Features contributing to the genuineness of portraits on banknotes

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Abstract

Portraits have been thought to be one of the most important security features on banknotes for a long time. Portraits are often printed as the main feature of banknotes at a very high resolution in intaglio press. We tried to investigate on how important portraits actually are and what factors were contributing to the perceived genuineness of portraits on banknotes with a psychometric experiment. Banknotes were presented to subjects, enclosed in envelopes to cover the area other than the portrait, and the genuineness of those banknotes were rated. The factors affecting the rating were asked to the subjects at the same time. It was suggested that natural wear and tear strengthen the perceived genuineness of tested banknotes. Even though the inspection of the banknotes was restricted to on and around the portrait, the importance of the portrait was not high compared to other features, and a significant fraction of subjects answered that they paid no attention to any part of the face, which requires reflection and reconsideration of the use of human portraits as a security feature.

Keywords: intaglio printing, security printing, counterfeit deterrence, image quality, face perception

1. Introduction

The first-line security of banknotes or paper money for the general public is based on people's perceptual inspection, and the value of banknotes is the matter of people's subjective confidence in those banknotes (Masuda, Pedersen and Hardeberg, 2015). Human portraits have been used on banknotes for a long time (Hymans, 2004). Portraits of respected persons became popular in European banknotes since the economic crisis of the 1920s to support people's confidence in banknotes (de Heij, 2012). Face perception is, psychologically, known to be special compared to the perception of other objects (Bruce and Young, 2012). The recognition of human faces and that of other objects are thought to be independent to each other according to neuropsychological studies (Moscovitch, Winocur and Behrmann, 1997). Human portraits are usually the main feature of a banknote printed in intag-

lio press with high line contrast and high resolution, and they have been thought to be one of the most important security features on banknotes. However, the rationales for the support of human portraits as a security feature are often only anecdotal (e.g., Colgate, Jr., 1996), and the advent of modern photomechanical and digital reproduction techniques is endangering the raison d'être of intaglio portraits as a first-line security feature (van Renesse, 2005). On the other hand, not a small number of central banks adopt motifs other than human portraits as the intaglio main feature of their banknotes (Cuhaj, 2014; Hymans, 2006).

The purpose of this study is to know whether human portraits are still important as a security feature, and how they are contributing to the perceived genuineness of banknotes.

2. Methods

The subjective genuineness of the tested banknotes was estimated from the rating data of the banknotes. Each banknote was covered by an envelope with a hole, and only the area on and around the portrait was presented

to observers to focus the attention of the observers to the portraits. The factors that the observers were attending to while they were rating the banknotes were verbally reported, then transcribed and interpreted.

Table 1: Banknotes used for the experiment (W and H represent the width and height of each oval hole, respectively)

#	Abbrev.	Banknote	Series	W (mm)	H (mm)
1	AUD5	Australian 5 dollar	2003	51	57
2	AUD10	Australian 10 dollar	2002	51	57
3	AUD20	Australian 20 dollar	2002	51	57
4	AUD50	Australian 50 dollar	2003	51	57
5	CAD5	Canadian 5 dollar	2013	51	64
6	CAD20	Canadian 20 dollar	2012	51	64
7	CLP1000	Chilean 1000 peso	2011	51	57
8	CLP2000	Chilean 2000 peso	2009	51	64
9	MXN20	Mexican 20 dollar	2004	44	57
10	MXN50(I)	Mexican 50 dollar (intaglio)	2004	44	57
11	MXN50(O)	Mexican 50 dollar (offset)	2004	44	57
12	NZD20	New Zealand 20 dollar	1999	51	57
13	RON5	Romanian 5 leu	2005	51	63
14	RON10	Romanian 10 leu	2005	51	64
15	RON50	Romanian 50 leu	2005	51	64
16	RON100	Romanian 100 leu	2005	51	64
17	SGD10	Singaporean 10 dollar	2005	51	63

2.1 Materials

Each of seventeen banknotes as shown in Table 1 was enclosed in an envelope made of black cartridge paper. Each envelope had an oval hole so that the portrait and its proximal background on the banknote was observable. The size of the envelopes was the same for all banknotes, 215 mm in width and 89 mm in height, but the sizes and positions of the oval holes were adjusted according to those of each portrait.

