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Analysis of Experiments to Determine Individual Colour Preference

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Abstract:
Finding an efficient way to understand individual colour preference is important to researchers and designers. This paper compares three research strategies to test individual colour preference including two research experimental environments (online and laboratory) and two research methods (multiple choice for N-alternative-forced-choice and multiple choice for rank-order). Three psychophysical experiments have been carried out. Participants were presented with six colour patches (red, orange, yellow, green, blue and purple) arranged in a random order on a computer display. In the first two experiments (Online experiment and Laboratory experiment I), participants were asked to indicate which colour square they prefer most; in the third experiment (Laboratory experiment II) participants were asked to rank their colour preferences of the six colour patches. The similarity between the results obtained from two experimental environments provides some validation for the online protocol and suggests that online experiments could be used more often. Pairwise comparisons for individual colour preference between genders and nationalities were carried out, and it was found that male and female responses were significantly different; but there was no statistical significance between Chinese and UK participants. The results from Monte Carlo simulations suggested that the rank-order method should be preferred for individual colour preference studies involving small numbers of participants (especially less than 15 participants).
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Keywords: individual colour preference; research strategy, research method.

INTRODUCTION

Individual colour preference is concerned with which colours individuals prefer[1, 2] and it has been actively researched for more than 100 years[3]. Individual colour preference *per se* has been studied by many researchers[4]. Although there are some general trends, for instance, people tend to prefer cool colours such as blue and dislike warm colours such as yellow and orange, individual colour preferences vary from person to person[5]. There are also some studies that show that gender[3, 6-11], context[12] etc. may affect individual colour preferences.

Finding an efficient way to understand individual colour preference is important to researchers[13-15] and designers[16-19]. In the field of individual colour preference, modern studies have used standardised colours[20], multiple experimental methods[20-23], and sophisticated statistical methods[2, 17]. Strengths and weaknesses of experimental methods/ behaviours/ techniques are presented and discussed in this paper. Major findings from individual colour preference studies are reviewed, including colour strategies, experimental methods, experimental materials and results. The populations, the task (responses behaviour/experimental methods, experimental samples (or materials), experimental environment and participants must be specified prior to collecting data. The displays/materials could be virtually any physical objects or images. The behaviour responses/experimental methods are probably forced-choice, ranking description of like or dislike.

The experimental methods can be classified as N-alternative forced-choice (N-AFC, N≥2), rank-order, affective judgments (or bipolar adjective), subjective rating and other tasks. In some respects, the optimal experimental method is N-alternative forced-choice[21], in which participants indicate which colour they '*like better*' (or prefer aesthetically) with all colours simultaneously presented on a visual display[12, 17, 24-28]. The average probability/percentage of choosing each colour over all others is a global measure of colour preference. The N-AFC paradigms have the advantages of a simple response to indicate choices, no memory load and minimal response bias effects. The 2-AFC is a special N-AFC method which is also called 'Paired-Comparison[3, 9, 22]. The 2-AFC task has the advantage of a simple response to indicate the choice from only two samples. However, the primary drawback is that when the complete matrix of comparisons is carried out, the work required becomes prohibitive with a large number (N(N-1)/2) of paired comparisons when there are N stimuli[30]. Thus, the investigators more likely conduct an incomplete comparison experiment with a high number of stimuli[31].

The other method is a rank-order task in which participants are required to order all colours from the most to the least preferred for all colours simultaneously displayed[23, 32-34]. The advantage is that participants provide more quantitative information from a single trial. The disadvantage, on the other hand, is that the one trial could be complex, requiring simultaneous presentation of all N colours (if the colour number is large/or spatially complex) and a potentially long and complex judgement.

The Rating method of colour preference is another alternative paradigm. The Rating and affective judgments (or bipolar adjective) could be made on response scales of given resolution (such as an N-point Likert scale)[2, 4, 29, 35-39] or continuous scales (such as a line-mark rating)[29, 40]. Participants are shown a single colour on each trial and asked to rate how much they prefer it[41]. The average rating for each colour is calculated as the colour preference measurements. The responses for each colour are simple; however, it might be difficult for participants to make consistent ratings across trials, especially at the beginning of task. Other measurement methods include description methods (ask participants provide the name of the colour they personally preferred), physical and behavioural measurements (for infant colour preference, count the time-length they look at the colour), and so on[23].

In terms of experimental materials (colours) many recent studies have compared six or eight hues (with 6 to 85 coloured samples)[12, 27]. Coloured samples/materials could be made by colour chips[36], colour cards/papers/fabric[22, 42] or digital colour patches displayed on a computer monitor[39]. Experimental environment could be classified as a restricted/controlled experimental place and lighting conditions, such as a Physical Laboratory with 2840-6500K colour temperature[34] or Darkroom with a D65 simulator[2]; and non-restricted, such as online survey[17] etc.

In terms of hue preference results, cool colours (such as green and blue) are generally preferred to warm colours (such as orange and yellow), with maximum preference at blue and minimum preference at yellow-green[3, 4, 33, 35, 43]. For saturation (chroma), some findings have suggested that adults generally prefer colours of higher saturation to those of lower saturation colours[37, 41, 44]. However, some research suggests that colour preference decreases for very high saturation which is reported as 'too vivid'[34, 21]. Brightness (lightness) is confounded with saturation across hues. Some research has suggested that adults tend to prefer colours of increasing brightness (at least to some point)[4, 44]; however, the effect is not always evident[41]. Recent studies tend to agree that colour preferences are universal (blue). However, some studies have found that colour preferences are not universal. Saito[36] suggested that cultural differences might influence colour preference. Ou *et al.* (2012)[9] thought cultural difference and personal taste should also be taken into consideration.

