.

Participants

The explorative nature of the RGT often requires a relatively small sample size of 6 to 25 participants to elicit their idiosyncratic views to a set of products [19, 26, 29]. The main purpose of this study is to make the designer in this project aware of the differences between designers' and users' conceptual model of smart lighting control apps, and provide insights about users' idiosyncratic perceptions, rather than emphasizing scientific rigor of the findings. Thus a compromise was made in terms of sample size.

We recruited 12 designers and 12 users. As an exploratory study, six product samples and 12 participants per group were sufficient to explore the major characteristics of user preferences [19].

Participants in the designer group were either professional designers or graduate design students who interned in a design consultancy company. These designers all had more than 3 years designing experience. 12 users were role played by college students who studied non-design related majors. "Lead users", who love DIY and tend to modify the products according to their own needs [30], were excluded in the participant screening and recruitment stage, as lead users may share many personal traits with designers. None of the participants retained in the user group had experience of attending any design workshops, or self-reported design or DIY as their hobby. College students are not representative for a general user population, as college students are more exposed to innovative technologies. We think it's still reasonable to use non-design related college students role playing ordinary users, as they are more likely to be potential users in near future

Experiment Procedure

The research methods were adapted from marketing and sensory analysis. The experiment procedure consisted of three phases: (1) familiarization with the six UIs; (2) eliciting participants' overall preferences for these UIs, (3) eliciting participants' idiosyncratic perceptions towards these UIs.

Each participant was required to assess all the six UIs. The assessment of these UIs was conducted individually. There was no interaction between participants.

When a participant arrived in the venue of the experiment, he or she would be welcomed and shown an Android mobile phone preinstalled with the interactive prototypes of these six apps. The high-fidelity prototypes are made in Axure RP (version 7). Demonstration videos illustrating how to use these six apps were played using another iPad. Participants were allowed to watch these videos any time during the experiment, and replay the videos as many times as necessary. When participants were familiar with the six apps, they were asked to rank these UIs according to their overall preferences.

The preference ranking was a holistic approach to assessing products. The RGT [24, 31] was then applied to elicit designers' and users' analytic perceptions about these UIs, i.e., the different dimensions underlying the overall differences of preferences (if there are any differences). Different from the conventional profiling techniques that ask participants to assess products using a set of predefined attributes, RGT is a semi-structured interviewing technique, allowing participants to assess the product using their own vocabulary and criteria. It is thus able to capture participants' idiosyncratic perceptions towards these UIs.

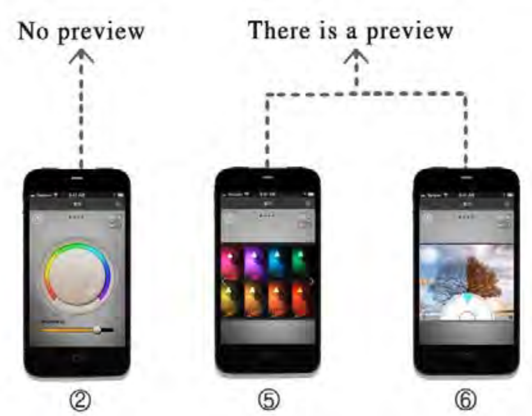

Figure 2. ATTRIBUTE ELICITATION USING TRIAD COMPARISON

The RGT procedure consists of attribute generation and rating on the basis of self-generated attributes [32]. The printouts of these six UIs were combined into four triads. Each triad contained three UIs and each UI was shown in two different triads. When a triad of UIs was displayed, the participant was asked to report properties or qualities that make two UIs alike but discriminate them from the third UI, Figure 2. The participant was asked to label the self-generated attribute as briefly and clearly as possible. When an attribute is elicited, the counter attribute (a contrast description) is sought, if the participant does not give a counter attribute spontaneously, the interviewer asks for one, using questions such as, "If this product has a preview, how is the other one different?" [22] Then the participant is asked to indicate which pole of attributes was preferable or how and why that particular aspect affected the UI. When a participant exhausted the attributes they were able to come up with for that triad, the next triad was shown and the same attribute elicitation procedure repeated.

After attributes elicitation of four triads, the participant would take a short break. The experimenter showed her record of elicited attributes to the participant, and asked if there were any duplicate attributes. When the elicited attribute list was confirmed, the participant was required to rate all the six UIs according to the attribute he or she generated. A 5-point semantic differential scale was used for the attribute rating.

