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Effects of awareness to security features on the confidence in banknotes

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Abstract

The value of a banknote is dependent on people's subjective trust in the banknote, and the resistance against counterfeiting is a key factor of people's confidence in the banknote. An experiment was conducted to investigate the relationships between the awareness to security features on banknotes and the perceived resistance against counterfeiting in those banknotes. It was found that the more security features subjects found by themselves on a banknote, the more resistant they perceived the banknote, which suggests that people's awareness to security features affects their confidence in the banknote. The perceived resistance was irrelevant to the number of public security features disclosed by the central banks, but was relevant to the familiarity to the note, which suggests the importance of practical experience with banknotes rather than the knowledge about them only. These findings can give a quantitative ground to the evaluation of the design of security features on banknotes.

Keywords: banknote, security printing, counterfeit deterrence, image quality

1. Introduction

A banknote doesn't have the same use-value as its face value. For example, if you used a €100 note as a tissue paper, its use-value would be the same as a piece of tissue paper, probably less than a cent, even though the face value is €100. Actually, the usability of banknotes as tissues would be terribly poor, and they don't have any practical use-value. The production cost of a banknote is much less than its face value (de Heij, 2010). A €100 note is actually produced at the cost of only €0.07. A €100 note has the value of €100 just because people exchange the note with another commodity that is worth €100. The exchange value of a banknote as the face value is guaranteed by people's trust in the banknote. There are a number of factors affecting people's confidence in a currency including the money supply in the market and the monetary policy of the central bank, and the resistance of the banknote against counterfeiting is an important factor. Even if a banknote is hard to counterfeit physically, people won't accept it unless they *believe* that the note is hard to counterfeit. Confidence in currency is a subjective matter of people's trust in banknotes.

There are a number of security features on a banknote. Security features are often categorized to three levels (Wielandt, 1998; Heinonen, 2007). Level 1 features are overt features that are easy to be authenticated by the general public without special inspection devices and proactively advertised by the central banks, which include intaglio portraits, watermarks, security threads, optically variable devices (OVDs) (van Renesse, 2005). Level 2 features need special inspection devices, such as magnifying lenses, ultra-violet lamps, magnetometric sensors, or infra-red cameras, and are for retailors and vending machines. Most of machine readable level 2 features are covert and the central banks are reluctant to disclose them. Level 3 features are covert and used only by central banks and forensic experts with sophisticated analytical instruments. Among these levels, level 1 features are the most important for the general public's confidence in banknotes and specific to banknotes compared to other payment methods, such as checks, credit cards, or electronic money systems. As legal tender, banknotes should be passable in any situation even on the street, and it is desirable that they can be authenticated merely by human senses, without inspection devices.

The importance of human perception studies on the design of banknotes has been recognized for a long time (Croney, 1970; 1974), but very few studies have been reported publicly. Collins et al. reported their perception studies to know how people could discriminate counterfeit U.S. banknotes from genuine notes and what security features were responsible for those decision (Collins, Mayerson and Worthey, 1985). In this report, a series of perception studies by Prof. Ivor Stillitz in 1970s for British pound notes were also reviewed thoroughly. The main conclusion of these studies was that banknotes should be designed to extend the time people spend observing the notes. Recently, psychophysical studies on the discriminability of counterfeit banknotes from genuine notes were conducted with United States (Hillstrom and Bernstein, 2002) and Canadian (Klein, Gadbois and Christie, 2004) banknotes. These studies revealed people's performance in the detection or discrimination of counterfeits, but their confidence in the banknotes were out of scope of these studies. People's confidence in banknotes has been of interest for central banks of the world, and has been surveyed with Euro in the Netherlands since 2005 and Canadian banknotes since 2004 (de Heij, 2006 and 2007; Visser and Dijkers, 2013; Taylor, 2006). However, these surveys were conducted by telephone interviews without presenting actual banknotes to the participants, thus the relationships between the confidence in banknotes and the sensory perception of security features are still unknown. The indices of confidence in banknotes on average between 2005 and 2011 were 7.1 for Euro notes and 5.5 for Canadian notes out of 10 (de Heij, 2012). However, the index of the Netherlands was measured by the rating in 0–10 scale to one question, and the index of Canada was constructed from the answers to four questions that were extracted from nine questions by a factor analysis. These indices can be used to track the fluctuation of confidence in each country over time, but their absolute levels are difficult to compare to each other between different countries.

