

Significance of Print Quality in Variable Data Printing

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Abstract

Print quality and variable data printing are two important topics when discussing digital printing and its ability to be a commercially successful printing technology. The aim of this paper is to determine the significance of print quality when using variable data printing to customize printed matters. In this study three levels of colour print quality and three levels of personalization; entirely static, personalized with name, and personalized with name, text and image, were established. Sample material was obtained by creating fictitious advertisements in the personalization levels, which were then printed at the print quality levels. A panel of respondents was asked to arrange the fictitious advertisements in order of preference. At all print quality levels, personalizing with only name led to a rather small increase in respondent preference compared to the static advertisements. However, personalizing with name, text and image led to a significant increase in preference compared to a static or name personalized advertisements. Hence, to attract the respondents a higher level of personalization should be used. The respondents were more forgiving towards low print quality when the advertising information was personalized. Furthermore, personalization contributes more at lower print quality levels, indicating that print quality is more significant in static printed matters or printed matters with a low level of personalization.

Keywords: Digital printing, Print quality, Variable data printing

1 Introduction

Before the 20th century, printing was the only way of spreading marketing messages and information to customers when referring to non-personal communication channels [1]. During the later half of the 20th century many new, non-printed, channels for reaching a mass audience have been introduced. Communication media like radio, television and the Internet have changed the way that information and marketing messages are pushed and pulled to and from customers. The new channels, with the global spreading of the Internet leading the way, have however made print just an output channel among others. Until professional digital printing was introduced in the beginning of the 1990's, printing was only possible to use when trying to reach a mass audience with static messages. Digital printing, in contrast to conventional printing technologies does not require a static printing plate (e.g. [2,3]), and is therefore suitable for producing mass customized [1] printed advertising material in e.g. one-to-one marketing [4]. Customized printing is based on the "*combination of variable information with output devices that do not require intermediate films or plates*" [3] Using digital printing for customization to make documents more effective as a business tool is a major economic driving force identified by the non-profit digital printing industry consortium PODi (e.g. [5,6]).

Variable data printing can be used to gain business success since customized advertising material can make a significant increase in response rate compared to static advertisements [7]. However, earlier studies indicate that the use of variable data printing is in general low among

printing houses [8] even though the technology has been available for over ten years. During this period the print quality of digitally printed matters has steadily improved and is today classified as good enough for many applications [2]. Print quality is a general measure of the success of a colour printing system and is an important customer requirement, along with other requirements such as cost, productivity, connectivity and reliability [9]. Furthermore, print quality is one of customer's top considerations when purchasing printed matters [10]. The digital printing equipment available today with the capacity to produce variable data prints range from inexpensive office copy-printers to high-speed production equipment, which also means large variations in print quality. Furthermore, the importance of colour has been stressed in earlier research [7]. The response rate from a mailing campaign increased by 46% when colour was added to a static advertisement. For a customized advertisement the increase for colour was 167%.

Print quality and variable data printing are two important topics when discussing digital printing and its ability to be a commercially successful printing technology. The aim of this paper is to determine the significance of print quality when using variable data printing to customize printed matters. The following research questions have been formulated to investigate the problem:

- What effect do different types of personalization have on the respondents' preference at different print quality levels?
- Is colour of any significance for the experience of personalized advertisements?

2 Material and Method

2.1 Research Approach

In spring 2006, 28 respondents participated in a significance evaluation of print quality and variable data printing. The group of respondents was selected to be equally distributed over age and gender. In this study, three levels of colour print quality and three levels of personalization were defined (Figure 1). The print quality levels were established by technical measurements and visual assessments. Fictitious advertisements were created at the three personalization levels. To adapt the advertisements to the panel of respondents, each respondent completed a questionnaire with information forming the basis for the personalization. The advertisements were then printed in the three colour print quality levels. In all, nine colour samples were obtained. In addition, three black and white samples were printed in the medium print quality level, one for each personalization level. An evaluation was conducted to determine the significance of print quality in personalized printed matter. The respondents were asked to arrange the fictitious advertisements with different levels of print quality and personalization levels in order of preference.