The whole experiment session lasted about 30-45 minutes.

RESULTS AND DISCUSSIONS

Participants' Overall Preferences

To explore whether designers' overall perceptions towards the six UIs were different from users' perceptions, participants' overall preference ranking data were analyzed using the multidimensional scaling (MDS) approach. The proximity of ranking data was measured using Spearman's rho. If two participants have similar perceptions of UIs, they would rank the six UIs in the same or similar order, the correlation of ranking data would thus be high. Using the same rationale, if two participants have very different perceptions, then the orders they ranked the six UIs should not be correlated.

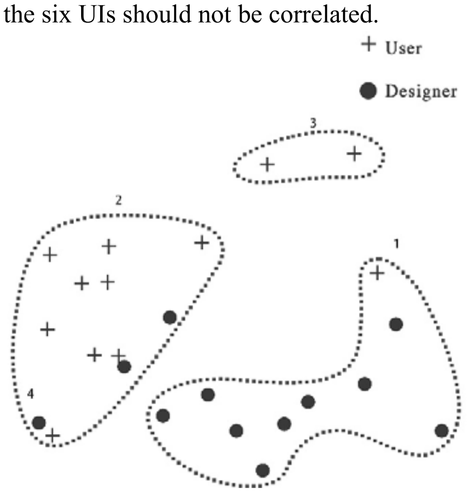

Figure 3. MDS MAP FOR USERS AND DESIGNERS' OVERALL PREFERENCE RANKING

The proximity of ranking data was examined by the PROXSCAL procedure in IBM SPSS v22. The proximity was visualized as Euclidean distances in a multidimensional space. The closer two participants are in MDS space, the more similarly they ranked the six UIs. Figure 3 shows the two-dimensional solution (S-stress value=0.04, optimal scaling factor =0.99). It reaches a good fit to the raw data. The meaning of axes is arbitrary in the MDS analysis. The two axes are thus not shown in the figure. Figure 3 shows that designers tended to cluster in the lower right half and users tended to cluster in the opposite direction. These two clusters had a minimal overlap.

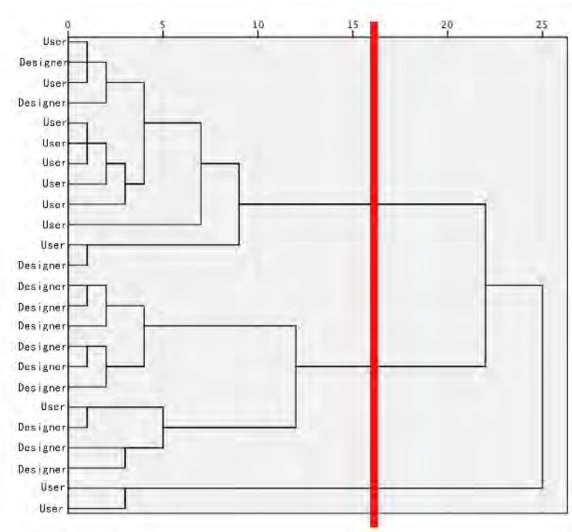

Figure 4. DENDROGRAM USING AVERAGE LINKAGE (BETWEEN GROUPS)

The distribution of users and designers in this 2D MDS space could be clustered into 3 groups, using Agglomeration hierarchical cluster (

Figure 4). Superimposing the group identifier in the MDS solution (**Figure 3**) shows that there was a designer-majority cluster (9 designers + 1 user), a user-majority cluster (9 users + 3 designers), and a small cluster with 2 users. Designers showed different perceptions towards the six UIs from the user group. A MANOVA test confirms that there was a significant multivariate difference between the two groups ($F(2,21) = 17.50$, $p < 0.001$; Wilks' $\lambda = 0.375$).

