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A User Study on Color Palettes for Drawing Query on the Touchscreen Phone

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Abstract **-** There has been little reported research on using color palettes on mobile devices to enable users to draw images in order to search for similar images. In this paper, we present a preliminary experiment designed to explore which color palette works best for searching for portrait painting by drawing color patches on mobile phone. Four color palettes, including two discrete color palettes with 256 colors and two continuous color palettes, were built into three Android applications. 37 participants conducted the tasks of producing drawings as input query image to search for a selected portrait painting. The results indicated that most participants preferred the color palette with full-color choices and they also got the best retrieval performance during refining drawings by use of the continuous color palette, while the 256 database-dependent colors facilitated the most first-attempt drawn queries to get the wanted painting back in the top-three of returned matches. The use of some other drawing interface elements was also concluded from our observations and interviews.

Keywords**:** Color palette, User interface design, Query by drawing, Painting search, Mobile application.

1. Introduction

Sometimes it is difficult for users to describe some pictures that they are looking for by using words, or users just have the mental image of a previously seen picture and they would like to search for the original picture or similar images. Drawing is an intuitive way for users to present their ideas in visual language. Recent advances in touch-screen devices make the *Query-by-Drawing* (QbD) method more attractive for making the drawn search input in real life.

There are a significant number of studies on QbD algorithms (Springmann et al., 2007) and drawing applications on both computer and touch-screen devices in different domains. However, little research explores the usability of the drawing interface from real user's perspective (Venters et al., 2001). Reading through the literature, different QbD systems work on their own image databases. The efficiency and accuracy of the QbD retrieval system are mainly tested on the experiment-generated sketches, because the variances in human drawings skills would have an uncontrollable effect on the search performance. For example, the testing sets of algorithms contain the tester-created (or artists-made) simple hand-drawn figures (Eitz et al. 2011, Hu 2010, Zhou et al. 2012) or human sketches made by tracing against the photograph (Eitz et al., 2009). However, Springmann et al. (2007) suggest that it is impossible to have a good retrieval quality if the input query image fails to express user's intention, even if powerful retrieval algorithm and efficient relevant feedback mechanism (Zhou & Huang, 2003) are available. And it is therefore important to explore the drawing interface elements from users' aspects, such as the color palette described here.

Rather than investigating the image retrieval algorithm itself, we tried to explore the user interface which suited the existing algorithms better. Specifically, the aim of this research is to determine which color palette(s) facilitate(s) people to draw better image queries. To answer the question, we built three user interfaces to allow users to draw the query as input of a portrait painting search system and we conducted a study to measure the users' satisfaction and task performance on four different color palettes.

2. Related Work

The color palette has been widely explored by data visualization researchers (Rogowitz & Treinish, 2009). For instance, the *Brewer color palette* for map visualization (Brewer et al., 2003), the *rainbow color map* (Borland & Taylor, 2007), and automatic color scheme generation (Wijffelaars et al., 2008). The purposes of their work are to convey information efficiently by presenting the proper color sets, while we aim to explore the effects of color palettes on users' drawings for search. To the best of our knowledge, there is no similar research in this area.

There are hundreds of color palettes user interfaces developed on both web and mobile applications. In the realm of computer graphic, a number of studies have been devoted to examine the effectiveness of color selectors (Henry et al. 2006; Moretti & Lyons 2002; Mason 1999) and some factors that affect the usability of such tool, such as color space (Douglas and Kirkpatrick 1996a,b; Yaguchi 2001; Zhang & Montag 2004) and the color picking user interface (Bauersfeld & Slater 1999; Montage 1999; Douglas & Kirkpatrick 1999). However, their experimental studies are based on 'color-matching tasks' that require participants to reproduce the given color shown in a filled square by using several color selection interfaces, and the efficient color selection interface is judged by comparing the accuracy and speed of matching color, which is separated from the context of real world application. As Moretti & Lyons (2002) conclude, colors that are picked out of context do not appear as expected when applied.