In the present study, we investigated how the general public's confidence in banknotes is affected by people's awareness to security features on banknotes. In Section 2, the experimental methods are explained in detail, and the results of the experiment are shown in Section 3. The results are interpreted and discussed in comparison with previous studies in Section 4. Finally, conclusions are drawn in Section 5.

2. Methods

2.1 Overall methodology

The present study tried to reveal the relationship between the people's confidence in banknotes and the awareness to security features on the banknotes. The scale of confidence was constructed from the rank order data of the banknotes according to the perceived resistance of banknotes against counterfeiting. The awareness to security features on banknotes was estimated by counting the number of security features noticed by subjects while they were observing the banknotes freely at hand.

2.2 Materials

Nine banknotes, shown in Table 1 and Figure 1, were chosen on a hit-or-miss basis and used for the experiment. Three of them, RON1, RON50, AUD5, were polymer notes, and the others were paper notes. They had been in normal use, and showed slight wear and tear including folds and wrinkles, but the damage was minimal and negligible.

2.3 Subjects

Sixteen subjects participated in the experiment. They were staff and students 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 youngest and oldest subjects were 24 and 52 years old, respectively, and the average age was 32. Two of them were females. 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.

2.4 Procedures

Experimental sessions were conducted in a viewing booth with D50 simulating fluorescent lamps, as shown in Figure 2. The illuminance, measured by Konica-Minolta CL-200, on the tabletop of the booth was 1 400 lx.

Table 1: Banknotes used for the experiment in alphabetical order of the abbreviations; the series shows the first issue year of each note

Abbrev.	Banknote	Series	Substrate
AUD5	Australian 5 dollar	1995	Polymer
CNY100	Chinese 100 yuan	2005	Paper
DKK100	Danish 100 kroner	2010	Paper
GBP10	United Kingdom 10 pound	2000	Paper
INR1000	Indian 1000 rupee	2012	Paper
NOK100	Norwegian 100 kroner	2003	Paper
RON1	Romanian 1 leu	2005	Polymer
RON50	Romanian 50 leu	2005	Polymer
USD5	United States 5 dollar	2008	Paper

Figure 1: Pictures of the banknotes used for the experiment (the inscriptions of "SPECIMEN" were overprinted only to avoid the reuse of these pictures, but were not on the original notes used in the experiment); only the front sides of the notes are shown here, but the subjects were able to observe both sides at will

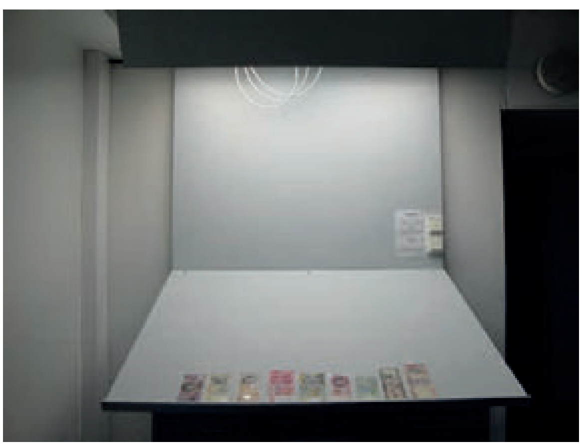

Figure 2: Experimental viewing booth – the tabletop was 120 cm wide, 85 cm long, 24 degree tilted, and illuminated at 1 400 lx by D50 simulating fluorescent lamps through a diffuser; the scene was recorded by a video camera from behind

