Numbers on banknotes
What is their use?

by Hans de Heij & Alwin van Gelder

Serial numbers have been included on banknotes since they were first issued. The number, which is unique for each banknote, allows the note to be traced and identified. Early banknotes were generally numbered by a central bank clerk, in clearly legible handwriting. A practice that prevailed for almost a century. Two centuries later, banknotes are still numbered, albeit that their everyday use, their significance and overall production volumes have changed. In the first of two articles on the subject, Hans de Heij and Alwin van Gelder of the Dutch Central Bank unveil the world of banknote numbers.

In 1968, the Dutch Central Bank was the first issuing authority to introduce machine readable numbers on banknotes. It was also the first organisation to establish a database of all banknotes in circulation, requiring banknotes to be registered (by means of a reading process). A little over 20 years later, in 1989, DNB again scored a first when it introduced bar code numbering on banknotes. And a little less than two decades later still, DNB remains the only central bank to register banknotes in circulation on a daily basis. Although many central banks were intrigued by the numbering system developed by DNB for its NLG notes, none of them actually introduced the concept. However, Rome wasn’t built in a day. Since around the turn of the century, many banknote printers have adopted the practice of reading and storing numbers of newly printed banknotes (on CD-ROM, for example). As highlighted by figure 1, the EUR notes currently feature OCR-B characters. There is no telling what the future may bring. Perhaps tomorrow’s banknotes will include a chip rather than a serial number. However, before we predict the future, let’s have a look at the past.

Security by virtue of handwriting (1814 - 1860)

For security reasons, Dutch banknotes were originally printed without their serial numbers or denomination (see figure 2). This information was added to the notes by central bank staff. Between 1814 and 1825, clerks in the employ of the Dutch Central Bank manually added the date and denomination to all banknotes issued by the bank. The actual amount was added twice and written out in full once. In addition, the banknote number was recorded twice. As indicated, the date on which the note was signed was also added by hand. Following the above ‘preparations’, the notes were signed by the bank’s board (a ceremony that took place each Wednesday morning). In total, four signatures were added: those of the president, two directors and the secretary. In order to imitate these Robin banknotes, as they were known, a counterfeiter would have to master eight different hands!

During 1856 and 1857, it was decided to create a complete new type of banknote. The Robin banknotes had been forged and counterfeited in 1853 and 1857 respectively. The emergence of photographic techniques allowed counterfeiters to reproduce a Robin directly, without the involvement of a die cutter or draughtsman. All Robin banknotes were replaced by new notes. The sheer number of notes in circulation at that time no longer allowed the banknotes to be signed and ‘completed’ by hand. As of the 1860 model banknote, the signatures of the bank’s board members and the date were printed by security printer Joh. Einschedé (a practice that had been applied to the denomination since 1825). For reasons of security, the board ruled that all notes would be numbered by the bank rather than the security printer. However, these serial numbers were no longer added manually. Instead, use was made of a letter press located at the bank. As an aside, the introduction of a letter press also heralded the birth of the bank’s in-house printing works.

Security by virtue of typography (1860 - 1968)

To prevent the theft and illegal ‘completion’ of unnumbered banknotes, a unique letter type was developed. It was used in combination with a system based on the concept of consecutive numbering. To further improve security, many identical numbers were printed on the banknote. In 1904, four numbers were printed on the face and back of the banknote while a (separate) series indication consisting of two letters was introduced for the first time (see figure 3).
Many central banks have historically asked their security printers to add consecutive numbers to their banknotes. However, many abandoned this practice around 1975, including the Swiss National Bank. Consecutive numbering was introduced for the following reasons:

- For each banknote, it is possible to reconstruct when and where the new note was delivered to individual banks and other customers.
- Tellers could determine the number of notes in an open bundle by looking at the serial numbers (this only applied to new notes).

Over the years, fewer numbers appeared on the NLG notes - the total was reduced to two in 1954 and just one in 1989. At the same time, the number of signatures was reduced from four to two (the President and the Secretary).

**Coins have no number**

Although the last NLG and Spanish ESP notes to be issued featured just a single number, the need to add unique numbers to banknotes is not immediately evident. After all, the coin, which does not have a serial number, is a widely accepted and highly successful payment instrument. Throughout history, coins have had an intrinsic value. The more precious metal of a given type a coin contained, the higher its value (this value also varied depending on the type of precious metal used). The Intrinsic value was underpinned by the value of the raw material. Moreover, the production of coins requires special skills and equipment.