Despite the fact that color is one of the most important features for content-based image retrieval (CBIR) system, little focus is on the color selection user interface. The most relevant work to ours is a study by Broek et al. (2002) in the sense that they review the color selection interface of ten CBIR engines. While we will explore the color palette(s) in the real-life scenario that users search painting by drawing the rough color sketch.

3. System User Interfaces

The systems are designed and implemented on the Android phone, which allows the free-hand drawing using the basic drawing interface elements.

3. 1. System Overview

The system adopts the Client-Server structure: on Client side, users interact with the mobile phone by drawing the query, then triggering the search and viewing the matched results; On the Sever, our *Windows Azure*^{TM} server (Web-1) 'fetches' the drawing sent from user's mobile phone, and after the search algorithm matches users' drawing with the database, the server sends several matched paintings back to user's mobile phone in the order of decreased relevance to user's drawn query.

We currently focus on the search for the color *half-length* portraits by drawing the rough color patches as query image. The database includes the set of 450 portrait paintings downloaded from the *Tate Gallery* website (Web-2). The global color features (Jacob et al., 1995) of the painting database are pre-calculated. Both the paintings and feature database are held on Windows Azure server. Jacob et al.'s (1995) *Fast Multi-resolution Image Querying* algorithm is implemented to match user's drawing against the features of painting database.

3. 2. Drawing Interface

The basic drawing tools consist of five-size brushes (10, 20, 30, 40 and 60 pixels), five-size erasers (10, 30, 40, 50 and 70 pixels), '*Undo*', '*Redo*', '*Trash*', and '*Search*' buttons on the top (see Fig 1, left).

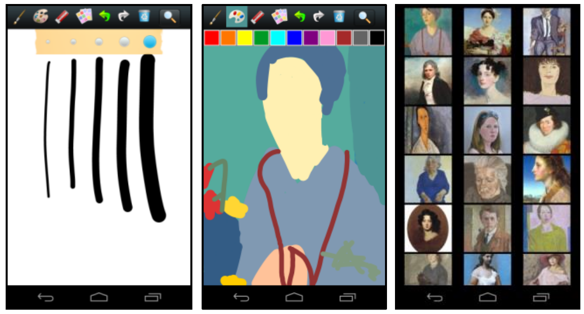

Fig 1. The user interface of our *Query-by-Drawing* system.

The brush color palette and the background color palette are separated to make it easy for users to choose or tune the correct color (the differences among systems are represented by both brush and background color palettes). When users select one background color, the whole canvas will be filled evenly with that color. After finishing the drawing, user presses '*Search*' button on the top left of mobile screen, user's drawing will be uploaded to the remote server at the back-end.

3. 3. Result Display Interface

The top 21 thumbnail images of the query results are continuously displayed with three images in one line (as shown by Fig 1, right) in the sequence of decreased relevance to user's drawing from left-right and top-down. The whole view of the image would be shown when user pressing the thumbnail. And user could browse the image one by one by left-right sliding the whole view. Users are also allowed to go back to the drawing interface to refine (or further refine) their drawings if they are not satisfied with the search results.

4. User Study

Inspired by Wijffelaars et al.'s (2008) color palette category, we conducted an experiment to explore the effect of two discrete color palettes (finite number of colors) and two continuous color palettes (infinite number of colors) on mobile painting search application. It is important to note that we are not making claims about the superiority of our search system, we are more interested in observe how people actually use the color palettes in our systems.

Fig 2. Combinations of color palettes built into the brush color and background color of system A, B, C.

4. 1. Experimental Design

Two discrete color palettes and two continuous palettes were designed to compare, as Fig 2 shows.

The reason for selecting these color pickers is because they are frequently used in color selection tools and contrasted with each other in terms of use strategy.