All the nine banknotes were set on the tabletop in a random order before each experimental session. The subject picked up each banknote by hand one by one, and inspected it without time limit. They were allowed to inspect the banknotes in any nondestructive way. The ceiling lamp was suitably installed so that the watermarks were clearly observed by the transmitted light. They reported aloud every time they found any security feature, and articulated whatever they found, pointing out the place of the feature by their fingers. When the oral report by the subject was not clear, the experimenter followed up to clarify what was meant by the report. However, no suggestions or questions to lead the subjects were made. The experimental sessions were video recorded, and the reports by the subjects were transcribed later. In the transcription of the video recording, the number of security features found on each banknote by each subject was counted. When a single physical entity consisted of several security features and the subject pointed out each feature separately, each security feature was counted as one point. For example, when a subject found a security thread and pointed out that the thread was windowed and had an OVD on it, the number of security features with this thread was counted as three points (thread, windowing, OVD). On the other hand, when several security features were pointed out by subject A, and subject B pointed out those features as a single feature as a whole, each security feature found by subject A was counted as one point, whereas the total point given to the features found by subject B was one point, and the point was equally divided to those features. For example, when subject A made a distinction between the background patterns by dry offset press and the portrait by intaglio press, each security feature was counted as one point. On the contrary, when subject B didn't make distinction between the two, and just pointed out the fine detail of overall printing as a security feature, each feature (background pattern and intaglio portrait) was counted as 0.5 point. The security features sought were limited to those detectable only by human senses such as sight and touch. When the subject mentioned features that are machine readable or that need special inspection devices such as a magnifying lens, ultra violet lamp, or chemicals, those features were ignored and not counted.

After the inspections of all the banknotes, each subject ranked the banknotes in an order according to their perceived resistance of each banknote against counterfeiting to be analyzed by the rank order scaling method (Engeldrum, 2000). More "hard-to-counterfeit" banknotes were placed to the left, and more "easy-to-counterfeit" banknotes were placed to the right.

3. Results

3.1 Number of features found

Figure 3 shows the numbers of security features found by the subjects for each banknote. Filled bars show the net number of features without overlap of the same feature. Hatched bars show the average number of the features found by each subject on each banknote. The net number had a large variability with a standard deviation of 4.15 ranging from the minimum of 8 to the maximum of 22. On the other hand, the average number was 3.9 for with a standard deviation of 1.7.

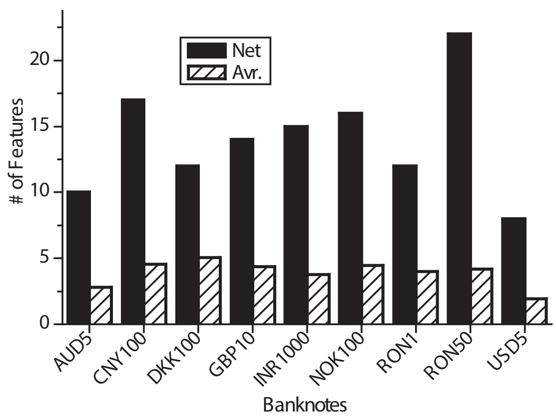

Figure 3: Number of security features found by the subjects on each banknote – filled bars show the net numbers of the features without overlap across subjects found on each banknote, and hatched bars show the average numbers of features found by each subject on each banknote

3.2 Perceived resistance against counterfeiting and number of features

The rank order data were interpreted as paired comparison data (Cui, 2000), and z-scores were calculated as the interval scales (Engeldrum, 2000) of the perceived resistance against counterfeiting for the banknotes using Colour Engineering Toolbox (Green and MacDonald, 2002). The result is shown in Figure 4. The error bars show the 95 % confidence intervals. Danish and Norwegian 100 kroners showed high resistances, which means they were recognized as "hard to counterfeit." On the other hand, Australian and United States 5 dollars were recognized as "easy to counterfeit."

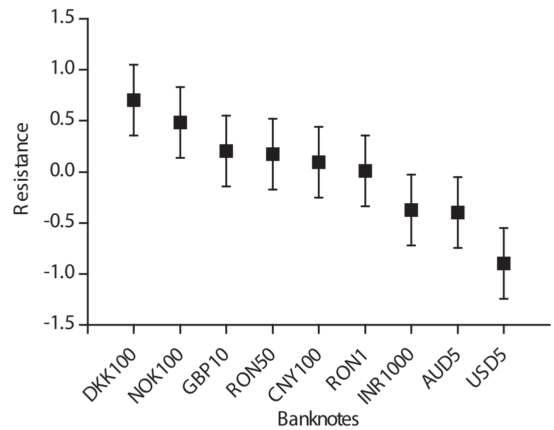

Figure 4: Perceived resistance against counterfeiting of each banknote; the ordinate shows the z-scores calculated as the interval scale from the rank order data; note that the ordering of the banknotes in this figure is according to the perceived resistances of the notes, and is different from those of Table 1, Figures 1 and 3

