

Australian Banknotes: Assisting People with Vision Impairment

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A key function of the Reserve Bank is to design and produce banknotes that meet the needs of all sections of the community. The Bank has consulted a wide range of subject matter experts and stakeholders to ensure that the next generation of Australia's banknotes reflects Australia's cultural identity, is secure and remains functional. One aspect of functionality is that the banknotes are accessible to people with vision impairment. This article outlines the work the Bank has undertaken to meet the needs of the vision-impaired community, from the paper decimal banknote series that was issued in 1966 through to the forthcoming next generation series of banknotes.

Introduction

The Next Generation Banknote (NGB) program was initiated by the Reserve Bank to upgrade the security features of Australia's banknotes so that they remain difficult to counterfeit. As part of the design process, the Bank must ensure that the banknotes are easily recognisable by the public, reflect Australia's cultural identity and can be used in machines for accepting or dispensing cash (such as automated teller machines (ATMs), self-service checkouts and vending machines).

Another key consideration in design is incorporating characteristics that assist people with vision impairment to recognise different banknote denominations. While current Australian banknotes already have some such features – including different sizes, contrasting colours and large denominational numerals – the NGB program provided an opportunity to consider additional enhancements to further assist those with impaired vision.

This article describes the features on Australia's banknotes designed to assist people with vision impairment, from the paper decimal banknote series that was issued in 1966 through to more recent work

by the Bank to introduce a new tactile feature on the forthcoming next generation series of polymer banknotes.

The Vision-Impaired Community

Vision impairment encompasses a variety of conditions that may be present from birth or result from a range of factors including disease, injury or age-related degeneration of the eye. Vision impairment is broadly defined as a limitation in one or more functions of the eye, and can be measured in terms of visual acuity (the clarity or sharpness of vision) (Australian Institute of Health and Welfare 2007).

Normal visual acuity is measured by Vision Australia¹ as 6/6 and indicates what a person with normal vision can see on a distance-based visual acuity chart² from a distance of 6 metres (Vision Australia 2012b).³ Low vision is measured as an acuity level of less than 6/18, which means that a person cannot see at 6 metres what someone with normal vision can see at 18 metres. The term 'legally blind' refers to a visual acuity of less than 6/60 in both eyes, or a field

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1 Vision Australia is a major national provider of blindness and low vision services in Australia.

2 Two examples of visual acuity charts are the LogMAR or Snellen charts.

3 Six metres is the equivalent of 20 feet, hence the term '20/20' vision.

of vision less than 20 degrees in diameter (Vision Australia 2012a).

Vision Australia estimates that there are 357 000 people in Australia who have low vision, with around 40 000 considered to be legally blind (Vision Australia 2012a). The most common causes of legal blindness are age-related macular degeneration, followed by glaucoma (Access Economics 2010).⁴ Furthermore, these common causes of blindness are becoming increasingly prevalent in the community as the demographic and public health profile of the population changes.

Banknotes typically incorporate a number of different features to assist people with different types of vision impairment. Importantly, most of these features make it easier for all people to recognise the different denominations of banknotes, so that the entire community benefits from accessibility.

Accessibility of Australian Banknotes

For many years, the Reserve Bank has been committed to ensuring Australia’s banknotes are accessible to all members of the community, including people who have vision impairment. In

this regard, a significant step was taken with the introduction of the paper decimal banknote series in 1966. This series featured denominations with different lengths and heights, and had distinguishing colours and large numerals. Feedback provided by the vision-impaired community prior to the introduction of the paper decimal \$100 banknote in 1984, however, suggested that the 5 mm length differential between denominations, used up to the \$50 banknote, was insufficient for accurate identification. As a result, the paper decimal \$100 banknote was designed to be 7 mm longer than the paper \$50 banknote (Table 1).