Two discrete color palettes include:

- **K-means color palette (database-dependent colors)**: 256 primary colors extracted from 450 portrait paintings by using *K-means* clustering. For system A's brush color palette (see Fig 2, top right), we manually separated these 256 colors into 7 visual groups (illustrated by Table 1). System A's background color palette (see Fig 2, bottom left) was made up of 256 colors in the original order of *K-means* clustering output.
- **Gradient color palette**: 256 basic colors were divided into 11 groups according to Berlin and Kay's 11 basic colors (Berlin & Kay, 1969), with 24 degrees of brightness of 9 basic colors and 38 degrees of '*Green*' color and one '*White*' and one '*Black*' (as bottom row in Table 1 shows). In each group, colors were displayed with shade from dark to light.

Two continuous color palettes are:

- **HSV color slider** (Fig 2, bottom right): the right color slider sets the hue (top-bottom); the left color square is selected to set the saturation (left-right) and lightness (top-bottom);
- **Color wheel** (Fig 2, bottom middle): the color wheel is used to determine the hue (sliding on the circle), and the slider below the wheel is used to select the brightness (left-right).

These color palettes were built as color pickers in three systems as Table 2 demonstrated.

Table 1. Color distributions of system A's and system C's brush color palette.

No. of colors	red	orange	yellow	green	cyan	blue	purple	pink	brown	grey	black	white	light
256 K-means colors	48		46	63		28			33	14			24
256 Gradient colors	24	24	24	38	24	24	24	24	24	24	1	1	

Table 2. Color palette for brush color and background color of System A, B, C.

System / **Color palette**	**A**	**B**	**C**
Brush color palette	K-means	HSV slider	Gradient
Background color palette	K-means	Color wheel	HSV slider

4. 2. Apparatus and Stimuli

One Ziggi USB camera is set on the desk to video-record participant's finger movement on the mobile screen during the drawing process.

Two *Google Nexus 4* (N4) mobile phones are adopted: one N4 phone is used to display the reference painting to participants; three systems (system A, B, C) and screen recording software *SCR Screen Recorder Pro* are installed on the other N4 phone. Two N4 phones are adjusted into the same settings, e.g. 100% lightness to reduce the effect of device lightness on participant's color perception. The stimuli are a portrait painting and a colored sketch shown by Fig 3.

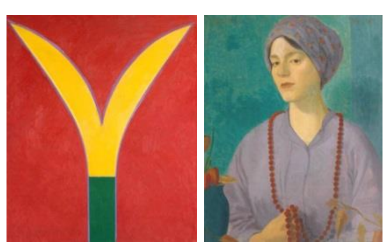

Fig 3. Left: the picture *Abstract A* for practice; Right: the painting *Portrait A* used in copy task.

4. 3. Participants

The tasks were performed by 37 participants (17 Female, Median age=25, Mean age=27.92, Range=19-57) with 2 left-handed and 35 right-handed, and one participant had the weak sight. All participants were recruited by ads and by open email at the University of Nottingham. The post-task questionnaires were completed by 35 participants.

4. 4. Procedure

We guided participants through both aims and tasks of the study, and then they gave their written informed consents for the study. After a demonstration of the systems' functionalities, participants were asked to complete the pre-task questionnaires before a drawing practice session (copying *Abstract A* shown in Fig 3, left). After participants got familiar with the user interfaces, we asked them to complete the copy task (copying *Portrait A* shown in Fig 3, right) on three systems. Participants were instructed to trace the proportion and color as accurately as possible, using color patches and ignoring the details like shading, outline, and so on. They were also suggested to select the background color first and then work on the foreground objects until they think their drawing accurate enough. No time limit was required.

On each system, participants had three times (including the refinements of their previous drawings or starting a new drawing from a scratch) to draw (or refine) and search for *Portrait A* to get it sitting in the top three results. After completing the drawing tasks, the questionnaires along with a short interview were carried out individually to collect participants' opinions on color palettes. All procedures were screen- and audio- recorded.

5. Results and Discussions

309 drawings were made by 37 participants. In general, participants were satisfied with the basic drawing interfaces.