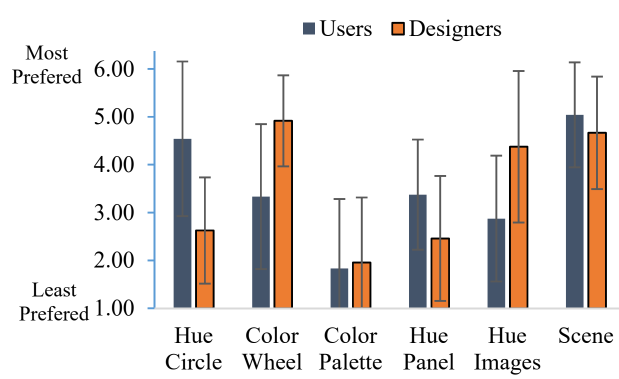

Figure 5. THE MEANS AND STANDARD DEVIATIONS OF SIX UIS' PREFERENCE RANKINGS

In the following analyses, we therefore aggregated data for each participant group. Figure 5 illustrates the participants' overall preference rankings in two groups. Users preferred the UIs ⑥ "scene" and ① "hue circle", while designers preferred the UIs ② "color wheel", ⑥ "scene", and ⑤ "hue images". The UI ③ "color palette" was least preferred by both groups. Users and designers had significant disagreements about their preferences towards to the UIs ① "hue circle", ② "color wheel", and ⑤ "hue images".

RGT-Elicited Attributes

The preference ranking indicated that users and designers were different in their overall perceptions towards to the six UIs. We then turned to exploring the specific dimensions or attributes underlying the overall inter-group differences.

Exploring designers and users' conceptions by categorizing the RGT-elicited attributes. The RGT triad comparison sessions yielded a total of 169 attributes when participants assessed the six UIs, with a median of 7 attributes per participant (min= 5, max=10). There were no significant differences between user and designer groups in terms of the number of elicited attributes. Designers generated 87 attributes about the UI designs of six apps, and users generated 82 attributes.

We printed out all the 169 participant-generated attributes with one attribute per card. Two independent research assistants (graduate industrial design students) were asked to examine these attribute cards using a grounded-theory-like approach. Two participant-generated attributes were merged into one category if they were assessed to be similar in their meaning. A total of 16 categories were identified in this open coding process, Table 2. The inter-rater agreement was satisfactory (Cohen's κ=0.78).

Table 2. CLASSIFICATION OF RGT-ELICITED ATTRIBUTES

1. Effectiveness	2. Efficiency	3. Emotional Appreciation
1.1. Continuous adjustment	2.1. Perceived ease of use	3.1. Vivid (output preview)
1.2. Clarity	2.2. Interactive	3.2. Visual appeal
1.3. Multi-function	2.3. Intuitive	3.3. Rich color
1.4. Integrated UI	2.4. Perceived affordance	3.4. Appropriate form
1.5. Accurate color adjustment	2.5. Predictable	3.5. Playable
1.6. Controllable (layout)		

Figure 6 shows the occurrences of recoded attributes elicited in each group's triad assessment sessions. The apps' capability to adjust lighting continuously ("1.1 continuous adjustment") and display the intended outcome in a vivid graphical preview or not ("3.1 vivid (output preview)") are two most important attributes that were indicated by both users and designers. Usability issues ("2.1 perceived ease of use") were also frequently mentioned (9 users and 8 designers).