The polymer banknote series, introduced from 1992, provided an opportunity for the Bank to enhance accessibility of Australia’s banknotes resulting in the following features (see ‘Box A: Accessibility Features of Australia’s Banknotes’):

- *Colours:* Strong colour contrast between denominations was considered by representatives of the vision-impaired community to be a particularly important way to help people with low vision to distinguish between different banknote denominations. The contrast in colours between denominations was, therefore, strengthened.

Table 1: Sizes of Australian Paper Decimal Series Banknotes

	First issued	Length (mm)	Height (mm)
\$1	14 February 1966	140.0	70.0
\$2	14 February 1966	145.0	72.5
\$5	29 May 1967	150.0	75.0
\$10	14 February 1966	155.0	77.5
\$20	14 February 1966	160.0	80.0
\$50	9 October 1973	165.0	82.5
\$100	26 March 1984	172.0	82.5

Source: RBA

⁴ Due to the large number of organisations that assist in representing the vision-impaired community in Australia, and the differences in definitions of what constitutes ‘blind’ versus ‘vision impaired’ or ‘vision loss’, the data and statistics that are made available on the vision-impaired community websites are not always consistent across the sources. A person with a vision impairment that can be corrected with prescription glasses would not be included in these statistics.

Box A

Accessibility Features of Australia’s Banknotes

During the development of Australia’s current polymer banknote series, the Reserve Bank consulted with representative groups about features that could be used by people with vision impairment to recognise different banknote denominations. From

this consultation, it was concluded that banknotes with different lengths, strong colour contrasts and large bold numerals would best assist the vision-impaired community (Table A1).

Table A1: Accessibility Features of Polymer Banknote Series

Different lengths	Colour contrasts	Large, bold numerals
130 mm 		
137 mm 		
144 mm 		
151 mm 		
158 mm 		

Source: RBA

- *Large, bold numerals:* Another feature strongly endorsed by the vision-impaired community for those with partial sight was large and bold numerals that contrasted with the background on the banknote. Reflecting the importance of this feature, enhancements to the style of the numerals on the polymer series were applied.
- *Different sizes:* Different-sized denominations are particularly beneficial to people who are blind and cannot identify colour contrasts or bold numerals. Based on feedback from the vision-impaired community relating to the paper decimal \$100 banknote, the increase in length of each denomination in the polymer banknote series, commencing with the \$5 banknote, was changed from 5 mm to 7 mm.⁵
- *Guides:* Banknote measuring devices can be used by people with vision impairment to distinguish different-sized banknote denominations. Taking advantage of the size differentials of the 1992 polymer banknote series, the Bank developed a banknote measuring device in conjunction with Blind Citizens Australia (BCA) (see 'Box B: Banknote Measuring Device'). Development and production costs were fully funded by the Bank and the device has been distributed for free through BCA.

In addition to the initiatives outlined above, the Bank also investigated other possibilities for inclusion on the first polymer banknote series that were ultimately ruled out. A critical point for consideration in tactile features is their durability (so that they can always be properly identified), along with their impact on the storage and processing of banknotes by machines. One of the possibilities considered was a tactile feature created through the application of raised-ink (intaglio).⁶ A critical drawback of this feature was that it was likely to degrade significantly over the lifetime of the banknote, particularly with the polymer banknotes which were expected to

last much longer than their paper counterparts. Following an examination of new and worn test banknotes with prototype tactile features, most representatives of the vision-impaired community expressed the view that a tactile feature should not be included on Australian banknotes unless better durability could be achieved.

Other features considered for inclusion, but ruled out at that time, were notched-edge and clipped-corner features. While these features offer obvious advantages to people with vision impairment, it was not possible to produce them accurately and cost-effectively in high volumes with the available production techniques.⁷ In addition, there were concerns that these features could diminish the durability of a banknote as well as cause problems with banknote processing, accepting and dispensing equipment.