5. 1. Self-rated Drawing Skill

The users' self-rated drawing skills were analysed based upon a 5-point scale data (1 means a very bad drawing skill and 5 means an excellent drawing skill) from pre-task questionnaires. It was concluded that most participants have bad drawing skills (as shown by Fig 4). We felt justified in use of low-drawing-skill participants because our *query-by-drawing* system was intended for use by the general public and most of who cannot draw perfectly.

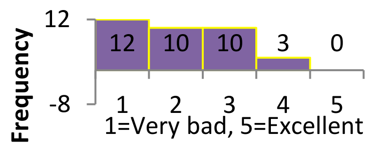

Fig 4. Distribution of self-perceived drawing skill scores.

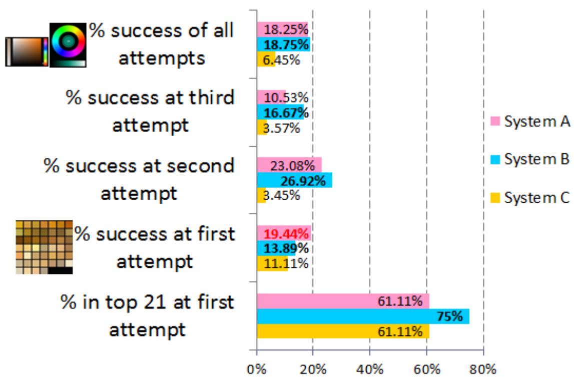

Fig 5. The success rate (%) at the first, second, third attempt, and the average success rate of all attempts on system A, B, C.

5. 2. Search Result Performance

Our evaluation of result performance was currently based on the position of the target painting in returned 21 paintings. The '***success***' is defined as getting the *Portrait A* in the top three results. At the first attempt, most participants (19.44%) succeeded on system A. However, most drawings on system B (75%) got the *Portrait A* in top 21 results, and most participants made successful queries with the refinements on B (as illustrated by Fig 5). Among three systems, both the first and refined drawn queries on system C worked worst.

5. 3. Drawing Procedure

The video logs were analyzed to review participants' drawing procedures.

5. 3. 1. Time Spent on Drawing

On average, participants spent the longest time to finish the first drawn queries on system B, with mean time of 587.944 seconds (9.80 minutes), whereas spending shortest time on system C, 430.571 seconds (7.18 minutes). There is no significant difference between the time taken on system A and B ($t(36)=.181$, $p=0.858$). Participants tended to become increasingly fast as increasing number of drawings.

Our analysis of the time spent on picking background color shows that the fixed color palette (14s) saved participant's time to find the desired color, while using color wheel (44s) is more time-consuming than using HSV color panel (20s). Thus it is inferred that participants spend less time to draw the foreground by using general 256 general colors (on system C) than 256 K-means colors (on A).

5. 3. 2. Brush Colors and Background Colors

Only the first-attempt drawings were analysed for the mean number of both brush color and background color being used, as shown by Table 3. Participants tried the fewest number of brush colors (rounded 10.5) when using the HSV color palette; while 256 basic gradient color palette confused participants to pick and try the most number of colours (17.9 brush colors for one drawing). That was because the color differences among adjacent color swatches were relatively small. As **Participant #7** reported, "*The brush colors (on C) don't have significant difference to the neighbors, so I have to try several times to get the just 'right' color*". There is no significant difference between A's and C's brush colors use ($t(34)= -.196$, $p=0.846$).

Table 3. The average number of colors picked for brush color and background color of the first-attempt drawing on system A, B, C.

	No. Avg. Brush Color	No. Avg. BG. Color
System A	17.51	2.23
System B	10.53	2.43
System C	17.89	1.43

Almost all participants used the background color picker, except for one participant, who forgot to pick the background color of his first drawing on system B. It is well known that portrait paintings normally have the textures because of physical canvas and paint. Therefore several participants attempted to draw the details on the filled pure background color. The HSV color palette still worked best with the fewest number of background color picked (mean=1.43), which is significantly different from the color wheel ($t(34)=3.271$, $p=0.002$) and 256 database-dependent colors ($t(34)=2.883$, $p=0.007$).