A number of studies have suggested that there is a universal individual colour preference across cultures[33, 36], genders[1, 45-46] and age levels[47-48]. Eysenck (1941)[33] found that Caucasian and other races have the same individual colour preference ranking: blue, red, green and purple. Saito (1996)[36] found that white and blue were the most preferred colours in Japan and Korea. Mikellides (2012)[1] analysed existing studies to derive general conclusions for individual colour preference, which were that blue is the most popular colour for both genders, and yellow is the least popular colour. Across age levels, for children (infants), there is no individual colour preference between genders; they all prefer warmer colour[47-48]. However, some studies concluded that different cultural backgrounds lead to different individual colour preferences. Child and Iwao (1969)[49] found there were colour saturation and brightness preference difference between Japan and USA. Ou and Luo (2003)[9] found that UK prefers 'cool' colours, and Chinese prefer 'clean', 'fresh' and 'modern' colours by analysing *colour emotion* data. Between genders, for children, Burkitt (2003)[50] noted sex differences; girls preferred pink and boys much prefer light blue. For adults, Hurlbert and Ling (2006)[3] found that females prefer more reddish colours than males, and males prefer more bluish colours than female. For the age levels, Lee *et al.* (2009)[13] found young people prefer light colours and elder people prefer dark colours. Dittmar (2001)[46] reported that the colour preference tends to be stable for adult people, but blue colour preference starts to decrease, and turn to prefer green and red when people enter old age[51].

This study is concerned with finding an efficient way/research strategy to understand/test individual colour preferences. There were three aims: 1) to identify the agreement of results of individual colour preference from different experimental environments (online and laboratory in this study); 2) to test the agreement of the results for individual colour preference from different research methods (multiple choice for N-alternative forced-choice and multiple choice for rank-order in this study); 3) to determine a lower limit number of participants for experiment methods choosing (when the number is equal to or greater than this limit, the experimental results tend to be consistent and reliable). This study aims to build a framework (the framework is described in the next section) that can help researchers and designer testing individual colour preference more efficiency.

FRAMEWORK FOR COLOUR PREFERENCE

Finding an efficient way to understand individual colour preference is important to researchers[52] and designers[53]. From the previous studies, a colour preference research strategy includes *experimental environment* and *research method* with various different circumstance, such as a various of number of colour-samples or *number of participants*. For this study, the hypothesis is that an efficiency individual colour research strategy may be strongly influenced by *experimental factors*; the factors are introduced in the following session. A framework has been designed.

In the framework for research strategy, the *experimental factors* consist with *experimental method factor*, *experimental environment factor*, *experimental material factor* and *participant factor*. *The experimental method factor* relates to multiple experimental behaviours, such as the N-alternative forced-choice, rank-order, affective judgments, bipolar adjective, subjective rating and other tasks. *The experimental environment factor* relates to where the experimental surrounding is restricted or not, such as experiment place (a dark room), time (restricted time of a day) or even technology. The experimental material factor relates to the types of experimental materials (such as colour chips or digital samples), also the number of samples. *The participant factor* relates to the types of participants (such as infant or adult, male or female), on the other hand, also relates to the number of participants take part in the task. Previous studies[41, 54], have suggested that experimental method is a significant factor for individual colour preference research strategy. However, the relationships between other factors (experimental environment factor, experiment method factor and participant factor) and the interactions between factors are not clear. Especially, determining a lower limit of the number of participants, which research strategy is more meaningful.

In this research, three experimental factors have been considered (*experimental method factor*, *experimental environment factor* and *participant factor*). The framework supported by experimental findings, captures the relationship between efficiency research strategy for individual colour preference with experimental factors, and explores the relationships between each factor. The study presented herein collects data for a large number of participants, and explicitly tests the hypothesis that the efficiency of individual colour research strategy may be strongly influenced by experimental factors.

EXPERIMENTAL DESIGN AND METHODS

This research is based on three studies (through Online Survey, Laboratory experiment I and Laboratory experiment II) and some aspects of these studies have been previously published[17]. The different research strategies were used in this research where the experimental take place (online survey or laboratory experiment), the research method (multiple choice for N-alternative forced-choice or multiple choice for rank-order) and the research environment (non-restrict or a dark laboratory with professional display) were varied. Participants were presented with six colour patches (red, orange, yellow, green, blue and purple) arranged in a random order on a display. In the first two experiments (Online experiment and Laboratory experiment I), participants were asked to indicate which colour square they prefer most (*6-AFC*: multiple choice for 6-alternative forced-choice). In the third experiment (Laboratory experiment II), participants were asked to give the sequence of their colour preference for the six colour patches (*rank-order*: multiple choice for rank-order).

The analysis described in this paper uses the data from a large number of participants (296 in total), and explicitly test the hypothesis that the efficiency of individual colour preference experimental performance might difference from varies research strategies (including research activities, research methods and research environment/materials) with different scales of participants. A comparison between the Online survey and Laboratory experiments allows the results from the internet and from the laboratory to be directly compared; the comparison between first two experiments (Online Survey and Laboratory experiment I) and Laboratory experiment II allows an analysis of the research methods (6-AFC and rank-order). Details are shown in TABLE I

TABLE I *The research strategies and activities details for this research.*

Studies	Research Methods	Research Environment and Materials	Number of Participants
Online Survey	Multiple Choice for 6-Alternative Forced-Choice	No	173
Laboratory experiment I	Multiple Choice for 6-Alternative Forced-Choice	Dark laboratory with a professional display	38
Laboratory experiment II	Multiple Choice for Rank-Order	Dark laboratory with a professional display	85

In this study, six colours (red, orange, yellow, green, blue and purple) were selected[23] from an Adobe HSB colour system[28]. As Moroney (2003)[55] has noted, the advent of sRGB (and ICC colour-management workflows) has provided some degree of convergence in colour encoding and display for the internet. Ideally, the six patches would have identical lightness and chroma so that hue is the only valuable in this study. However, since different hues exhibit their maximum chroma values at different lightness values, keeping lightness and chroma constant would limit the colours to quite low chroma. Consequently, in this study there was some variation in lightness and chroma. The colours were defined as sRGB values for display and TABLE I lists these sRGB values and also the CIE measurements (using a Minolta CS100A colorimeter) of the colours when displayed on a laboratory display (used for the Laboratory experiment I and Laboratory experiment II).