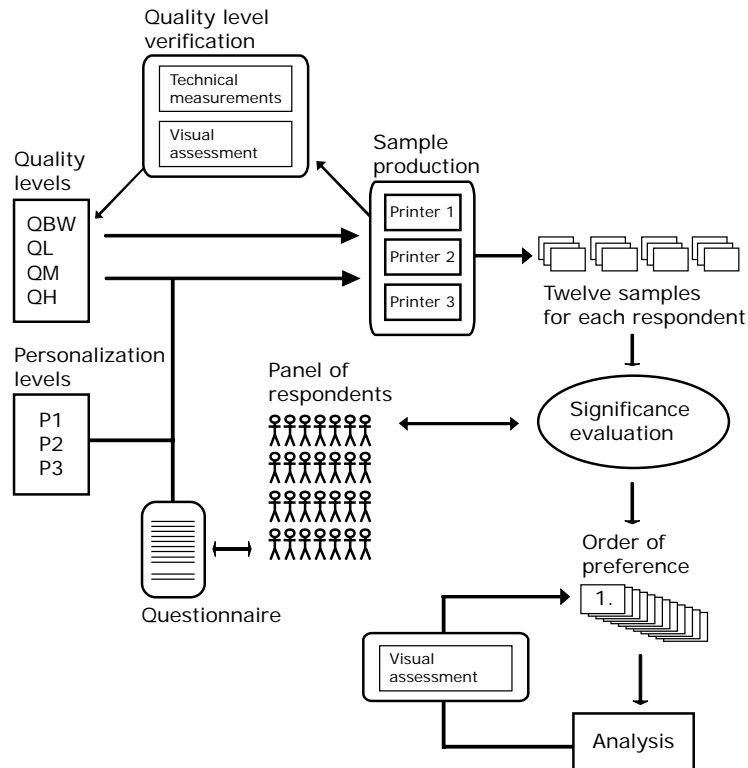


Figure 1: Schematic overview of the research process.

2.2 Personalization and Evaluation Material Design

The questionnaire, which formed the basis of the personalization of the test material, concerned travel and specifically the respondents' opinion of travel. The respondents were asked whether he/she preferred to travel in Sweden or abroad, if he/she preferred metropolises, seaside resorts or skiing resorts, with whom the respondent preferred to travel and how important high hotel standard, reasonable prices and the destination itself were when choosing destination. The respondents were also asked to grade how much they enjoyed different activities (e.g. golf, art, tourist attractions etc.) using a five-point Likert Scale, spanning from very uninterested to very interested [11]. The questionnaire also contained a section with background data e.g. age and gender.



Figure 2: Example of fictitious advertisements used as test material in the significance evaluation.

All advertisements were designed as an offer for a trip to a specific destination and hotel. The advertisements were created in 210 x 148 mm (A5) and consisted of a logotype, a catch phrase, an image and a text area (Figure 2). All advertisements were in Swedish since all respondents were native speaking Swedes. As in an ordinary advertisement, the variable images in this study were mainly selected to give the respondent a feeling of the destination. Three levels of personalization were determined and denoted *level 1*, *level 2* and *level 3*. The level 1 advertisements were entirely static and hence all respondents were given the same advertisement. In these advertisements the respondents were addressed as “Dear Traveller”. The level 2 advertisements were the same as level 1 and hence had the same offer and the same image. However, in these advertisements the respondents were addressed with their own name (e.g. “Dear Thomas Mejtoft”). In the level 3 advertisements, the offer was adapted to each respondent in terms of destination, hotel standard and hotel location. The choice of image was based on the destination or the preferred activity while on vacation. The hotel standard and the vicinity of the hotel were based on the respondent’s answer on the importance of the hotel standard and the preferred activity while on vacation respectively. This resulted in the use of nine different images. Further, the respondent was addressed by name in the same manner as the level 2 personalization.