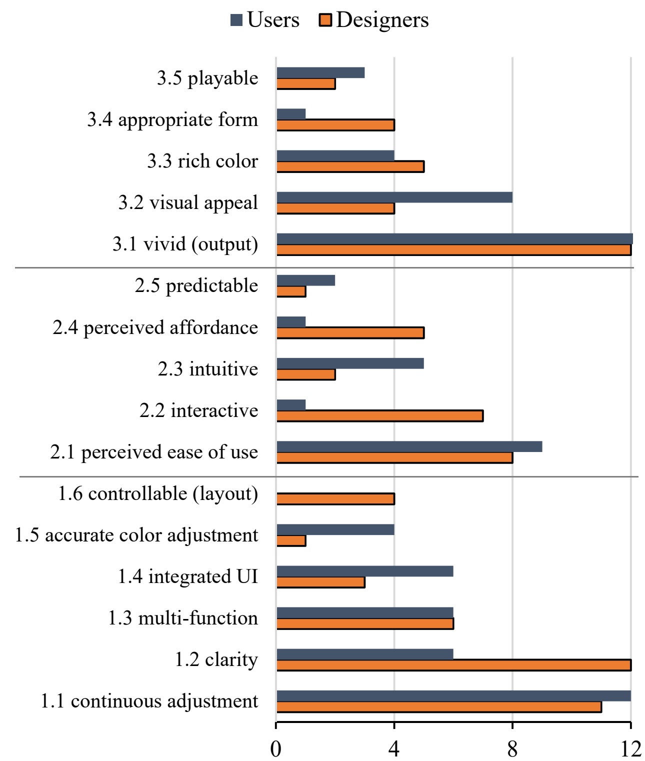

Figure 6. FREQUENCY OF 16 RECODED ATTRIBUTES

Figure 6 also indicates several different criteria that users and designers used to assess the UIs. All designers were concerned with the capability of clearly delivering the intended color effects ("1.2 clarity"), while only half of the users brought up this issue. Designers paid attention to whether the lighting control was interactive ("2.2 interactive"), the UI clues (e.g., clickable zone) for possible actions ("2.4 perceived affordance") or the UI layout signifying the intended functions ("1.6 controllable (layout)"), and whether the UI elements seemed appropriate for the functions ("3.4 appropriate forms"). These design issues are often emphasized in design texts, e.g., Norman's "The Design of Everyday Things" [11].

Hassenzahl and Wessler [24] classified user generated attributes in three categories: Type A, "descriptive;" Type B, "evaluative, useful for artifact selection;" and Type C, "evaluative, useful for artifact redesign" [24]. We recoded the RGT-elicited attributes using these three categories. It was found that, though descriptive and evaluative attributes may mix in our original 16 categories, our categorization could roughly map to Hassenzahl and Wessler's coding scheme as Table 3. The agreement between manual coding and automapping from 16 categories was 0.65.

These attributes that designers were concerned with were all "evaluative" in Hassenzahl and Wessler's design relevancy categorization. In particular, our three categories (i.e., "1.6. Controllable (layout)", "2.2. Interactive", and "2.4. Perceived affordance") were considered as relevant for providing direction to improve the design. Designers articulated all these three categories, while users generally showed little consciousness of these design-relevant attributes. This echoes Krippendorf's [9] argument that designers employ professional sense-making instead of ordinary sense-making that users use.

Table 3. ROUGH MAPPING BETWEEN OUR CLASSIFICATION AND HASSENZAHL AND WESSLER'S DESIGN RELEVANCY TYPES [24]

Descriptive	Evaluation (useful for selecting alternatives)	Evaluation (useful for improving design)
1.1. Continuous adjustment	1.2. Clarity	1.6. Controllable (layout)
1.3. Multi-function	1.4. Integrated UI	2.2. Interactive
3.1. Vivid (output preview)	1.5. Accurate color adjustment	2.4. Perceived affordance
3.3. Rich color	2.1. Perceived ease of use	
	2.3. Intuitive	
	2.5. Predictable	
	3.2. Visual appeal	
	3.4. Appropriate form	
	3.5. Playable	

On the other hand, users used another set of vocabulary. They were more concerned with visual elements in the UI ("3.2 visual appeal"), whether the operations seemed intuitive ("2.3 intuitive") and UI elements displayed a holistic feeling ("1.4 integrated UI). These attributes related to selection among a few design alternatives. They did not clearly refer to concrete measures taken to resolve design-relevant problems.

Abstracting RGT-elicited attributes into broader theme. We then looked for a further level of abstraction. The 169 RGT-elicited attributes and the 16 categories were reviewed one more time. It seemed that the 16 categories were under three broader themes of effectiveness, efficiency, emotional appreciation. The two research assistants were then asked to classify the 16 categories into these three broader themes. The inter-rater agreement was high (κ =0.81).

Figure 7 shows the frequency distributions of the three themes. When the attributes were further aggregated, there was no significant difference between two groups, $\chi^2(2)=0.75$, $p=0.69$. It indicates that, though users and designers applied different sets of vocabularies during the UIs assessment, the main themes they were concerned with were similar and comparable. This also shows the value of using a two-step classification analysis, the findings extend our understanding of the important attributes that need to be considered to improve the (UI) designs of the lighting control apps.