The average width and height of the oval holes were 49.8 ± 2.7 mm (S.D.) and 60.2 ± 3.4 mm (S.D.), respectively. Figure 1 shows an example of the specimens with the Australian 10-dollar banknote.

2.2 Subjects

Twenty one subjects including 18 males and 3 females with a mean age of 32 years (range: 19–61 years) participated in the experiment. They were staff, students, and a visitor of the Faculty of Computer Science and Media Technology at Gjøvik University College, but were not experts in banknote and security printing. They are all color normal, and normal or corrected-to-normal sighted. The instructions to the subjects were given both orally and in writing, and were understood clearly. The familiarity to each banknote was inquired to each subject by a questionnaire before each experimental session, and no one was familiar to any of the banknotes.

Figure 1: An example of the specimens used for the experiment with the AUD10 banknote

Figure 2: Experimental viewing booth

2.3 Procedures

Experimental sessions were conducted in a viewing booth with D50 simulating fluorescent lamps, as shown in Figure 2. The tabletop was 120 cm wide, 85 cm long, 24 degree tilted, and illuminated at 1 400 lx by D50 simulating fluorescent lamps through a diffuser. The illuminance was measured by Konica-Minolta CL-200. The scene was recorded by video camera from the side.

The subjects wore cloth gloves on their both hands, and were allowed to judge the specimens only by vision. She/he was instructed to judge the degree of her/his agreement whether each banknote was genuine according to the 5-category Likert scale. Five white papers indicating the levels of rating, "Strongly agree", "Agree", "Neither agree nor disagree", "Disagree", and "Strongly disagree", were lined up from left to right on the table. The subject picked a specimen from a deck one by one, and put the specimen onto one of the 5 rating papers. The order of the specimens in the deck was randomized for each subject. The subjects were not informed whether the deck contains any counterfeit banknotes.

After the subjects finished rating of the specimens, they were asked what features in the whole open area of each banknote they were attending to, and what criteria they were using during the rating session. At the end of the session, the subjects were also asked which part of the faces of portraits, if any, they were attending to during the rating. The responses of the subjects were video recorded, and transcribed afterward.

Statements by subjects were reported by the open question method. When a statement was not clear, the exper-

imenter followed up to clarify what was meant by the statement, but no suggestions were made to lead the subject. Video recorded responses of subjects were transcribed literally, and then summarized as the keywords in Table 2 by one of the authors (OM).

Summarization of raw statements into selected keywords was done regardless of the context of the statements – whether they were mentioned positively or negatively.

Table 2: Keywords for the features in overall rating of banknote genuineness

Keyword	Meaning and actual expressions
Background	Background other than the portrait.
Design	Design, arrangement, or combination of elements.
Detail	Fineness, high resolution.
Goniometric	Goniometric properties including gloss, raised intaglio lines.
Integrity	Overall integrity or conformity of elements.
Portrait	Intaglio portrait. Main figure of the banknote.
Photoreality	Photoreality of portraits and pictures.
Quality	Overall quality of printing.
Texture	Texture, pattern, shading, tone, contrast.
Wear	Wear and tear, fold, wrinkle.

3. Results

3.1 Rating of genuineness

Figure 3 shows the histogram of the category rating 5-level Likert scale on whether each banknote looks genuine. Each of 21 subjects made ratings of 17 banknotes, which comes to 357 ratings in total. Even though all of the specimens were actually genuine, only half of them were rated as "Strongly agree" and "Agree". A quarter of them were rated as "Neither agree nor disagree" and the remaining quarter were rated as "Disagree" and even "Strongly disagree".