2.3 Defining and Verifying Print Quality Levels

To create and define different levels of print quality a test form was printed on a number of different paper grades in a number of different printers. Based on a visual evaluation performed by the authors, three paper/printer combinations were chosen to represent the three levels of colour print quality. The levels were denoted *low*, *medium* and *high*. To verify the accuracy and distribution of these three colour print quality levels a more comprehensive evaluation was performed in terms of technical measurements and a visual assessment with a panel. A test form consisting of a test chart for technical measurements and images for visual evaluation was printed in all three printers. The test chart contained colour patches for measurements of print gloss, print mottle, sharpness, and colour gamut. The test form was printed on the chosen paper grade in the three printers.

The colour gamut volume was calculated on the basis of CIELAB-values from printed areas of full tone cyan, magenta, yellow, red, green, blue, black and paper white. The CIELAB-values were measured with a GretagMacbeth Spectroscan spectrophotometer. The settings used were D₅₀, two degrees and the No filter. The test areas for print mottle and sharpness were scanned at 300 ppi using an Epson Expression 10000 XL desktop scanner. The measures of these quality

factors were calculated using Matlab® image analysis routines, which are developed to correlate with the visual appraisal. Print mottle was measured from areas of full tone cyan and full tone green. Sharpness was measured from two regions; a black vertical and horizontal line on white background and a black vertical and horizontal line on a yellow background. Hence, the sharpness metrics *black raggedness vertical*, *black raggedness horizontal*, *colour raggedness vertical* and *colour raggedness horizontal* could be calculated. Print gloss measurements were performed with a Zehntner glossmeter ZLR 1050M. Measurements were done on a full-tone black area and on a full-tone green area at an angle of 75°, according to the standard [12].

As mentioned earlier, a visual assessment was conducted to establish the accuracy of the print quality levels used in the study. The outcome of a visual assessment depends on the motif used [13]. Further, an image evaluation will be more useful if several types of images are used [10]. To avoid any influence from the different images included in the study, this assessment involved all nine images used in the advertisements at each of the three colour print quality levels, in total 27 samples. The samples were presented to a panel of 14 experienced print quality observers. The images were presented three at the time; one image printed in each print quality level. The method used was category scaling [10]. Each observer was asked to express their opinion of the general print quality of each sample on a 10-point numeric rating, where a larger number implied better print quality. The assessment was performed in a standard daylight viewing illumination, D₅₀. The result was presented as the mean value for each print quality level.

Earlier research [14] has shown that experienced print quality observers and inexperienced respondents might judge print quality differently. Therefore, another visual assessment was performed, this time using the respondents participating in the significance evaluation of the advertisements. Hence, it could be investigated if this difference could affect the results of this study. The samples used were the level 1 advertisements printed in the three colour print quality levels, i.e. the most frequent advertisement in the significance evaluation. The assessment was performed using the same method and under the same conditions as the assessment with the experienced observers. The data regarding each respondents view on the print quality levels also gave another dimension in the analysis of each respondent's answer in the significance evaluation. This data made it possible to adjust the results and base the three colour print quality levels on how each individual respondent perceive the print quality at the different levels. That is, if a respondent perceived the established medium level quality to be the best, the ranking of this sample was adjusted to be used in calculating the mean value of the high print quality level. Furthermore, this assessment enabled a comparison between the experienced print quality observers and the inexperienced respondents regarding appraisal of print quality.

2.4 Sample Production

The three colour print quality levels were all produced by using the same paper grade in different printers. To produce the samples, the three levels of personalization were then printed at the three colours print quality levels. In addition, the three levels of personalization were printed in black and white on the paper/printer combination producing the print quality level denoted medium. Hence, a total of twelve types of samples were produced, nine colour and three black and white. The encoding of the samples is presented in Table 1.

Table 1: Encodings of levels of personalization and print quality.

| | | Personalization | | |
|---------------|---------------|---------------------|-------------------|------------------------------------|
| | | Level 1 (Static) | Level 2 (Name) | Level 3 (Name, Text & Image) |
| Print Quality | Black & White | P1-QBW | P2-QBW | P3-QBW |
| | Low Color | P1-QL | P2-QL | P3-QL |
| | Medium Color | P1-QM | P2-QM | P3-QM |
| | High Color | P1-QH | P2-QH | P3-QH |

For each type of sample a unique set was produced for each respondent and all samples of personalization level 2 and level 3 were conformed to the specific respondent based on the answers obtained from the questionnaire.