In the early days, banknotes were considered little more than 'a piece of paper' with little intrinsic value to speak of. Reproductions could be made using simple equipment only. This may be why bookkeepers and accountants required a unique number to be added to the notes. As far as banknotes are concerned, trust is derived from the fact that they are widely accepted by everyone as a means of exchange. In addition, they are guaranteed by the central bank, in its capacity as the only legal issuer of banknotes. Damaged banknotes could be exchanged at central banks provided the redemption rules were met (banknote identification).
Redemption rules
The Dutch public has historically been able to return damaged NLG notes to the central bank. By presenting more than half of a banknote, thus ensuring that at least one of the note’s serial numbers was legible, members of the public were able to obtain a refund from a cashier. At a later stage, use was made of a transparent film with an embedded grid. The redemption rule applied by DNB at that stage was based on the percentage of the note that was actually ‘delivered’. A minimum redemption value of 25% of the face value of the note was applied; for redemption rules the number on the banknote was no longer relevant.

The introduction of the euro caused the redemption rule to be changed again. Provided more than 50% of a banknote is handed in at a central bank, the face value of the note will be refunded in full. No refund is paid if half the note (or less) is handed in. This leaves only one - disputable - reason to print two serial numbers on a banknote: to detect notes that have been altered (which happens only incidentally). However as two numbers on banknotes can occasionally introduce printing errors (e.g. non identical numbers) and also require increased quality check, printing just a single number is more efficient. If numbering errors may pass the printers quality check they will at least not be visible to the general public.

Until 1970, central banks tended to sort and inspect banknotes (for signs of counterfeiting) manually and as part of a continuous daily process. Assuming the sorted notes were considered fit and genuine, they re-entered circulation. From 1965 onwards, DNB experimented with automated sorting machines, allowing the authenticity of banknotes to be checked by detectors rather than humans. In addition to third-party detectors, DNB developed and used proprietary detection equipment. However, when it came to the reliability of these machines, there was no prior experience whatsoever.

Figure 2
Example of a Robin banknote, dated 1 November 1814 and written by 8 different hands.

Figure 3
NLG 10/Syndic, issued in 1943. A special typographic number on the back combined with two separate series designations comprising two letters (2AK, shown on the right).
All banknotes are unique documents, identified by their serial number. In other words, no banknotes can have the same ID. If two banknotes do match, one must be illegal! This simple conclusion led DNB to develop a database containing the numbers of all banknotes in circulation. For the database to be of use, these numbers had to be machine readable. DNB issued its first banknote with a machine readable number in 1968 (the NLG 10/Frans Hals note). This note used the so-called Optical Character Reading Type B font or simply OCR-B. This font could (and can) be read by the human eye and a camera.

The sorting machines used by DNB were fitted with two cameras - one to read the A-number and one to read the B-number. The use of two numbers allowed reading errors (a 3 as opposed to an 8 or a 0 rather than a 9) to be detected and corrected. Last but not least, the validity of the number was checked using a so-called modulo 9 check, whereby the last digit of the OCR-B number served as the verification digit. As all numbers are stored in a database (figure 5), the accuracy with which banknotes are read must be high. In the early days, when computer capacity was still limited, the comparison of numbers in circulation and numbers not in circulation was performed at night using DNB’s mainframe computer. These days, numbers may readily be processed in real-time and online.

**NLG numbering schemes**

The numbering scheme developed for the NLG notes was based on a four-character series number (eg. 1234) and a five-digit banknote number (eg. 12345). In other words, each series contained 100,000 notes. This series size had been agreed by DNB and Joh. Enschedé, and all notes were delivered on the basis of the series number. Although the numbering of each series was sequential, faulty notes within a given series were not reprinted. Instead, Joh. Enschedé informed DNB of any missing numbers (by means of a tape). Other printers might use numbering schemes were the first two digits of a number represent the location of a specific note on a sheet.

DNB has read banknote numbers since 1973, for the following reasons:

1. **Detecting counterfeits**
   If two or more banknotes with the same serial number are detected in the database at one or more processing points, one or more banknotes must be counterfeit (or an unauthorised note, e.g. coming from stolen sheets without numbering or produced for a fake order like described in ‘The man who stole Portugal’. If banknotes are processed by a central bank, their identification data can be stored in a database and compared to other banknote data, either online or offline.