Nominal values of 2, 1, 0, −1, −2 were first assigned to the 5 categories from "Strongly agree" to "Strongly disagree" of the raw rating data, respectively, and then an interval scale was constructed with Torgerson's law of category judgement, Condition D (Engeldrum, 2000), using the Colour Engineering Toolbox (Green and MacDonald, 2002), and the interval scale of "gen-
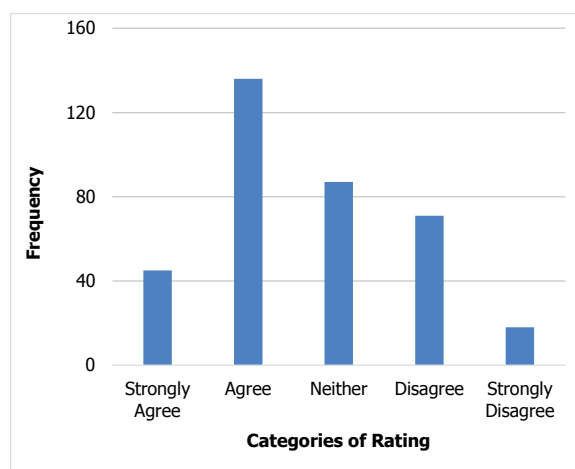

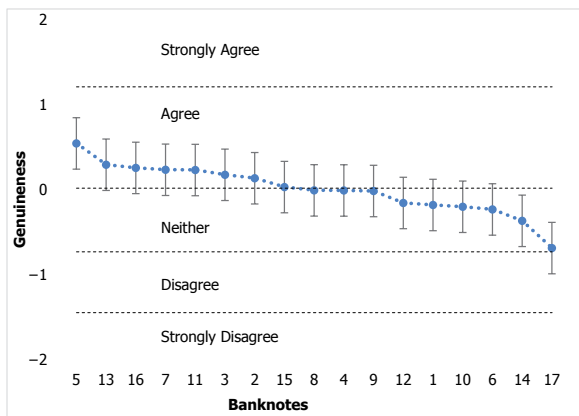*Figure 3: Histogram of category rating in 5-level Likert scale on whether each banknote looks genuine*

Figure 4: Interval scale of "genuineness" of the banknotes, where the error bars show the 95 % confidence intervals, and the horizontal lines show the borders between adjacent categories

uineness" of the banknotes was calculated as shown in Figure 4. The 95 % confidence intervals of the top 3 highly rated banknotes (5, 13, 16) did not overlap with those of the last lowly rated banknotes (14, 17).

3.2 Criteria of rating

Overall criteria of rating genuineness of banknotes were tallied as follows: The primary and secondary criteria were tallied separately, and each criterion was assigned 1
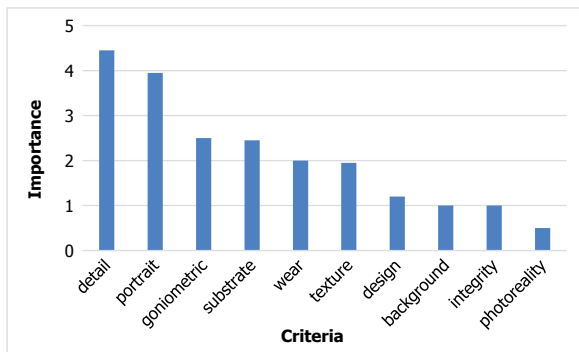

Figure 5: Importance of primary criteria in rating the genuineness of banknotes
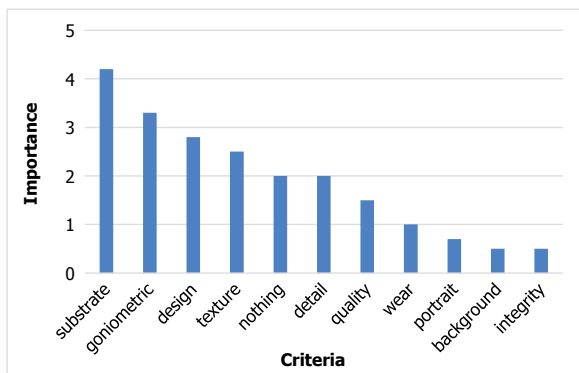