Even though the static sample could be produced using conventional printing technology, all samples were printed in digital printing to ensure consistency of print quality between the three levels of personalization. In general, conventional printing is regarded to give slightly higher print quality than digital printing. This implies that the static advertisements could potentially get a higher print quality if printed using conventional printing technology. However, this quality difference is constantly changing as the quality of digital printing is improving. As the purpose of this study is not to compare digital and conventional printing the potential quality differences between the two printing technologies will be disregarded.

Since all respondents' sets of samples were unique, there was a risk of copy to copy variation in the production of the samples. Nevertheless, to ensure the accuracy between the different copies and ensure a minimal variation between the different sets, all samples were visually investigated after production. The samples were found to be visually indistinguishable and hence any possible copy to copy variation should not affect the results of this study.

2.5 Significance Evaluation

Rank order [10] was the method used in the significance evaluation of the advertisements. This method is suitable when having few samples that are easy to mix up and when the effort from the respondents should not be too demanding. The evaluation was carried out by the 28 respondents. Each respondent was presented to a unique set of all 12 samples. The respondents were asked to view the advertisements one at the time – look at the image and read the text – and decide how appealing each sample was to them, i.e. how well each sample caught their attention. The respondents were then asked to sort the samples in order of preference. The order of precedence was translated to ranking points. The best ranked sample got twelve points; the second best got eleven points and so on down to the lowest ranking sample that got one point. The evaluation was performed in a standard daylight viewing illumination, D_{50} . Each respondent performed a colour vision deficiency test before the evaluation. This test contained two samples from the Ishihara test plates, designed to separate the persons with colour defects from those with normal colour appreciation [15]. No respondents showed any tendencies towards colour defects.

3 Results

3.1 Print Quality Levels

The accuracy of the defined print quality levels was confirmed both by the technical measurements (Table and Table) and the visual assessment by the experienced observers. The high quality samples had larger colour gamut volume and higher print gloss than the medium quality samples. No significant differences between these two print quality levels were found in print mottle or sharpness. The medium quality sample had larger gamut volume and lower colour raggedness, i.e. better sharpness, than the low quality sample.

Table 2: Technical measurements of colour gamut volume, print mottle and print gloss.

| Print Quality | | Colour Gamut Volume | | Print Mottle | | Print Gloss | |
|---------------|--------|---------------------|--------|--------------|-------|-------------|-------|
| | | | | Cyan | Green | Black | Green |
| | | QL | 219050 | 0.06 | 0.25 | 67.08 | 68.85 |
| QM | 308330 | 0.03 | 0.14 | 32.57 | 42.73 | | |
| QH | 417910 | 0.02 | 0.25 | 97.80 | 99.10 | | |

Table 3: Technical measurements of sharpness.

| Print Quality | | Black raggedness | | Colour raggedness | |
|---------------|------|------------------|----------|-------------------|----------|
| | | Horizontal | Vertical | Horizontal | Vertical |
| | | QL | 5.51 | 18.75 | 44.83 |
| QM | 5.78 | 5.26 | 5.63 | 4.96 | |
| QH | 7.66 | 6.18 | 7.66 | 5.73 | |

The visual assessment of all the nine images in the three colour print quality levels, performed by the experienced observers, showed that the print quality levels were accurately defined (Figure 3), regarding both order and distribution.