TABLE II *The sRGB and CIE L*a*b* colour coordinates of the six basic colour squares.*

Colour coordinates of the six basic colour squares						
Coloured Squares	Red	Orange	Yellow	Green	Blue	Purple
sRGB	255, 0, 0	255, 127, 0	255, 255, 0	0, 255, 0	0, 0, 255	127, 0, 255
CIE L*a*b*	40.01, 55.08, 58.27	49.84, 28.88, 64.20	72.35, -17.18, 80.75	63.85, -68.14, 69.37	17.65, 75.93, -89.76	29.46, 61.16, -63.54

The Online survey was made and launched by Google Form (left image in Fig.1) and the 6-AFC research method was employed. Each participant was presented with the six colour patches (randomly display) and participants were asked to indicate which of these was their preferred colour. Laboratory experiment I and Laboratory experiment II were coded by MATLAB R2019a. The 6-AFC and the rank-order research methods were used in Laboratory experiment I and Laboratory experiment II. However, in Laboratory experiment II, participants were asked to rank the colour patches in order of their individual colour preference (from most preferred to least preferred). The participants did this by clicking on the colour they most prefer using the mouse and the selected colour patch would disappear each time they gave an answer so that the rank-order preference was thus obtained. The size of each colour patches was 50 × 40 mm displayed (randomly) on a uniform grey background (CIE $L* = 50$) both for Laboratory experiment I and II. All three studies were part of 'consumer product-colour purchase decision' studie[17]. The experiments were carried out to ascertain the colour that participants would prefer to buy for products, and to determine the relationship between individual colour preference and product-colour preference. The experimental interfaced were illustrated in Fig. 1.

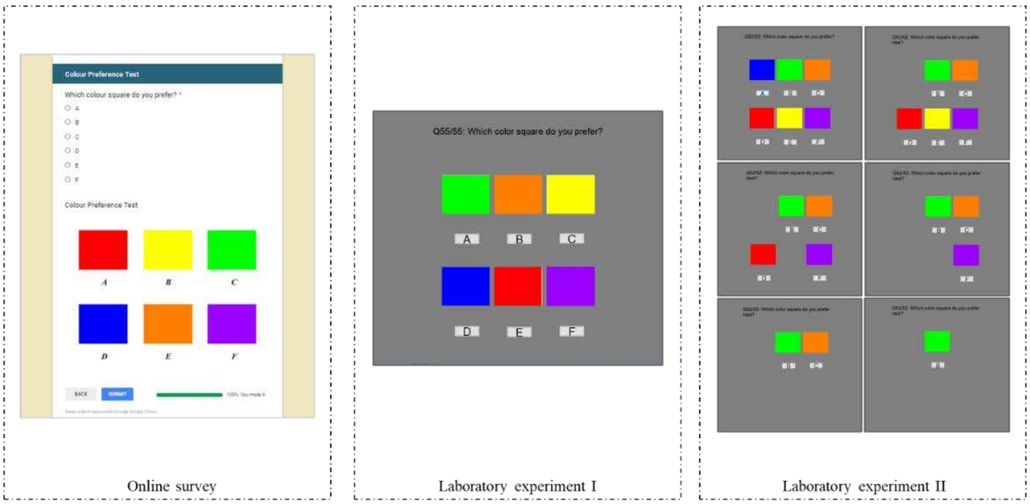

Fig. 1 Graphical user interface for Online survey, Laboratory experiment I and Laboratory experiment II in which the coloured patches were presented randomly for each participant.

The Online survey was less well-controlled than the Laboratory Experiments, due to likely variation in display technology (such as iPad, laptop, PC, smartphone etc.) and viewing conditions (day-time or night-time). The Laboratory experiments took place in a darkened room in the Experience Design Laboratory at University of Leeds. Stimuli were displayed on an HP DreamColor LP2480zx Professional Display (24-inch Diagonal LCD Backlit Monitor, the luminance of the display white was 218 cd/m^2). Participants viewed the screen from about 60 cm (See Fig. 2). A total of 173 participants (62 males, 111 females) were recruited to the Online survey; recruitment was by cascade sampling in response to links to the survey that were posted on social media websites. For Laboratory Experiment I, a total of 37 participants were recruited to take part, including 18 males and 19 females. A total of 85 participants were recruited to take part in the Laboratory Experiment II, comprising of 42 males and 43 females, all participants for Laboratory experiment I and II were students or staff at the University of Leeds (details are shown in TABLE I). Further details about the participants can be obtained from the earlier publication relating to a different aspect of this study[17].