Figure 6: Importance of secondary criteria in rating the genuineness of banknotes
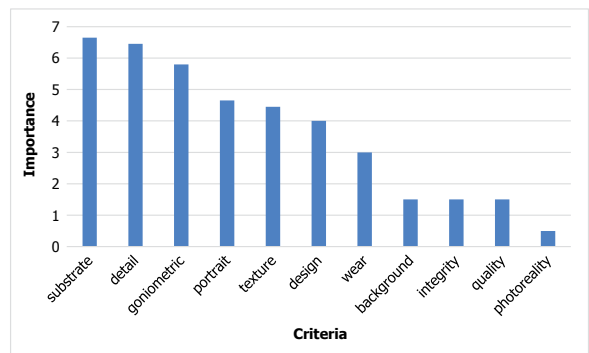

Figure 7: Summed importance of primary and secondary criteria in rating the genuineness of banknotes

point for each subject. When the subject stated his/her criterion of rating with an expression that contains multiple concepts across several keywords in Table 2, the assigned 1 point was divided to the keywords according to the importance of each keyword. For example, when a subject stated that the primary criterion was the conformity of portrait and background, the keywords "Integrity", "Portrait", and "Background" got points of 0.5, 0.25, and 0.25, respectively, for this subject. These points assigned for each subject were summed up for each keyword and are shown in Figure 5. The secondary criteria were also calculated in the same way, and are shown in Figure 6. When a subject had only primary criterion but no secondary criterion, the secondary criterion of this subject was counted as "Nothing". Figure 7 shows the histogram of the summed importance of the primary and secondary criteria.

Table 3: Additional keywords for the rating of individual banknote

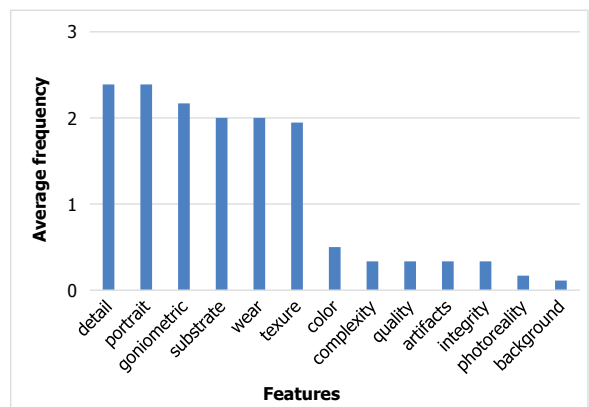| Keyword	Meaning and actual expressions
Artifact	Artifacts, noise or errors in printing.
Color	Color of elements.
Complexity	Complexity or elaboration in configuration of elements.

Figure 8: Histogram of features mentioned for highly rated banknotes individually

3.3 Comparison between highly and lowly rated banknotes

Features that were mentioned by subjects to each bank-note were compared between highly rated banknotes (5, 13, 16) and lowly rated banknotes (14, 17). In counting features mentioned to individual banknotes, three new keywords in Table 3 were needed in addition to those
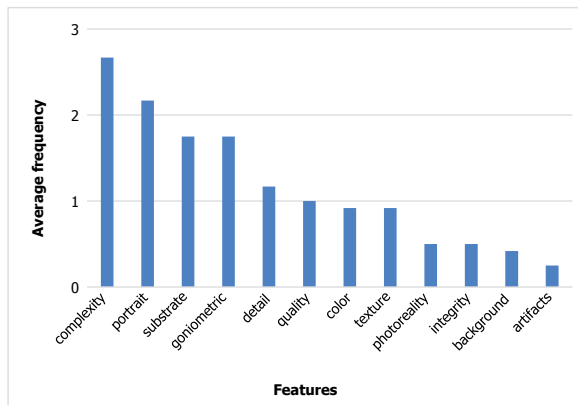