2. **Registering banknotes used to pay a ransom**
   Provided the banknotes used to pay a ransom are recorded, they can be detected when they pass the first processing point. This may help a subsequent police investigation. In 1987, the Dutch police solved a major crime with the assistance of DNB’s number reading system. A ransom had been paid to the kidnapper of a well-known Dutch businessman. When the kidnapper subsequently used one of the NLG 250 notes to pay for groceries in a supermarket, he was soon caught. The DNB system allowed the notes to be traced to the commercial bank and the supermarket respectively.

3. **Quality assurance**
   Number reading allows the central bank to submit a claim to the banknote manufacturer if the quality of the notes is inadequate. Quality-related feedback from public or professional users can be traced to the party that printed the notes. The appropriate production data can be retrieved, allowing production and quality improvements to be introduced.
4. Internal and external fraud
The banknote production process and logistics supply chain involve internal and external processing and handling operations during which banknotes are registered. In turn, this helps to prevent fraud. As the identification number is unique, it allows the note to be traced to its physical storage location (package, bundle, container, etc.). This reduces the time needed to track the location of banknotes during internal investigations and audits. Knowledge of the fact that banknotes are being traced (both within the production facilities and at the central bank) may serve as an additional deterrent. If the system spots a banknote that was previously destroyed, a further investigation can be initiated.

5. Circulation trials
Circulation trials allow potential improvements to banknotes to be tested under live circulating conditions. One basic and simple circulation trial involves registering (either manually or automatically) the percentage of unfit notes on a regular basis. This percentage can subsequently be compared to those of reference series. For this type of test to be conducted, the banknotes must contain identifying information, either in relation to the individual note or to a series. Between 1977 and 2002, DNB used its number reading system to conduct various banknote circulation trials. One of these investigated differences between the paper produced by two paper mills, while another highlighted the impact that the direction of the main paper fibres has on the useful life of a banknote. A further trial was designed to investigate the influence of various coatings on the banknote. DNB gained valuable experience from these trials. To give an example, it was able to prove that the useful life of the so-called DAR coated banknotes doubled compared to uncoated banknotes, allowing production volumes to be reduced by 70%\(^{12a, b}\).

---

4 Van Gelder, A.H.B.Th.; 'Reading, registration and processing of banknote numbers', presentation to CSI Conference 1993.
8 Buitelaar, T.; handout during Interpol Conference Amsterdam 10 April 2002.
9 De Heiij, H.A.M.; 'Durable banknotes: an overview'. Presentation of the BPC/Paper Committee to the BPC/General Meeting, Prague 27 May - 30 May 2002 - Confidential.

The second part of this article will be included in the next issue.
Numbers on banknotes - part II

What is their use?

by Hans de Heij & Alwin van Gelder

In the previous edition of KJD&I, Hans de Heij and Alwin van Gelder of the Dutch Central Bank explained how (serial) numbers came to be included on banknotes. This article contains the second and final part of their paper, which focuses on the use of barcodes.

At the end of part I, we briefly discussed how circulation trials allow central banks to test various aspects of a banknotes under live conditions. The introduction of the barcode (1980 - 2002) not only allowed individual notes to be tracked, it also enabled De Nederlandsche Bank (DNB) to attain very high levels of reading performance (see figure 1). As far as we are aware, there is only one other country in the world that has included barcodes on banknotes. That country is Lebanon, which introduced barcodes in 1994 (see figure 2). Although the Canadian authorities have also used barcodes on their banknotes (since 1988) these are only used to indicate the denomination of the note. In other words, all notes of the same denomination contain the same barcode. As the single barcode could be read more accurately than two OCR-B numbers combined and barcode readers were far less expensive, it was decided to replace them with a single barcode only! Another advantage of the barcode is that it takes up less space, despite containing more information. The introduction of a barcode-based number allowed DNB to update the information content of the banknote number. The barcode on Dutch banknotes consisted of 13 characters, three more than the OCR-B number. The use of these characters is explained in box 1.