To know what is affecting the perceived "resistance," the correlation between the z-scores and the number of security features was shown in Figure 5. The horizontal axis of Figure 5(a) is the net number (without duplication of the same feature) of security features found by the subjects on each banknote. On the other hand, the horizontal axis of Figure 5(b) is the average number of security features found by the subjects on each banknote. The net numbers have poor correlation (coefficient of determination $R^2 = 0.2321$; analysis of variance (ANOVA), $p = 0.19$) to z-scores (perceived "resistance"), whereas the average numbers have very good correlation ($R^2 = 0.8769$; ANOVA, $p << 0.01$).

3.3 Effect of familiarity on the banknote

In the present experiment, we had 16 subjects and 9 banknotes (Table 1). Therefore there were 144 pairs

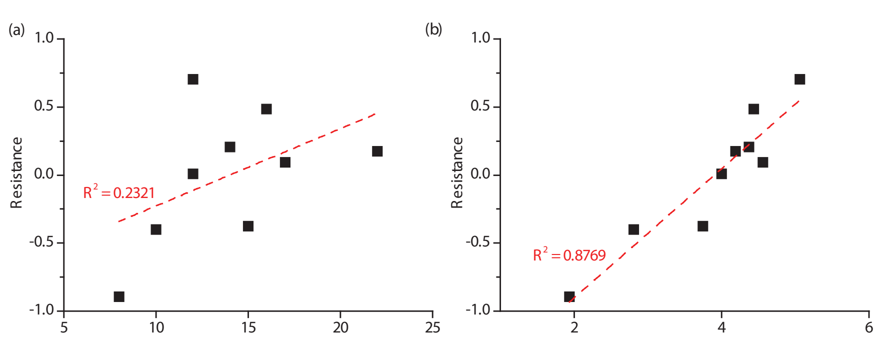

Figure 5: (a) Correlation between the perceived resistance against counterfeiting and the net number of security features found on each banknote; (b) correlation between the resistance and the average number of security features found on each banknote by each subject

of subjects and banknotes. In 38 pairs among them, the subject was familiar to the banknote, that is, the subject are or used to be using the banknote routinely. To know the effect of familiarity to banknote on the number of security features found, the number of security features found by each subject on each banknote was normalized against the average number of security features found on each banknote. Figure 6 shows the result. It shows a slight tendency that the subject found more security features with familiar banknotes than with unfamiliar ones although the difference was not significant (2-tailed t-test, $p = 0.28$).

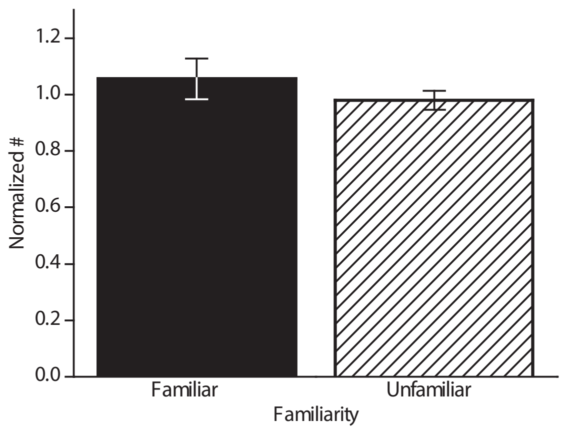

Figure 6: Number of security features normalized against the average number of features found by each subject on each banknote – the filled bar shows the average across familiar banknotes, and the hatched bar shows the average across unfamiliar banknotes; error bars show the standard errors of the means

On the other hand, as shown in the histogram of Figure 7, familiar banknotes (filled bars) are more likely to be assigned to higher ranks than unfamiliar ones (hatched bars), which is statistically significant (Mann-Whitney U-test, $p \ll 0.01$). Note that each point on the horizontal axis of Figure 7 does not correspond to each banknote, but to the rank of perceived resistance. This histogram shows how many banknotes were assigned to each rank by the subjects for each familiarity. Rank 1 is the highest rank and the most resistant to counterfeiting, and rank 9 is the lowest rank and the least resistant.