Figure 9: Histogram of features mentioned for lowly rated banknotes individually
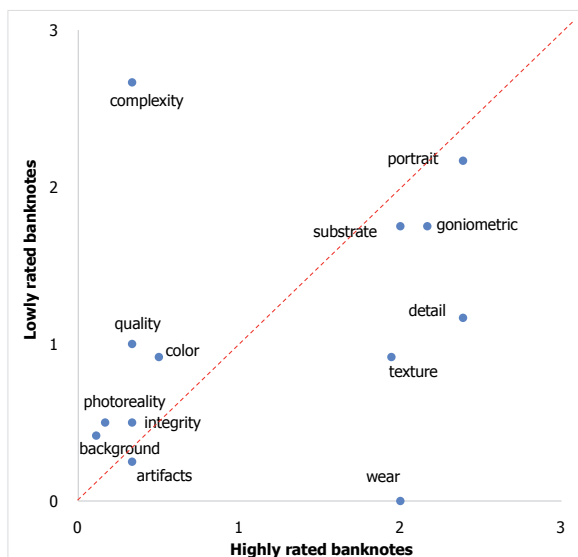

Figure 10: Scatter plot of the frequencies of features mentioned to highly and lowly rated banknotes

for overall criteria in Table 2. These additional keywords might be implicitly included in those in Table 2, but were not mentioned consciously for the overall rating of bank-notes. For the rating of individual banknotes, these key-words were mentioned expressly and were not ignorable.

The features mentioned for each of highly rated bank-notes were counted and averaged across all three bank-notes as shown in Figure 8.

In the same way, features mentioned for each of lowly rated banknotes were counted and averaged across two banknotes as shown in Figure 9.

The histograms of Figure 8 and Figure 9 were merged as a scatter plot as Figure 10.

Figure 11 shows the importance of parts in the face of the portrait. Each subject answered which parts of the face, if any, she/he was attending to during the session. If a subject had any facial parts she/he attended, the sub-ject earned one point of importance. When the subject answered more than one parts, the one point was divided to each part according to the importance of each part. For example, when the subject answered three parts and said that each part was equally important, each part earned 1/3 of point. When the subject didn't answer the degrees of importance of the parts explicitly, the experimenter estimated the degrees subjectively according to the verbal expressions by the subject. Seven subjects answered that they didn't have any part of the face to attend to, which were classified as "None" in Figure 11.
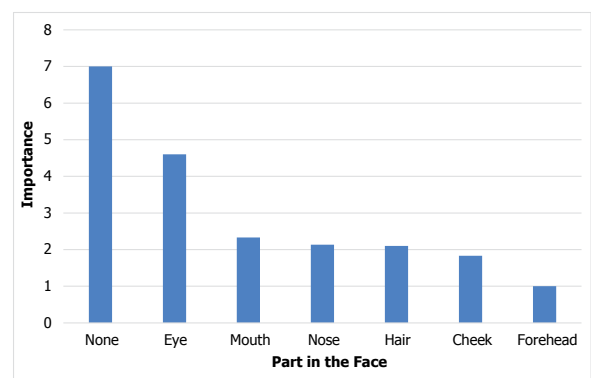

Figure 11: Importance of parts in the face of the portrait.

4. Discussion

As shown in Figure 3, the distribution of the histo-gram was skewed, and the peak of the histogram was at "Agree" and not at the center ("Neither"), which is natu-ral because all the specimens were actually genuine bank-notes. Even though the subjects didn't know whether the specimens contained counterfeits, a quarter of specimens were classified as counterfeits ("Disagree" and "Strongly

Disagree"), and only a half of specimens were classified as genuine banknotes with confidence ("Strongly Agree" and "Agree"). The restriction of observable area (only on and around portraits) and perceptual modality (only with vision but without touch) might have decreased the genuineness of the genuine banknotes compared to the normal observation condition.

As shown in Figures 5–7, the importance of "Portrait" was ranked number 2 as a primary criterion and number 9 as a secondary criterion. The summed importance of "Portrait" was number 4 after all. On the other hand, the importance of "Detail" was larger than "Portrait" both as a primary and secondary criteria. "Substrate" and "Goniometric" were also ranked higher than "Portrait" in the summed importance. Even though the observable area was restricted only to around the portrait, the portrait itself didn't attract so much attention of the subjects. A possible cause of this result can be that it was too obvious to mention and the subjects just omitted to mention it even though they were aware of it. Another possible cause is that the portrait was not actually very important in judging the genuineness of banknotes. The latter possibility is discussed again later with the results of Figure 10 and Figure 11.