As such, the serial number represented an arbitrary subdivision within the barcode, introduced to facilitate banknote production. The introduction of a model code helped DNB to overcome future problems relating to the simultaneous issuance (and circulation) of different versions of the NLG 100 note (such as with the so-called ‘De Ruyter’, issued in 1972, and ‘Snipe’ notes introduced in 1981). To discriminate between these notes, which were the same size and used the same OCR-B number format, the OCR-B numbering of the Snipe was printed in magnetic ink. In addition, the serial number of the De Ruyter note ascended (starting at 0000) while the serial number of the Snipe note descended (starting at 9999). Another reason for including an additional character in the barcode of the new series was that the available numbers for the NLG 25 (Sweelinck) and NLG 10 (Frans Hals) notes were fast running out. As far as the NLG 25 was concerned, it was decided in 1987 to add a ‘t’ before the serial number (creating the t11 OCR-B character). Unfortunately this was not possible for the Frans Hals note owing to a lack of space. Instead, it was decided to start numbering notes from scratch on the assumption that early NLG 10 banknotes would no longer be in circulation.

Barcode character coding: the 2-out-5 code

Each character included in the barcode comprises a so-called 2-out-5 code. In other words, each character uses 5 bars, three of which are narrow (0.3mm) and two of which are wide (0.7mm). A narrow bar denotes a one (1), while a wide bar denotes the number zero (0). Via a conversion special table the binary notation of the number 2 would therefore be 11001. One essential aspect of the dedicated code that we created - the so-called DNB code - was that both the printed and the unprinted bar form part of the character. Both contain information. The barcode has a Hamming rate of 2 (this means that at least two bars should be switched to create another digit (eg, a 3 instead of a 6). Just below each character, there is a small (height: 1mm) character, which can be read by the human eye (this does not apply to the denomination code and modulo check). As DNB required a bespoke typographic design, Bram de Does of Dutch security printers Joh. Enschedé developed a special font.

The height of the barcode itself is 7.5mm. Its design is restricted by the width of the smallest bar and the height of all the bars. The width of the smallest bar should be around 0.3mm, allowing the barcode to be produced using letterpress printing techniques. A maximum bar height of 10mm is recommended because of mechanical limitations of the numbering box on the printing press. The barcode on Dutch banknotes has a total height of 9.5mm (7.5mm for the bar, 1.0mm line space and 1.0mm for the legible number). The space between the characters is 1.2mm. No start or stop codes are used, but 'quiet zones' instead. The modulo check uses base 13. rest value 0.
Figure 1
First banknote with a barcode number: the NLG 25 (Robin), issued in 1989.

Figure 2
Since 1994, the central bank of Lebanon includes a single barcode on its notes. The code is clearly visible on this LBP 100,000 note, issued in 2004.

No additional security features such as fluorescent numbering ink or magnetic ink were used. In addition, different colours than black could be used, depending on the recognition capabilities of the barcode readers used by the printer and the central bank. Also the background could be printed in a colour.

The barcodes were printed on sheets using a Super Numerota letter press. The numbering boxes were sourced from Zeiser while the ink was supplied by Sipca. The numbering machines managed to print the barcodes at a rate of approximately 3,500 sheets per hour. To safeguard quality, the printed barcode was checked using a special reading and quality control device developed by Philips. All barcodes printed on every 500th sheet were inspected and checked.

Barcode reading at the central bank (1989-2002)
Barcode reading technology for the high-speed reading of banknotes was developed during the period 1987-1989 (capability: 14 banknotes per second at 4 m/s). Since 1990, the two OCR-B readers installed on each sorting machine have been replaced by a single barcode reader. The reading reliability of the single barcode was much higher than that of the double OCR-B number! The false acceptance rate of the barcode reader (BCR) was less than one in a billion (10^-9). Other advantages are the low price of the BCR reader and "high design freedom" of the printed barcode in the note.

As indicated, the barcode was read at a speed of 4 m/s. Tests conducted in 1990 showed that the BCR can operate at speeds up to 8 m/s. Moreover, several handheld barcode readers were developed for offline applications. These handheld devices can read, store and, if necessary, download/upload barcodes onto/from a PC.

Is a barcode more secure than OCR-B?
Since a barcode cannot be read by humans, DNB was regularly questioned about the security of barcodes from a counterfeiting perspective. After all, there is no need for counterfeiters to (re)produce barcodes that are never checked by the public anyway. DNB indeed found that the barcode presented counterfeiters with a considerable hurdle, which the vast majority of them refused to take (only in two instances were new barcodes created). Having said that, some counterfeiters change the small lettering below certain types of barcodes.