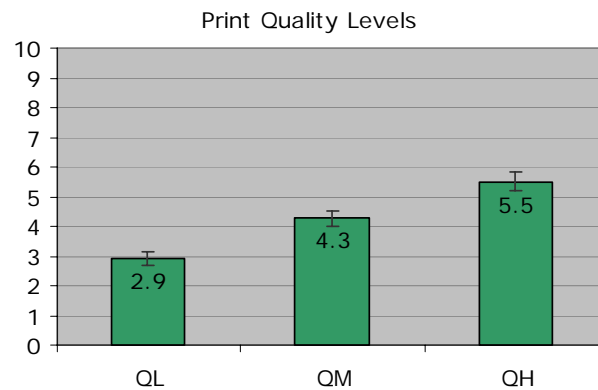


Figure 3: The results from the visual assessment of all the nine images in the three colour print quality levels (with 95% confidence intervals), performed by the experienced observers.

The visual assessment performed by the inexperienced respondents, indicated that they also found the print quality levels as accurately separated. Hence, in general both the experienced and the inexperienced respondents assessed the print quality levels similar. However, as expected, the individual observers had different views on the range, order and distribution of the print quality levels.

3.2 Outcome of Significance Evaluation

The results from the significance evaluation were cross-referenced to the background data collected from each respondent. It could be concluded that there were no considerable differences in opinion based on gender or age.

In the significance evaluation, the respondents put the samples in order of precedence. The significance evaluation showed that the samples with level 3 personalization were, at all three colour print quality levels, preferred over the level 1 and level 2 personalization samples (Figure 4 and Table 2).

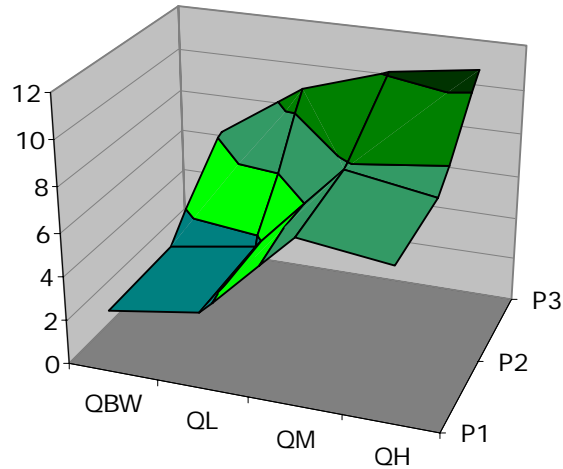


Figure 4: Mean value according to print quality level and personalization level.

Table 2: Mean value according to print quality level and personalization level.

| | | Personalization | | |
|---------------|---------------|---------------------|-------------------|---------------------------------|
| | | Level 1 (Static) | Level 2 (Name) | Level 3 (Name, Text & Image) |
| Print Quality | Black & White | 2.82 | 3.04 | 6.18 |
| | Low Color | 3.46 | 3.68 | 8.79 |
| | Medium Color | 7.39 | 7.86 | 10.11 |
| | High Color | 6.86 | 7.14 | 10.68 |

Basically print quality is something that is perceived by the customer rather than objectively determined by a printing house, printing press manufacturer or an expert panel. As mentioned earlier, the visual assessment performed by the respondents indicated that there were differences in how the different respondents appraised the print quality. Adjustments were made to the data from the significance evaluation using the outcome of the visual assessment performed by the respondents. This made small but noticeable corrections to the results (Figure 5).

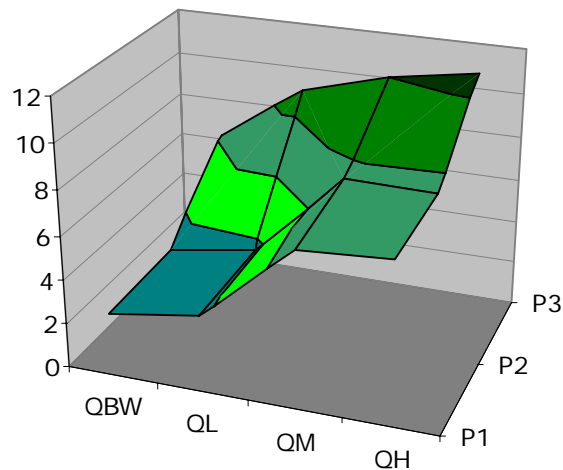


Figure 5: Adjusted mean value according to print quality level and personalization level.