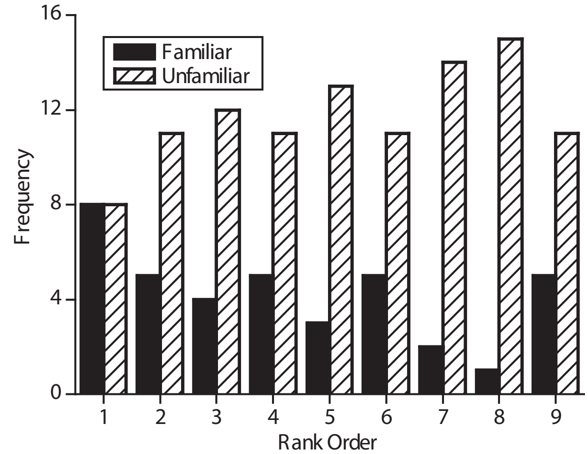

Figure 7: Histogram of the rank orders of the perceived resistance against counterfeiting – filled bars show familiar banknotes, and hatched bars show unfamiliar notes

3.4 Public security features

The numbers of public security features disclosed by the issuing central banks are obtained from their websites (Reserve Bank of Australia, n.d.; Changchun Central sub-branch The People's Bank of China, 2009; Danish National Bank, n.d.; Reserve Bank of India, n.d.; Norges Bank, 2014; National Bank of Romania, 1 leu, n.d.; National Bank of Romania, 50 lei, n.d; Bank of England, n.d.; United States Currency Education Program, n.d.), and compared with the net and average numbers found by the subjects, as shown in Figure 8.

The average number of public features was 7.7, the average number of features found by subjects, 3.9, was almost a half of the average of which. The number of public features had very poor correlation with the actual numbers found by the subjects (Net numbers, Figure 8(a): $R^2 = 0.1553$; ANOVA, $p = 0.29$. Average number, Figure 8(b): $R^2 = 0.0068$; ANOVA, $p = 0.83$). Naturally, the number of public features had no correlation with the perceived resistance against counterfeiting, as shown in Figure 9 ($R^2 = 0.0078$; ANOVA, $p = 0.82$).

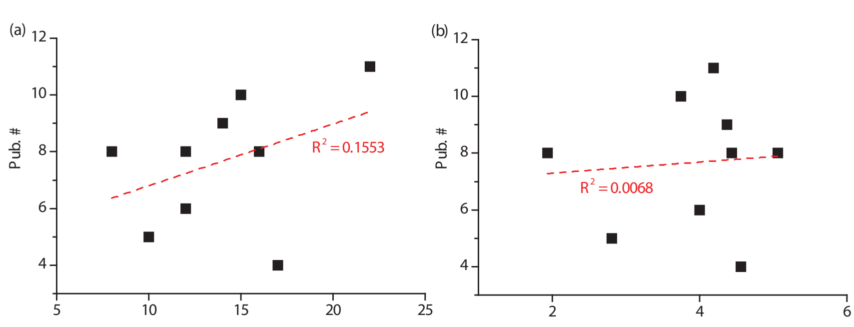

Figure 8: (a) Correlation between the number of public security features disclosed by central banks and the net number of security features found by the subjects; (b) correlation between the number of public features and the average number of features found by each subject on each banknote

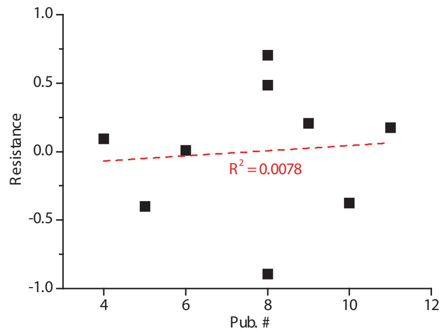

Figure 9: Correlation between the perceived resistances against counterfeiting and the number of public security features disclosed by central banks