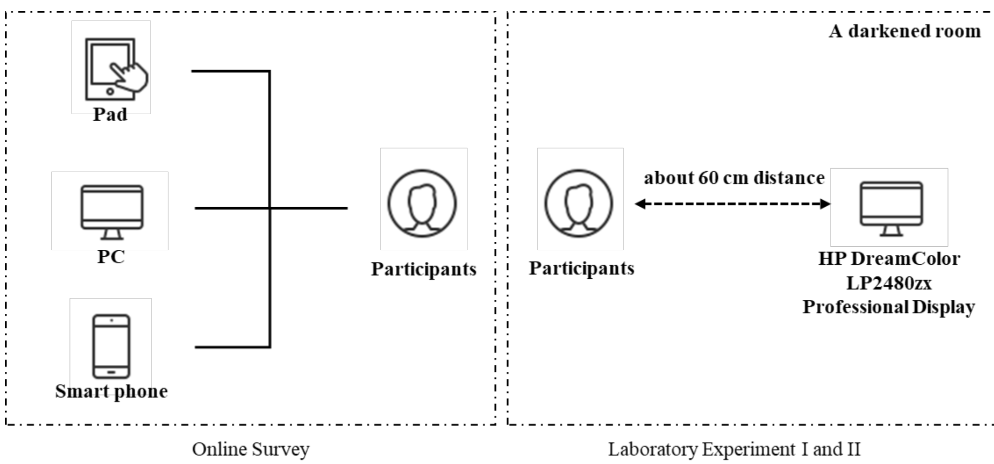

Fig. 2 Picture experimental setting (Online Survey, Laboratory experiment I and Laboratory experiment II).

RESULTS

Individual colour preference response by different experimental environments.

First, considering the data collecting from different experimental environments (online and laboratory), 296 responses (comparison of 173 online responses and 123 laboratory responses) were collected from multiple choice for 6-alternative forced-choice (6-AFC) method, which from Online Survey, Laboratory experiment I and Laboratory experiment II (that is, only the colour that was placed in the first choice was considered; the other choices were discarded).

The preference scores for online experimental environment were blue (26%), followed by red (21%), orange (16%), yellow (13%), purple (12%) and green (12%); the preference scores from laboratory experimental environment were blue (31%), followed by red (23%), orange (13%), yellow (13%), purple

(13%) and green (7%), which represents the same colour-preference-rank with 6-AFC method (see Fig. 3.1). Also Fig. 3.2 shows the correlation between the individual colour preferences from two experimental environments. The vertical and horizontal axes represent the individual colour preference percentages from online and laboratory respectively. Each coloured diamond point on the graph refers to one of the colours and it is evident (r^2=0.93, p=0.002) that there is a significant correlation/agreement between the two experimental environments' results.

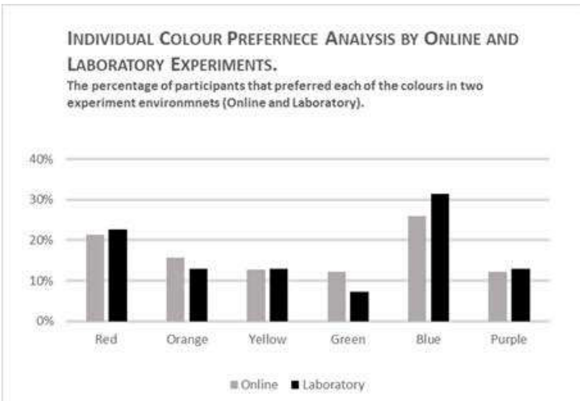

Figure 3.1 Individual colour preference analysis by Online and Laboratory Experiments.

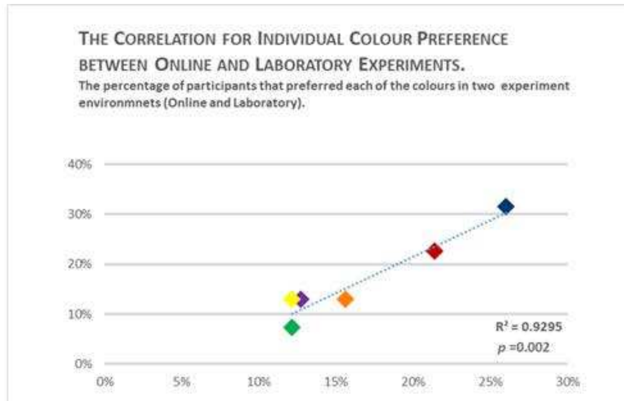

Figure 3.2 The correlation for colour preference between Online and Laboratory Experimental environments.

Fig. 3 Individual colour preference distributions and the correlation for colour preference between online and laboratory experimental environments (online results come from Online Survey; laboratory results come from Laboratory Experiment I and Laboratory Experiment II).

A test for statistical significance was carried outing using the Chi-Square test of independence to investigate whether the experimental environmental factor has a significant influence on colour preference results. Pairwise comparisons between individual colour preference results from online and laboratory experimental environment were carried out (173 online 6-AFC responses and 123 laboratory responses only consider the colour was placed in the first choice). It was found that there was no statistical significance between two environments (p=0.714>>0.05) for individual colour preference (see TABLE III).

TABLE III *Chi-Square Test of Independence result for individual colour preference by experimental environments/martials (online and laboratory).*

Chi-Square Test of Independence			
	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	2.907[a]	5	.714
Likelihood Ratio	2.969	5	.705
Linear-by-Linear Association	.169	1	.681
N of Valid Cases	297		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 12.53.

Scaling individual colour preference

In this section, 296 responses were collected from 6-AFC method which from Online Survey, Laboratory experiment I and Laboratory experiment II. The individual colour preference percentage is simply the number of times that each colour was selected in the 6-AFC experiment. In this section the ordinal rank and comparative data are converted to interval-data z scores.