Reading numbers on euro banknotes, reduced database (since 2002)
The introduction of the euro in 2002 required DNB to return to OCR-B number reading. DNB does not have a database of all the euro notes issued in the eurozone. Instead DNB uses "reduced number reading applications", based on both the numbers of banknotes received from circulation and of re-issued banknotes. Although DNB reads both numbers on euro banknotes, only the number at the top right is specially designed for number reading applications. The existing OCR-B number contains 12 positions, including a letter which denotes the Eurosystem National Central Bank (NCB) (see box 2).

The number on the euro notes indicates the National Central Bank that is responsible for producing the note. Much attention and speculation surrounded the numbering system used on the euro banknotes, especially during the first months following their introduction in 2002. While the European Central Bank (ECB) had not publicly disclosed details of its numbering system, the correct denotation of the letters circulated on the Internet within days of the euro's launch. In keeping with its policy to confirm correct solutions, the ECB provided standard answers to all NCBs. Moreover, the NCB or country codes were published on the ECB website some time thereafter. The decoding of the letter in the plate number on the front of the notes took a little longer. The country codes were broken by Mr. Antens, a Dutch student with an aptitude for mathematics. He compared the barcode used by a Spanish football game to the barcode on an NLG 10 note. He also analysed the numbering on the euro banknotes, and discovered the numerical equivalent of the eurozone country codes (e.g. Netherlands = P = 26). Antens subsequently published his letter codes and the check digit 9, as printed on euro banknotes (see table 1).

Today's user requirements
Let's have a look at today's situation, and start by listing the requirements of today's users and other stakeholders. Table 2 provides an overview of all parties who use a banknote identifier. In this respect...
the banknote identifier may contain information that refers to its production origin and may be used to trace production defects. This production information (e.g. the plate number on the euro notes) may directly refer to the involved paper mill or printer and is valid for large volumes of banknotes. In addition, the banknote identifier may contain so called product information which uniquely characterizes each individual banknote. This product information should fix the denomination, model, serial and banknote number as well as the modulo check information. Production and product information could also be combined in one identifier, in one banknote number.

In addition to the reasons stipulated by the DNB in the first part of this article, banknote identifiers – e.g. a printed banknote number - can be used for the following applications.

1. **Proof of delivery - ATM transactions**
   Equipping a banknote with a unique product identification allows specific banknotes to be linked to specific withdrawals and specific clients (ATM-based ID readers can register which banknotes are issued to which member of the public, provided such records are kept). This would allow operators to establish whether a banknote was issued by a certain machine. If customers claim to have withdrawn a counterfeit banknote from an ATM, this can also be verified.

2. **Support quick payment at point-of-sale terminals**
   Product scanners in supermarkets and other points of sale can be used to read barcodes on banknotes - or other payment instruments - and based on the product identification automatically calculate and issue the correct change (once the note(s) has/have been authenticated). Such systems would speed up in-store cash transactions and prevent manual errors.

3. **Highlighting counterfeits and verification**
   Storing the data used to identify counterfeit banknotes in a publicly accessible central database allows a broad audience to be alerted to possible counterfeits (assuming a unique identifier is used).

4. **Inventory of banknotes in transit**
   If banknote are stolen in transit (between two processing points), the data obtained at the last processing point can be used by the police authorities.

5. **Tracking banknotes while in circulation**
   Tracking the whereabouts of banknotes while in circulation allows authorities to establish how far and how frequently they "travel". The resultant information can also be made available whenever banknotes pass a given processing point.

6. **Circulation within a currency zone**
   Identifiers can also be used to track banknotes in a country or currency zone as they crisscross the area.

7. **Improving sorting algorithms and sorting quality**
   One of the factors that determine the quality of a banknote is its age (the time that has lapsed between the date of issuance and the date on which it is read at a given processing point). When sorting the banknotes in circulation, this age-related data can be used to support the sorting algorithm. This requires the banknote to carry a product identification.

8. **Supporting - and improving the performance of - sorting machines / detector maintenance**
   Provided an unambiguous relationship can be established, identifiers can be used to verify the performance of sorting machines and detectors. Banknotes that have been rejected can easily be traced for visual inspection.
9. Online quality monitoring
As an ultimate quality monitoring application, it is even possible to track and trace individual banknotes on a continuous basis. The quality of individual production lots (batches) can thus be monitored. The resultant information can be fed back to banknote manufacturers, and be used by R&D units to improve the quality and life-length of the note.