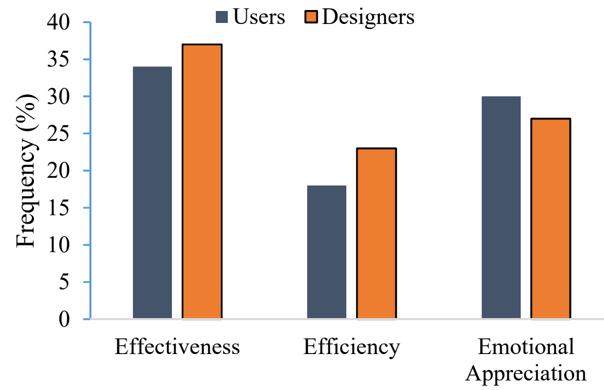

Figure 7. DISTRIBUTION OF THREE THEMES

Rating with RGT-Elicited Attributes

RGT elicits idiosyncratic views from participants. The detailed list of elicited attributes varied from one participant to another. To assist interpersonal comparison, the original RGT ratings using self-generated attributes were then transformed into matrices of (6 UIs × 16 recoded attributes). Each row, i.e., specific values of 16 attributes, represents a "UI profile", an individual participant's perception towards this UI design. Three composite variables of "effectiveness", "efficiency" and "emotional appreciation" were calculated using the arithmetic means of related attributes.

Modeling preference with three themes. The preference data could be modeled using these composite variables as determinants. The linear regression models for users and designers are shown in the following two equations. Standardized coefficients were used. All the three predictors were significant at the 0.01 level. The R-squares were 0.725 and 0.719 respectively.

$$\text{User Preference} = 0.485 * \text{effectiveness} + 0.251 * \text{efficiency} + 0.414 * \text{emotional appreciation}$$

$$\text{Designer Preference} = 0.467 * \text{effectiveness} + 0.274 * \text{efficiency} + 0.425 * \text{emotional appreciation}$$

Both groups seemed to use a similar approach to assess the UIs. Their preferences of the six UIs were more affected by their perceptions of effectiveness and emotional appreciation than efficiency.

Perceptual maps of the UIs. Though users and designers used similar underlying themes to assess the UIs, they may have different understandings of particular UIs using these themes. This was examined using Principal Component Analysis (PCA) [33]. An aggregated matrix was calculated for each participant group. 16 RGT-elicited categories were constructed as principal components (i.e., axes) of a multidimensional perceptual space, and the six UIs were visualized as points in this perceptual space. To assist the interpretation of the perceptual map, three composite variables "effectiveness", "efficiency" and "emotional appreciation" as well as preference data were included as supplementary variables. These supplementary variables were superimposed onto the perceptual map as vectors. The projection of six UIs on a certain variable vector visualized the relationships of the six UIs on that variable.

Figures 8 and 9 show the users' and designers' perceptions towards the six UIs. Two-dimensional solutions respectively explain 69.1% and 75.7% variability of original RGT rating data (in terms of inertia). The quality of conceptual maps was sufficient for the exploratory purpose.

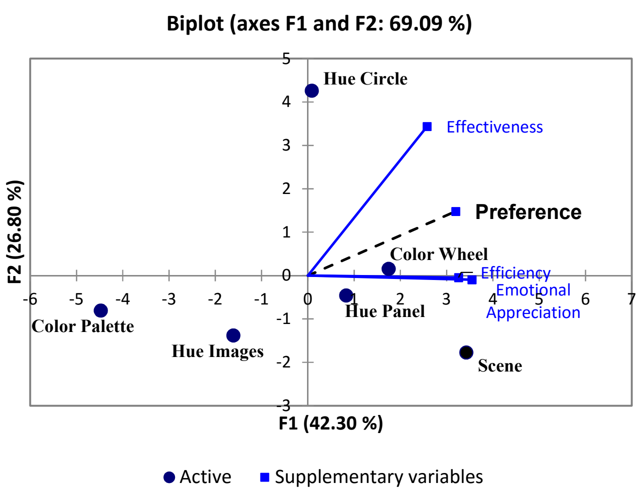

Figure 8. USERS' PERCEPTUAL MAP (PCA)

For both perceptual maps, the UIs ③ Color Palette and ⑤ Hue images were located in the negative direction of the first component, separating from the other four UIs. Both UIs ③ and ⑤ provide a range of predefined lighting settings, the control was done by clicking the discrete icons. Hue and brightness of the lighting were adjusted at the same time. The adjustment of the other four UIs were continuously swiping, rotating or sliding. The hue and brightness were set individually. The mode of operation seemed to be the key design feature determining people's overall perceptions. This corresponds to the categorization of RGT-elicit attributes. All participants, with a single exception, mentioned this mode of operation ("1.1 continuous adjustment")".

For both maps, the UIs in the first quadrant were more ideal as that was the direction the preference vector pointed to. The three composite variable vectors as well as the relative positions of the six UIs show users and designers may differentiate the six UIs from different perspectives.