4. Discussion

In the present study, the subjects were able to find 3.9 security features in average across all the banknotes tested, which is more than the numbers with previous studies. A research by European Commission's Anti-Fraud Office (OLAF) reported an average knowledge of 1.3 security features with 53 non-expert subjects (Gentaz, 2005). De Nederlandsche Bank (DNB) commissions an opinion poll on euro banknotes every two years (de Heij, 2008), and in the latest 2013 poll, Visser and Dijkers investigated the awareness of security features by telephone interview with a sample of 1 000 persons, and reported that 2.6 security features were mentioned in average across all the age groups, and 3 security features by the age group of 18–35 years old (Visser and Dijkers, 2013). In these studies, the subjects had to answer without observing actual banknotes, whereas in our study, the subjects had banknotes in their hands during the session. The differences in methods and ages of subjects might have caused the difference in the numbers of found security features.

The perceived resistance against counterfeiting of banknotes, which is thought to be one of the key factors of people's confidence in the banknotes, were estimated from the rank order data. The estimated resistance had very good correlation only with the average number of security features actually found by the subjects themselves on each banknote. Even though the average number had a small variance, it explained the variability of the perceived resistance of banknotes very well. No other metrics showed good correlation with the resistance. The more features people find on a banknote by themselves, the more secure or reliable they think it is.

On the other hand, the net numbers or public numbers of security features showed poor correlation with the perceived resistance, which means that even if a lot of security features are designed and installed on a banknote, they won't work unless they are noticed by the general public. Level 1 security features for the general public should be designed user-friendly and self-explanatory (de Heij, 2010; van Renesse, 1998). Banknotes should be designed to lead the users to notice the security features on them by themselves spontaneously. Our findings can give a quantitative ground to this conventional guideline for the design of banknotes, and can contribute to develop metrics for the evaluation of security features and the design of banknotes.

It is often said that people accept a banknote as a genuine one when its quality is high enough. People don't have any mental model of the genuine banknote to be compared with the banknote under reference. The genuineness of a banknote is directly perceived from the note, not from the appraisal by comparing between the test note and the ready-trusted genuine specimen as in forensics. The poor correlation between the number of public features and the perceived resistance supports this view.

Only a half of public features advertised by the central banks were actually found by the subjects in the present study. In addition, the number of public features had very poor correlation with the number of found features. These facts suggests that the information of the general public on security features has limited effect on anti-counterfeiting (de Heij, 2006; Lancaster, 2006; European Central Bank, 2007). On the contrary, familiar banknotes were more likely to have more security features found on them and perceived as more resistant against counterfeiting. These facts suggest that the knowledge alone is not enough to detect security features. If the effect of familiarity to a banknote on the detectability of security features is not a matter of knowledge or a cognitive effect, it can be an effect of perceptual leaning (Kellman, 2002). Previous experience of inspecting the banknote might have improved the ability of subjects to find more security features on that note. Not only knowledge on banknotes but also hands-on practice with actual objects is needed to detect security features, which in turn leads to increase the perceived resistance against counterfeiting. Klein et al. conducted psychophysical experiments in which subjects discriminated genuine and counterfeit Canadian banknotes, and found that the performance of the subjects was improved even after the subjects just repeated the same discrimination experiment without receiving any informative training as much as the improvement by video or leaflet training (Klein, Gadbois and Christie, 2004), which is consistent with our results.

5. Conclusions

The value of a banknote depends on people's subjective confidence in the note. We investigated the confidence in banknotes from the viewpoint of the perceived resistance of the notes against counterfeiting. We found a correlation between the average number of security features found by subjects on each banknote and the perceived resistance of the note, which suggests that the awareness to the security features on a banknote affects people's confidence in the note. It is also suggested that the awareness to security features on a banknote is irrelevant to the knowledge of the note but is relevant to the familiarity to the note, which implies the need for not only informative education but also perceptual hand-on training with actual samples to improve people's confidence in banknotes. Our findings can give a quantitative ground to a conventional guideline that security features on banknotes should be self-explanatory, and can contribute to develop new metrics for the quality evaluation of banknotes.

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