For ease the frequency has been converted to a *per cent* value indicating the per cent of participants who selected each colour. The individual rank data from each participant were combined to mean rank data and subsequently proportion values (between 0 and 1) where the greater the value the greater the preference of the participants for the sample. The proportion values were converted to interval scale values z using the inverse of the cumulative standardized normal distribution according to case V of Thurstones Law of Comparative Judgement[56]. In order to compare two experimental methods, the interval scale values z have also been used on 6-AFC methods. There is a well-known problem in that calculating z is not possible when the proportions are exactly 0 or 1 (which can happen if all participants rank a sample as most or least preferred, for example). In these cases, proportions of 0 and 1 are replaced with 1/999 and 999/1000 respectively which is standard practice[57-58].

The colour preference sequence for z value/scores for 6-AFC method were blue > red > orange > yellow > purple > green, which represents a similar colour-preference-rank with Rank-Order method (blue > red > orange > yellow > purple > green) (see Fig. 4.1). Fig. 4.2 also shows the correlation between the individual colour preferences from the two research methods. The vertical and horizontal axes represent the individual colour preference percentages from rank-order method and 6-AFC method respectively. Each coloured point on the graph refers to one of the colours and it is evident (r^2=0.9) that there is an agreement between the data from the two methods.

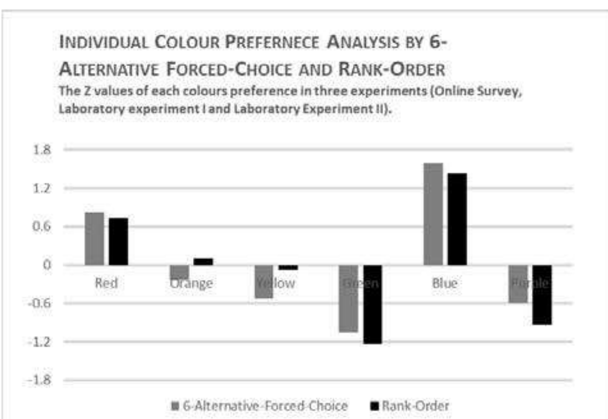

Figure 4.1 Individual colour preference Z value distributions colour preference between 6-AFC and rank-order research for full data.

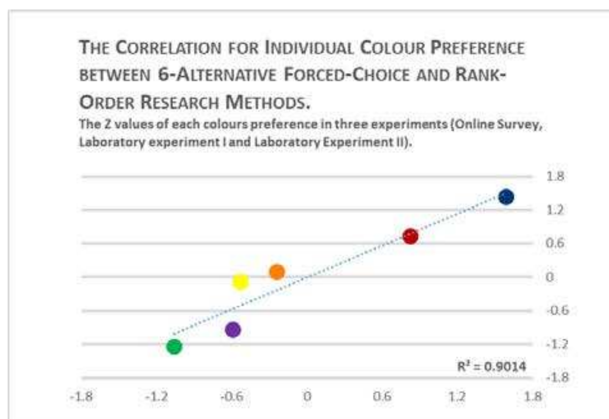

Figure 4.2 Individual colour preference Z value colour preference correlation between 6-AFC and rank-order research for full data.

Fig. 4 Individual colour preference Z value distributions and the correlation for colour preference between 6-AFC and rank-order research methods (6-AFC results come from Online Survey, Laboratory experiment I, Laboratory experiment II; rank-order results come from Laboratory Experiment II only).

Reader might argue that the data from Fig. 4 were collected from a different population (two of the three experiments, the Online Survey and Laboratory Experiment I, did not collect rank-order data). In order to reduce this differentiation, Fig. 5 analyses the results from Laboratory Experiment II only. The colour preference Z value/scores for 6-AFC method were blue >red >yellow>orange >purple >green; for Rank-

Order method were blue > red > orange > yellow > purple > green which represent a similar colour-preference-rank (see Fig. 5.1). Also Fig. 5.2 shows the correlation between the individual colour preferences from two research methods. The vertical and horizontal axes represent the colour preference percentages from rank-order method and 6-AFC method respectively. Each coloured triangle on the graph refers to a colour and it is evident (r^2=0.82) that there is still an agreement between the two methods' result (from the same experiments).

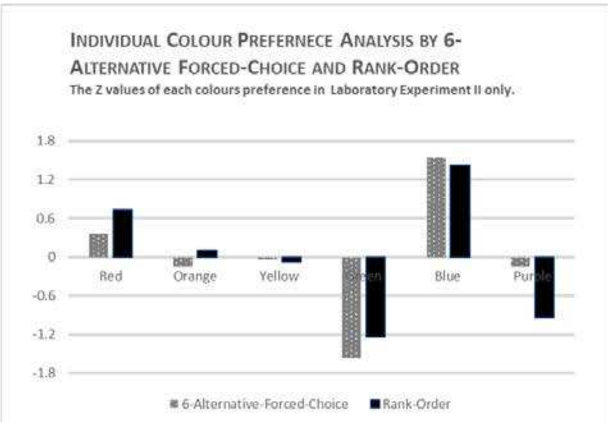

Figure 5.1 Individual colour preference Z value distributions colour preference between 6-AFC and rank-order research for Laboratory Experiment II only.

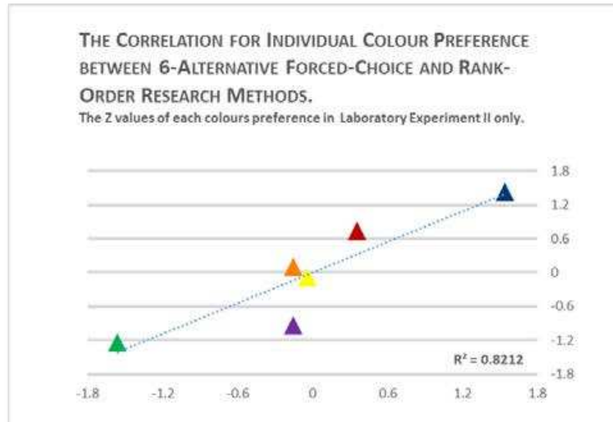

Figure 5.2 Individual colour preference Z value colour preference correlation between 6-AFC and rank-order research for Laboratory Experiment II only.