5. 3. 3. Use of Eraser, Undo, Redo

We only analyze the first attempt drawings on three systems to explore on which system participants made fewest mistake. The results indicate that the first queries drawn on system B require least times of '*Rubber*' and '*Undo*' uses, while drawings on system A made most mistakes comparing those on other two systems. Furthermore, the '*Undo*' function was substantially more frequently used by participants than '*Rubber*' and '*Redo*'.

5. 3. 4. Refinement

The refinement seemed to help users produce better and more successful drawings. Participants developed the expertise in color selection by practice and learning from search results. Four out of 37 participants, who have had the experience of CBIR system, tried to understand the system's outputs and then incrementally modified their initial drawing to make progress, e.g., adjusting the background more bluish.

5. 4. User Satisfaction

The post-task questionnaires were designed to collect the personal subjective feelings about picking the brush color and background color on three systems.

It is concluded from Fig 6 that, both the brush color picker and the background color picker of system B were favorite ones; participants hated most to use the brush color picker of system C and the background color picker of system A. That means, most participants preferred the HSV color palette and the color wheel. Similarly, most participants hated 256 K-means colors.

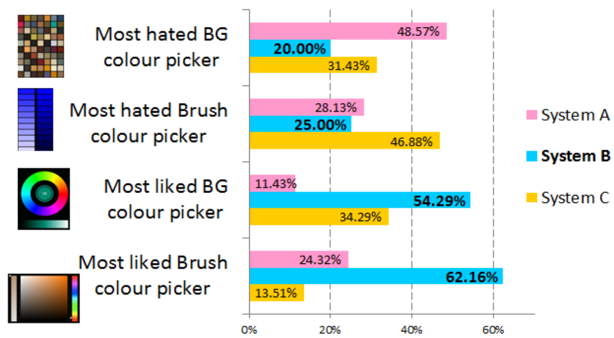

Fig 6. Participant preferences on brush color picker and background color picker of system A, B, C.

It is interesting to notice that most of the participants felt that they spent least time and effort on system B (57.58%) and spent most effort on system C (48.24%). However, the video analysis shows that actually participants spent most time on system B, which is totally contrary to their self-perceived time costs.

Participants were also asked their opinions on whether the color choices for both brush and background were enough to use or not. 87.5% of participants rated 256 K-means colors supplied least color choices. A half of participants indicated that HSV color palette owned most color choices, although some participants could not tell if HSV color palette had more colors than Color wheel.

6. Conclusion and Future Work

We explored the effects of four color palettes on users' drawings via three-version of a *search-painting-by-drawing* mobile application. After analyzing the observed 37 participants' behavior, the recorded finger movements, short interviews and questionnaires, the color palette which supplied the full freedom to mix the color worked best on the existing image matching algorithm. Most of the participants preferred to use HSV color palette than the discrete color palette.

One of the limitations of this study is considering only copy task and four basic color palettes. While these experimental conditions help in limiting the scope of the study and avoid the inclusion of many undesired factors in the results. And the portrait painting chosen in copy task is made up of at least five secondary colors that require user to mix or to select colors by themselves. The potential problem might be the lack of interest to repeat drawing the selected portrait many times, which surely resulted in some mental workload that affected users' drawings. As some participants commented, "*This lay looks miserable, depressed…I don't like to draw it…*". Controlling the light of the experimental environment is also an important factor that affects people to judge the colors.

Many of other issues related to drawing user interface still exist to be explored. For example, solving the fat-finger problem; if the interactive drawing is more important to users than the speed and ease of use? Whether the task type affects users' preference of the interfaces and drawing performance? E.g. the task of searching for landscape paintings, or the timed task, or the task of drawing from their own real-intension or imagery, etc. Our future work will investigate these issues.

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