Table 3: Adjusted mean value according to print quality level and personalization level.

| | | Personalization | | |
|---------------|---------------|---------------------|-------------------|------------------------------------|
| | | Level 1 (Static) | Level 2 (Name) | Level 3 (Name, Text & Image) |
| Print Quality | Black & White | 2.82 | 3.04 | 6.18 |
| | Low Color | 3.43 | 3.64 | 8.93 |
| | Medium Color | 7.00 | 7.54 | 10.00 |
| | High Color | 7.29 | 7.50 | 10.64 |

It could be noted in Figure 5 that the dip in Figure 4 in grading between medium and high quality for level 1 and level 2 personalization evened out when the results were adjusted to conform with how each respondent perceived the print quality.

4 Discussion

Defining accurate and relevant print quality levels was a difficult task since print quality is a subjective matter. It was also hard to analyze the exact print quality experience of each respondent. However, the results from the general visual assessment with experienced print quality observers indicated that the print quality levels were relevant. Adjusting the results from the significance evaluation and basing the three colour print quality levels on how each individual respondent perceived the print quality of each different level further limited the influence of any differences in perceived print quality among the respondents.

The influence of the choice of personalization levels, type of advertisement, layout etc. can not fully be determined from this investigation. However, the use of a general subject like travel, a basic layout and three distinct personalization levels would give a good indication of the general outcome of an analysis of the significance of print quality in variable data printing.

As mentioned earlier, digital printing and conventional printing differ in their ability to produce customized printed matters. While digital printing can be used for both static and variable data printing, conventional printing technologies, such as offset, can only be used for printing static matters. If cost and speed is taken into account conventional printing technologies are often used for longer run lengths and digital printing for shorter run lengths or variable data printing since the production cost for digital printing is higher than conventional printing for longer runs (e.g.[2,16]).

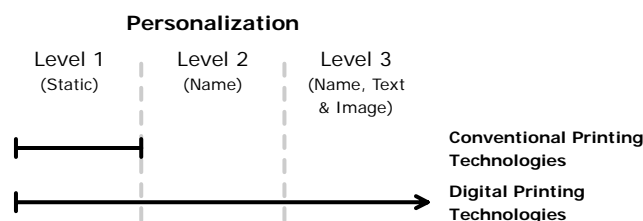


Figure 6: Possible printing technologies to use at different levels of personalization.

Translating this study into a commercial perspective, means that when moving from a level 1 personalization (static) to a level 2 personalization (name), a change in printing technology has to take place. Accordingly, a level 3 personalization (name, text & image) also has to be printed using digital printing, since some information is personalized (Figure 6). However, it should be

noted that in this study all samples have been printed in digital printing to ensure consistency of print quality between the three levels of personalization.

The mean value over all print quality levels of a level 2 personalization does not differ substantially from using a level 1 personalization, leading to an increase of 5.8% in appraisal by the respondents. Further, adding personalized text and images (level 3) improves the appraisal by another 65%. As mentioned before, customizing some part of a print requires digital printing. Taking into account the higher production cost of digitally printed advertisements (if a long total run length is presumed), the motivation to personalize by using name only is in fact low.

Regarding print quality, it is possible to distinguish a mean increase of 33% in appraisal when using colour at the low print quality level instead of black and white printing. However, a further increase of 53% is noticed when increasing the print quality from the low level to the medium level. When increasing the print quality even more there was only a 3.6% increase in appraisal.

Looking at personalization level 3, the low quality samples differed only slightly from the medium and high quality samples (8.9 vs. 10.0 and 10.6). However, at level 1 and level 2 personalization, the low quality colour samples clearly differed from the other two levels (level 1: 3.4 vs. 7.0 and 7.3; level 2: 3.6 vs. 7.5 and 7.5). This indicated that the respondents were more forgiving towards low print quality when the advertising information was personalized.