As shown in Figure 8, there was a clear difference between the more frequently mentioned features (from "Detail" to "Texture") and less frequently mentioned features (from "Color" to "Background") in highly rated banknotes. On the contrary in lowly rated banknotes, the difference of frequencies among features was gradual as shown in Figure 9. The clear dichotomous distribution of features for highly rated banknotes in Figure 8 suggests that the features that contribute to genuineness are limited and the relative importance among them are almost equal.

As shown in Figure 10, the features on and around the diagonal line of the graph are important in both highly and lowly rated banknotes in almost the same degree. Features in the upper right corner such as "Portrait", "Substrate", and "goniometric" are important for both highly and lowly rated banknotes. On the other hand, features in the lower left corner such as "Color", "Integrity", or "Artifacts" are not so important in neither highly and lowly rated banknotes. On the contrary, "Complexity" and "Wear" are far away from the diagonal line, which means that they were peculiarly important for lowly or highly rated note, respectively. Actually, "Complexity" was mentioned in a negative context for lowly rated banknotes, that is, the lack of complexity, excess simplicity, or poorness of configuration was designated to lowly rated banknotes. "Quality" was also mentioned more frequently to lowly rated banknotes in a negative context that the printing quality of those banknotes were poor. On the other hand, "Wear" was mentioned more frequently to highly rated banknotes than lowly rated banknotes, which means that the wear and tear of the highly rated banknotes were natural, and such natural damages did not harm the genuineness of the banknotes. On the contrary, reasonable and plausible wear and tear makes the banknotes look more genuine. The banknotes tested in the present study were polymer-substrate banknotes. The durability of polymer banknotes is known to be much longer than paper banknotes (Wilson, 1998). The fact that the feature "Wear" were rarely mentioned to lowly rated banknotes suggests that the intactness and flawlessness might have harmed the genuineness of those banknotes conversely.

As shown in Figure 11, one third of the subjects answered that they paid attention to no part of the face of the portrait even though the observable area was restricted only to on and around the portrait. Among the rest of the subjects, the part that attracted the strongest attention was the eye, and its importance was about twice of that of following four parts (mouth, nose, hair, cheek). Only one subject answered that the forehead was important. The fact that the eye was the most important is consistent with the conventional design policy in portrait engraving (Church and Setlakwe, 2004; de Heij, 2012). Since a third of the subjects didn't pay attention to any of the facial parts it might throw doubt on the conventional dogma that the peculiarity of facial perception gives a ground to use human portraits as the main feature in intaglio press. Further work should be carried out to investigate this, preferably with more subjects. As shown in Figure 10, "Portrait" was mentioned frequently both in highly and lowly rated banknotes when individual banknotes were reviewed. However, as in Figure 7, "Portrait" was ranked number 4 in importance when overall criteria were asked. There is a recent trend that the size of the portrait on a banknote is getting larger (de Heij, 2012; Board on Manufacturing and Engineering Design, 2007). Evidence-based verification of the effectiveness of human portraits as a security feature would be needed for further research.

5. Conclusions

Portraits are often considered to be one of the most important security features on banknotes. In this work, we investigated how important portraits actually are and what factors were contributing to the perceived genuineness of portraits on banknotes with a psychometric experiment. In the experiment, banknotes were presented to 21 subjects, who rated the genuineness of the banknotes. The results indicate that natural wear and tear strengthen the perceived genuineness of the tested banknotes. Even though the inspection of the banknotes was restricted to on and around the portrait, the importance of the portrait was not high compared to other features, and a significant fraction of subjects answered that they paid no attention to any part of the face, which requires reflection and reconsideration of the use of human portraits as a security feature.

Acknowledgements

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