Fig. 5 Individual colour preference z value distributions and the correlation for colour preference between multiple choice for 6-alternative forced-choice and multiple choice for rank-order research methods (come from Laboratory Experiment II only).

Monte Carlo analysis of individual colour preference by different research methods.

This work seeks to explore the effect of experimental methods on the individual colour preference scale values (the relationships between experimental method factor and participants number factor). A Monte Carlo simulation conducted to explore the level of agreement of the 6-AFC and rank-order methods. In total 85 participants took part in Laboratory Experiment II. When responses from all 85 participants are considered the two methods' performance is similar. However, in practice many studies will use fewer participants; how robust will the methods be when the number of participants is reduced? In this work the data from the 85 people are sub-sampled. If use fewer than 85 participants, then the question is which ones should we include? A Monte-Carlo procedure is therefore necessary; we sub-sample the full population repeatedly taking a different sub-sample each time.

The following four steps are used:

1) Subsample n of the data from *the 85* participants randomly where *n* is [*85, 80, 75, 70… 10, 5*] (Step 1);

2) Calculate the individual colour preference *z* score for each *n* scale participants (n = 85, 80, 75, 70, 65, 60, 55, 50, 45, 40, 35, 30, 25, 20, 15, 10 and 5) to obtain the two distributions (from 6-AFC and rank order methods) of individual colour preference for each *n* scales (Step 2);

3) Construct the r^2 (correlation coefficient) calculated between the individual colour preference from all the data (*n* = 85) and from the sub-sampled data (*n* = 80, 75, 70, 65 etc.) (Step 3, Fig. 6 illustrates an example for 6-AFC method and Fig. 7 for Rank-Order method for Step 3);

4) Compare the r^2 distributions between the two methods (Step 4, Fig. 8).

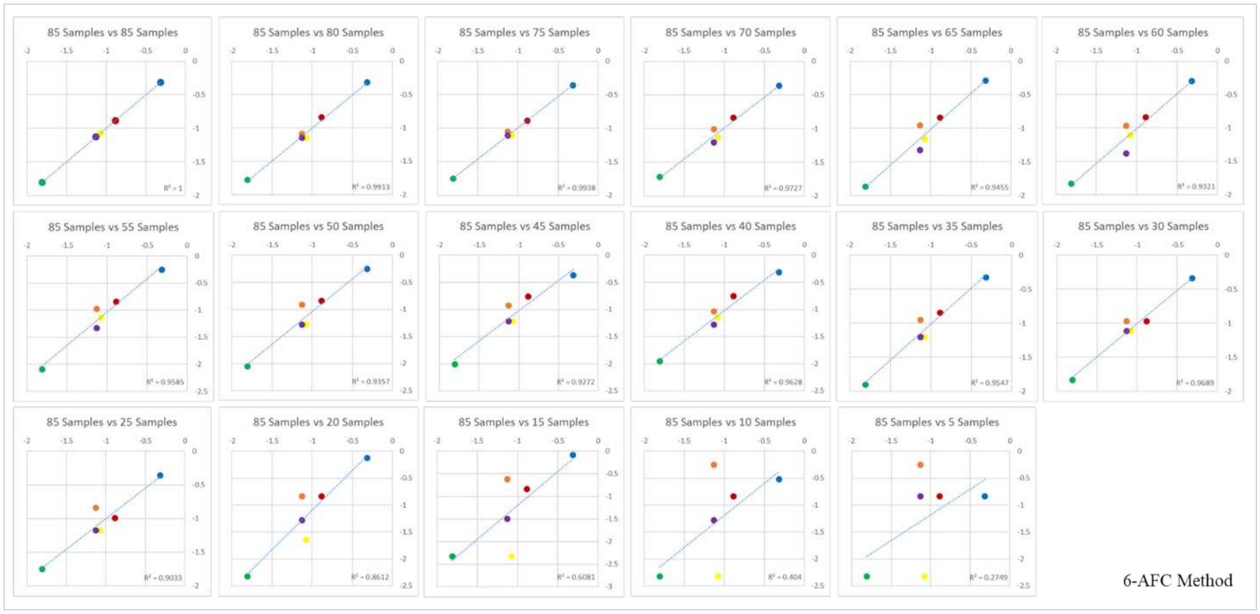

Fig. 6 The correlation for the individual colour preference between full samples (n=85) and each the sub-sampled samples (n=85, 80, 75, 70, 65, 60, 55, 50, 45, 40, 35, 30, 25, 20, 15, 10 and 5) from 6-AFC method (an example illustration for Step 3).