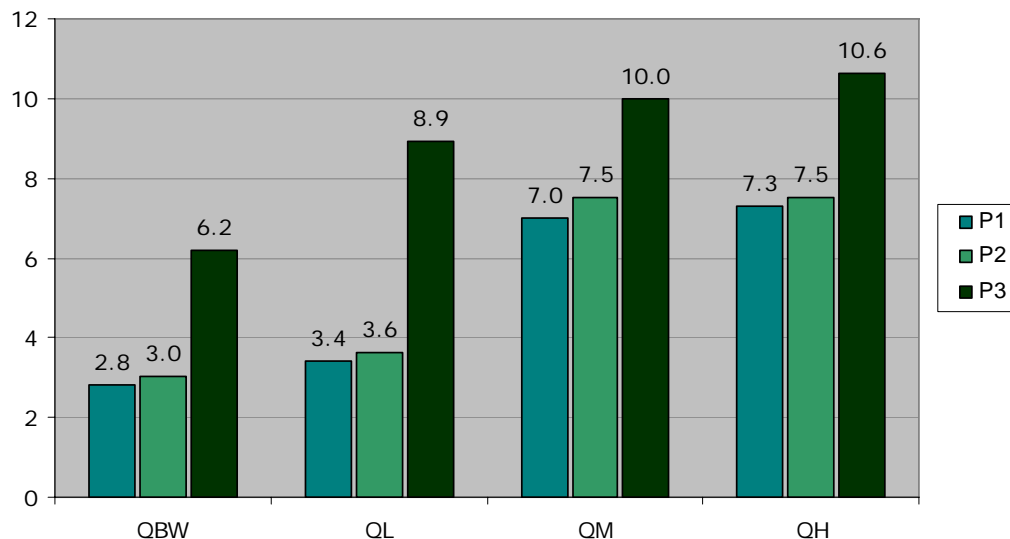


Figure 7: Adjusted mean value, sorted according to print quality level.

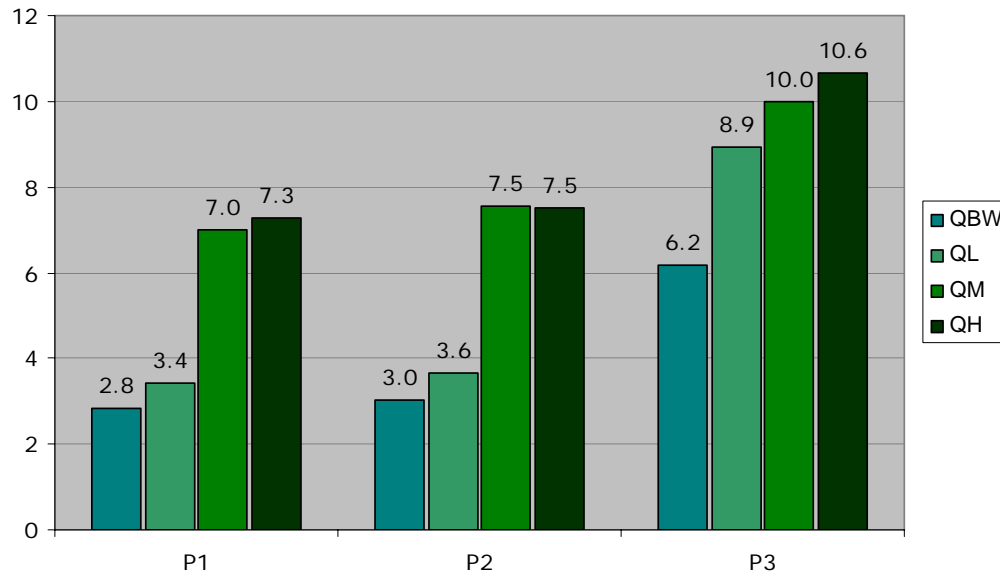


Figure 8: Adjusted mean value, sorted according to personalization level

The black and white samples showed the same tendency as the colour samples, i.e. a slight increase in preference between the level 1 and level 2 personalization, but a considerable increase between level 2 and level 3 (Figure 7). At each personalization level the colour samples were more appealing to the respondents than the black and white samples (Figure 8). Further, a level 3 personalization black & white advertisement is less appealing than both level 1 and level 2 personalization colour samples at high and medium print quality in colour. However, as noted in Figure 7 and Figure 8 the respondents believed that the level 3 personalized black and white sample were more appealing than the level 1 and level 2 personalization of the low and medium print quality in colour. This means that if the cost of colour printing, in comparison with black and white, is much higher than the cost of personalization, a black and white printed matter with high personalization could be preferred.