Requirements
The following demands can be made of the banknote identifier (e.g., a number) to be included on modern banknotes:
1. Just a single identifier should be used, preferably on the back of the note (not a public security feature).
2. It must be possible to read the identifier using a machine. Human readability is optional for some applications.
3. Machine readability requires reading errors to be detected.
4. Omni-directional reading capabilities would be preferable.
5. The identifier should occupy only a small section of the banknote.
6. It should be possible to read the identifier at high banknote transportation speeds (up to 10m/s).
7. Preferably it should not be possible to isolate the identifier from the banknote (‘non-portability’).
8. Content-related requirements:

8.1 Possible identifier information on the banknote
- denomination;
- banknote series (details of series);
- banknote model (details of models of one denomination - eg, between a current model and a possible upgrade within the same series);
- responsible issuing bank;
- unique individual note identification.

8.2 Possible identifier information on manufacturing of the banknote
- year of production;
- manufacturer of substrate;
- printer;
- production lot.
Looking at the future
To meet user requirements, several solutions are possible, including the OCR reading solutions currently in use as well as several types of multidimensional barcodes (figure 3). Most of these barcodes are already widely applied for the purposes of tracing and industrial stock management. The appearance of an identifier has no intrinsic security value. As a consequence, there is no need to hide (certain aspects of) the feature for security reasons. Having said that, the application of a (bar)code suggests that the banknote is processed at some stage during the banknote handling cycle. From a design perspective, it is preferable to integrate the barcode during the early stages of the (banknote) design process. Compared to traditional OCR numbers, the latest (bar)codes can contain far more information than just a number. Moreover, multidimensional codes can be recognised with high reliability using small and inexpensive reading equipment. The use of a (bar)code obviates the need to duplicate the commonly used banknote numbers, saving valuable space, which can be allocated to other important features. One widely mentioned disadvantage of a (bar)code is that it cannot be read by humans. Although this can, of course, be overcome if the identifier is also printed using readable characters, the information contained in barcodes is only of interest to a small group of users. If there is a need to read the code by the general public, it can even be captured using an ordinary mobile telephone equipped with a camera. The image is subsequently sent to a centralised database for analysis (and the relevant information is returned to the user). Similar (commercial) applications are already in use to collect business information. The necessity functionality of an identifier could also be included in a chip (see figure 4). Two current alternatives are:
- A contactless reading solution that uses a Radio Frequency Identification (RFID) inlay with yes/no functionality and a printed antenna;

Figure 3
Different types of barcodes.

- A contact-based reading solution whereby the chip comes into direct contact with the reader/detector. As the RFID solution allows information to be transferred on a contactless basis, it appears to be the most promising alternative. However, embedding an inflexible object like a chip in a banknote (and reliably connecting it to an antenna) will prove quite a challenge, not least because the chip is likely to be thicker than the banknote substrate (preventing the chip from being covered). The presence of a bulge in the paper may lead to additional (local) wear or damage while the banknote is stored or in circulation.

According to the Banque de France, a chip would have a capacity of 128 or 256 bits, with a read/write capability of approximately 10,000 write cycles. The chip's thickness would preferably be about 30 microns while its price should not exceed 2 euros each. The surface of the chip must be very small, possibly less than 0.5 mm². The surface of the antenna is larger: around 15 mm x 15 mm. The reading distance would be in the range of 1 to 10 mm. Recent technological developments allow the antenna to be integrated in the chip (see figure 4).

Whether a chip makes a chance to be part of a banknote is also depending on the perception of the public. Until today it seems that a chip gives the public the feeling that their banknotes are no longer the anonymous means of payments. Also the risk of robbery of "chipped" banknotes may be perceived as an increased risk: "They can see what I have in my wallet!" The latest printing techniques also allow a number to be added to a banknote by means laser engraving (of a metallic area of the banknotes, such as foil). Metallic offset printing is another alternative. Although advanced magnetic properties have also been developed, these do not yet appear to cater for existing user requirements.

3. Ankers, C; "Bankbiljetten en de Primera División" Natuur & Techniek Wetenschapsmagazine, Juli/Augustus 2002