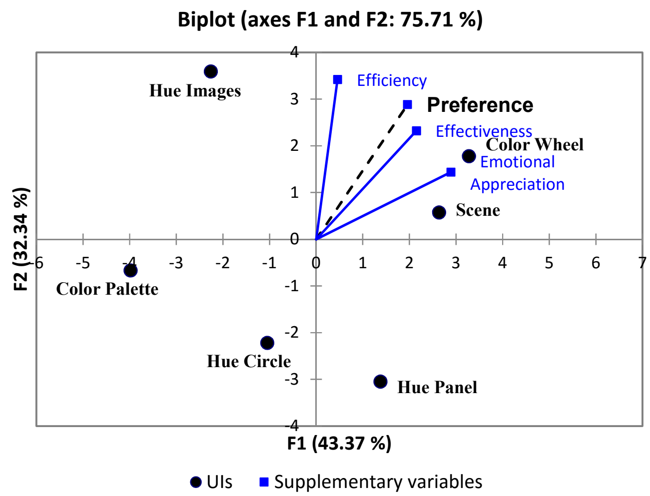

Figure 9. DESIGNERS' PERCEPTUAL MAP (PCA)

Users considered that the UIs ② "color wheel" and ④ "hue panel" were similar, indicated by their short distance in Figure 8. The central areas for these two UIs were hue space. It seemed that visual impression, particularly the visual pattern of color combination, strongly affected users' perceptions towards the UIs. The UIs ① "hue circle" and ⑥ "scene" both have a wheel-shaped control for lighting color and a separate slide bar for illumination intensity. The shape of UI elements does not seem to be have a large impact on overall perception for users.

In both users and designers' perceptions, in fact, the shape of the individual UI elements seemed to play a less important role than the color impression. The UIs ① "hue circle", ② "color wheel" and ⑥ "scene" all have a large circle or wheel shape in the central area of the UIs. But both users and designers perceived "hue circle" and "color wheel" quite differently, as indicated by remote distances in both perceptual maps.

When the color effect was reduced, the UIs ② "color wheel" and ⑥ "scene" were perceived more similarly. Maybe the separate slide bar enhances the similarity of perceptions.

Whether or not using images as a preview of lighting effects seemed not to be an important attribute when differentiating the UIs. The UIs ⑤ "hue image" and ⑥ "scene", which include image previews, were not perceived similarly for both users and designers groups.

Comparing Users with Designers' Conceptions in Design Project.

It has become a consensus among design practitioners that users' "voice" should be incorporated in designing process, as designers and users have different conceptual models, and may use different sets of vocabularies to describe products. To implement elicitation of user insight in practical design projects, more flexible and cost-effective tools and techniques are required. This case study shows that RGT plus overall preference ranking could fulfill the requirements of rapidity and flexibility. With good planning and preparation, the data collection and analysis could be done in about 3-5 days. A relatively small sample size is often sufficient to outline major differences between designers and users, to help designers to better understand prospective users' specific conceptions of target products. For application in practical projects, the design team should form the designer group of the study, so they could be more conscious about how users may differ from them. Prospective users are more diverse in their backgrounds. It is recommended to recruit a large sample size when time and resource allow.

Both RGT and preference ranking elicit users' responses by exposing them to a set of products, intermediate design alternatives and/or competitors' products. The insights gained are limited by the particular products included in the study. This method is more suitable for incremental design projects rather than radical design projects [34].

CONCLUSION

This paper describes a case study exploring the differences between users' and designers' perceptions towards the UI designs of smart household illumination and control apps. RGT and preference ranking were chosen as rapid techniques to incorporate user insights in practical design projects. The comparison between designers' and users' perception towards the same set of products assists designers to better understand their prospective users. The results of this case study show that users and designers have different perceptions towards the UIs of smart lighting control apps. Users' perceptions may be more influenced by visual aspects of the UIs, e.g., color patterns. Designers may be more aware of the operation mode of the UIs. It also highlights some factors considered by users that have not been sufficiently noticed by designers. The gap between designers' and users' perceptions should be narrowed. The relationship between UI design features, people's subjective evaluation, and overall preferences could be used to guide the following concept developments.

To effectively implement in practical design projects, we made a compromise in sample size. Caution should be exercised when trying to generalize the findings of this exploratory study.

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