This research study is just a brief introduction to investigating the interaction between variable data printing and print quality. Nevertheless, in this investigation the importance of specific images, subject and layout of the advertisements have become noticeable. Future research must take in consideration these factors by extending the investigation even further. For example, the choice of images could affect the results not only by the motif but also by the balance and composition of the colours in the images. That is, an image with highlights would most likely print differently than a highly saturated image. Furthermore, the selection of the image on the static sample is important, since this image is the one that most samples had printed. In this study this was the image that the correction was based on, which raises the validity of the investigation.

The levels of personalization could be divided into more unique levels to separate the effect of personalized text and images and investigate these two individually. This is especially important since the results from this study show that personalization with name only (level 1) does not make any significant change in appraisal from a static sample. Could appraisal be raised even further by for example removing the name from level 3 personalization, and making the personalization more “invisible” to the respondent? This could also be studied with for example eye-tracking equipment to investigate how the respondents observe each sample before making a decision of order or preference.

5 Conclusions

With the type of printed advertisements, print quality levels and personalization levels used here, personalizing with only name led to a rather small increase in respondent preference compared to the static advertisement. However, personalizing with name, text and image led to a significant increase in preference compared to a static or name personalized advertisements. Hence, to attract the respondents a higher level of personalization should be used.

The respondents were more forgiving towards low print quality when the advertising information was personalized. Furthermore, personalization contributes more at lower print quality levels, indicating that print quality is more significant in static printed matters or printed matters with a low level of personalization.

In general, colour prints seemed to be preferred over black and white prints. No differences were found between the three sets of colour advertisements and the black and white advertisements regarding the significance of print quality and personalization. The highest personalized black and white sample was more appealing than the lower personalization levels of the low and medium print quality in colour. Consequently, a black and white printed matter with high personalization could be preferred if the cost of black and white printing is much lower than colour printing.

The conclusions in this study were consistent with previous research regarding both the effectiveness of variable data printing (e.g. [5,7]) and the importance of print quality [10]. However, this study was inconclusive with earlier research that suggests a considerable increase in the response rate when using name personalization instead of static advertisements [7]. Instead, the results from this study indicated an insignificant difference between static and only name personalized advertisements. Future research should consequently include a fourth personalisation level in which the text is personalised but without the name personalisation to clarify the significance of text personalization.

In contrast to other studies (e.g. [7]) this study has focused on the respondents experience in a qualitative study rather than actual response rates in a quantitative study. This illustrates that it is possible to get knowledge on the importance of print quality in relation of variable data printing in a time and cost effective study.

This study further advances the scientific knowledge by introducing the print quality concept in the discussion of variable data printing. The two concepts are individually important in both research and the industry and this study gives knowledge about where resources should be focused to make a printed matter more effective in catching the attention of the customer.

Acknowledgements

The authors would like to dedicate a special thanks to all the respondents in the significance evaluation and the observers in the visual assessment for their participation. We would also like to thank our supervisors *Prof. Nils Enlund*, KTH, *Prof. Björn Kruse*, Linköping University, *Dr Marianne Klamann*, STFI-Packforsk, and *Dr. Per-Åke Johansson*, STFI-Packforsk for their valuable comments. The *Kempe Foundations*, the *EU Structural Fund*, the Swedish printing research program *T2F*, and the *industry participants in the DigiPrint project* are gratefully acknowledged for their financial support.

The authors are grateful for the scholarship from *Tryckeriföreningens stiftelse för utbildning och forskning (TUF)*, that made possible to present this research at the 2007 Taga Conference in Pittsburgh, USA.

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