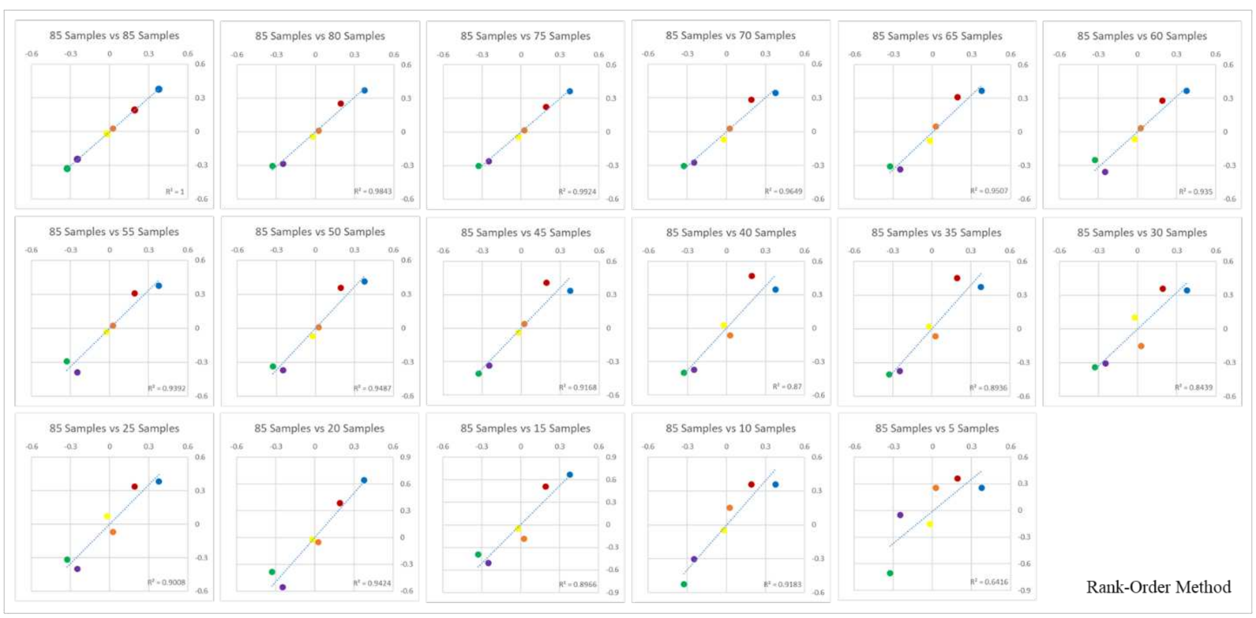

Fig.7 The correlation for the individual colour preference between full samples (n=85) and each the sub-sampled samples (n=85, 80, 75, 70, 65, 60, 55, 50, 45, 40, 35, 30, 25, 20, 15, 10 and 5) from Rank-Order method (an example illustration for Step 3).

Fig. 6, Fig. 7 and Fig 8 are an example illustration for Step 3 and 4. The vertical and horizontal axes represent the correlation coefficient (r^2) values and n scale samples (n=85, 80, 75, 70, 65, 60, 55, 50, 45, 40, 35, 30, 25, 20, 15, 10 and 5). In Fig. 8, the blue and red lines show the r^2 distributions form rank-order and 6-AFC methods (each point represents the correlation coefficient for each n scale samples). Compare the small-scale samples tests (n=10 and n=5), the correlation coefficients hold on the high agreements (r^2=0.92 and r^2=0.64) for rank-order method; the correlation coefficients decrease sharply to the low agreement positions (r^2=0.4 and r^2=0.27) for 6-AFCmethod.

Fig. 6, Fig. 7 and Fig 8 show how robust each of the two methods are as the number of participants taking part in the experiment reduces. The experiment with 85 participants is assumed to be the correct data (the true scale values) and as the correlation (where $n < 85$) between the calculated scale values and the true scale values reduces the experiment is considered to be less robust. As can be seen in Fig.8, the rank-order method is more stable than the 6-AFC method. However, the sub-sampling was random and were the sub-sampling to be repeated there is no certainty that the same result would occur.

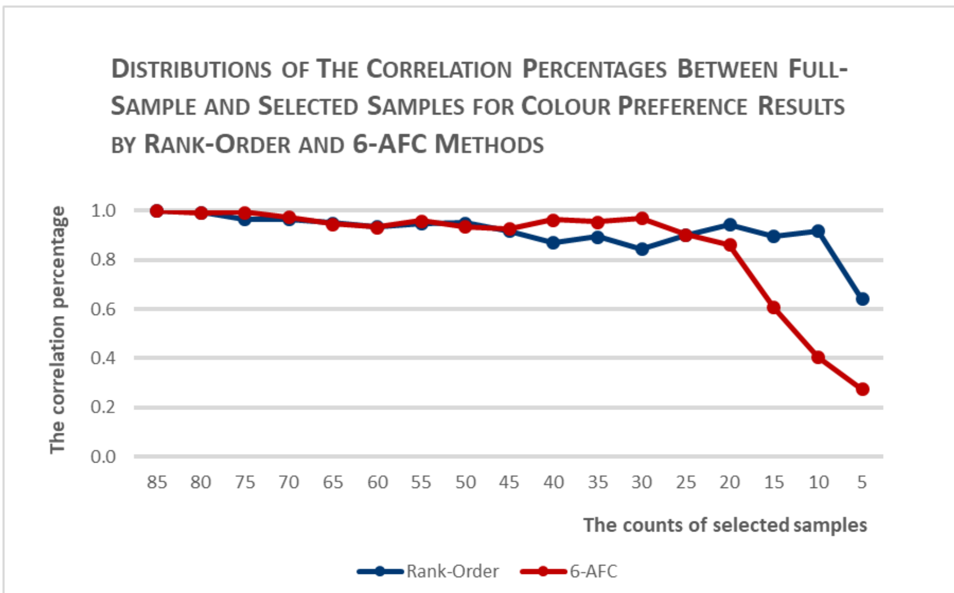

Fig. 8 An example illustration for the correlation coefficient distributions form Rank-Order and 6-AFC methods. Each point represents the correlation coefficient for each n scale samples (n=85, 80, 75, 70, 65, 60, 55, 50, 45, 40, 35, 30, 25, 20, 15, 10 and 5). The vertical and horizontal axes represent r^2 values and n scale samples.

In order to more fairly compare the stability of the two methods, the simulation was repeated 1000 times (the Monte Carlo), each time starting with a different random set of scale samples and the mean correlation coefficient (averages overall 1000 trials) was used as a measure of performance. In Fig. 9, the vertical axes represents the correlation coefficient (r^2) values scales, and horizontal axes represents the n scale samples (n=85, 80, 75, 70, 65, 60, 55, 50, 45, 40, 35, 30, 25, 20, 15, 10 and 5), each box plots represents a correlation coefficient for each n scale samples. Fig. 9 displays the box plots for the r^2 distributions from 6-AFC (left image) and Rank-Order (right image) methods[20].

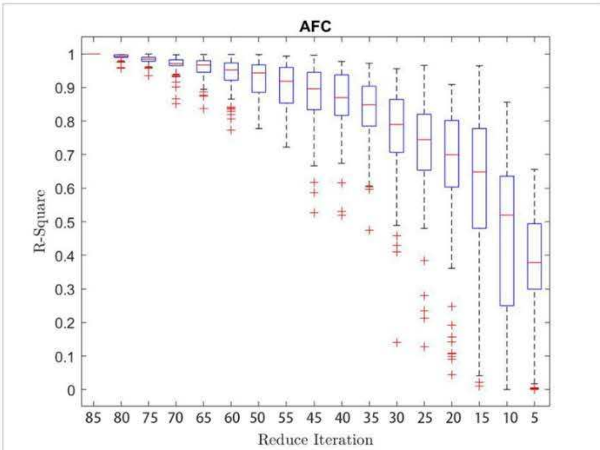

Figure 9.1The line and box plots for r^2 distributions from 6-AFC methods.

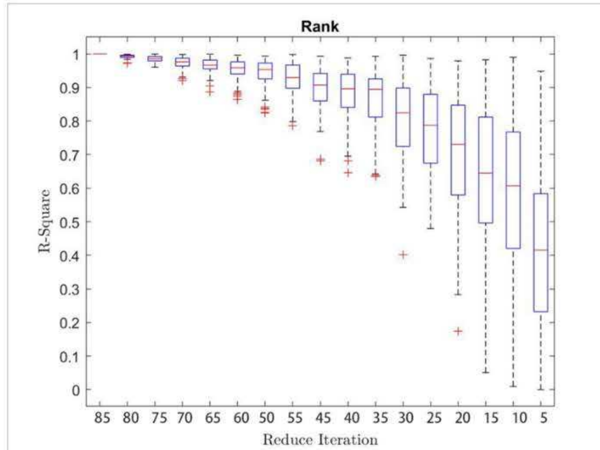

Figure 9.2 The line and box plots for r^2 distributions from Rank-Order methods.

Fig. 9 The box plots for the r^2distributions from 6-AFC and Rank-Order methods.

Notice that for both methods, taking n=5 as an example, it is evident that the Rank-Order method median (shown by the red horizontal line) is slightly higher than 6-AFC method (r^2 ~ 0.37 in 6-AFC method, r^2 ~ 0.42 in Rank-Order method). However, there is substantially more variation in 6-AFC method (shown by the line plots) which ranges between approximately from 0.65 (for n =5), whereas the Rank-Order method ranges approximately from 0.98. Furthermore, Fig. 9 show that the *outliners* (red stars) from the 6-AFC methods are much more than in Rank-Order methods. Both of these happens for most values of n. In other words, the results from Monte Carlo simulations show that the Rank-Order method is more relay and stable than the 6-AFC method for individual colour preference when n is small. This suggests that, for studies involving small numbers of participants (participant factor), the rank-order method (experimental method factor) should be preferred.

DISCUSSION AND CONCLUSION

Although the Online experiment was less well controlled than the Laboratory experiments, due to likely variation in display technology and viewing conditions (*experimental environment factor*), it has the advantage in that it is relatively easy to recruit a large number of participants. The similarity between the results obtained from these two experiments provides some validation for the online protocol and suggests that online experiments could be used more often (despite the relative lack of control); this could allow the recruitment of many more participants than are typically used in highly controlled laboratory experiments and this could provide more robust estimates of Independence colour preference for groups of participants (that could be differentiated by factors such as gender and culture or even socio-economic status). Validation of online location as a research technique opens up the possibility of large-scale studies involving thousands of participants which could yield interesting insights into whether there is any effect of age, gender, cultural background etc. on individual colour preferences.

The individual colour preference results from this study gave two descending orders of individual colour preference from multiple choice for 6-alternative forced-choice method (Blue > Red > Orange > Yellow > Purple > Green) and multiple choice for rank-order method (Blue > Red > Orange > Yellow > Purple > Green) were similar. It shows that blue is the most strongly preferred colour in both two statistic methods; purple and green are weakly preferred. The evidence shows an agreement between the two methods' result (r^2=0.90). This study also employs the Monte Carlo Analysis method to compare the result performance of the 6-AFC and rank-order research methods for individual colour preference by repeating 1000 trials. The results from Monte Carlo simulations show that the average correlation coefficients (r^2) variation range for 6-AFC method is wiled than rank-order method. In other words, the Rank-Order method has a high level of agreement with each trial than the 6-AFC method for individual colour preference. In other words, the results from Monte Carlo simulations show that the rank-order method is more stable than the 6-AFC method for individual colour preference when only small number participants take part in the experiment. This suggests that, for studies involving small numbers of participants (less than 15 participants), the rank-order method should be preferred (the framework).

Finally, for individual colour preference, it is noted that this work was concerned with that aspect of colour known as hue only (six hues). However, it is acknowledged that lightness and chroma may also be considerable. The work in this study is also limited to comparing the results from other research methods (such as affective judgments method, bipolar adjective method, paired-comparison method etc.) for individual colour preference. It is clear that much more work is required in this field.

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