The Next Generation Banknote Program

Following the issue of the current polymer banknote series, the Bank continued to conduct research into new anti-counterfeiting technologies, eventually resulting in the establishment of the Next Generation Banknote program in 2007 and the public announcement in 2012 that new banknotes would be issued within several years (RBA 2012). The primary purpose of upgrading Australia's banknotes is to improve their security; however, this program has also provided an opportunity to explore how banknote accessibility can be further enhanced, including the possible addition of a tactile feature. The Bank's choice of feature – embossed 'bumps' for people to feel the difference between denominations – has been informed by extensive research and consultation.

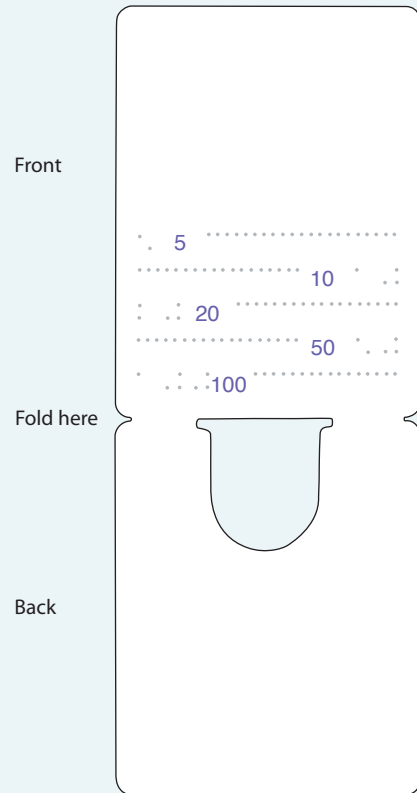
5 Lengths of the 1992 polymer series banknotes are: \$5 – 130 mm; \$10 – 137 mm; \$20 – 144 mm; \$50 – 151 mm; \$100 – 158 mm. The height of all denominations is 65 mm.

6 Intaglio printing is a process that involves applying ink that has been pressed into the recesses of an etched or engraved plate onto the destination surface, resulting in raised print.

7 One example of why it is difficult to produce banknotes with notched edges or clipped corners relates to the process of cutting individual banknotes from the sheets on which they are printed. After all of the features and artwork have been printed, the sheets, which can hold up to 45 banknotes, are cut into individual banknotes using guillotines. This process helps to minimise waste. At present, the banknote printing industry does not have the technology or equipment that can cut the sheets into individual banknotes with notched edges or clipped corners accurately and without significant waste, and, therefore, noticeable costs.

Box B Banknote Measuring Device

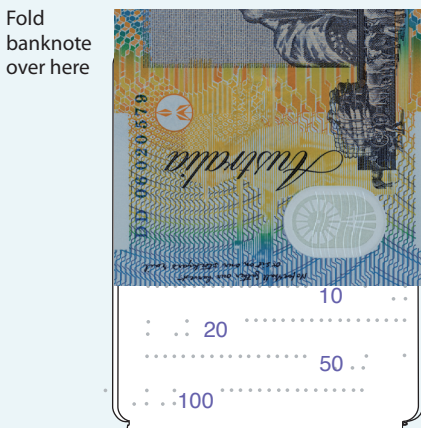
Figure 1: Banknote Measuring Device



1. Plastic banknote measuring device that folds to fit easily into a standard wallet or purse.



2. The short edge of the banknote is placed in the fold of the measuring device, ready to be folded around the device.



3. Braille numerals align with the different lengths of each denomination.

Source: RBA

International literature

As part of the Bank's research into improving accessibility, key studies and bodies of research conducted by other relevant overseas agencies were reviewed.

One of the earlier comprehensive studies of banknote design for the vision impaired was conducted by the National Research Council (NRC) in the United States (National Research Council 1995). The study examined how banknote issuing authorities provided assistance to the vision-impaired community to distinguish between banknote denominations. It identified varying banknote denomination sizes, large high-contrast numerals and different banknote colours for each denomination as features that the vision-impaired community would find useful. The NRC concluded that varying banknote sizes by denomination was the most effective feature to assist the vision-impaired community, but this was tempered by the observation that it was also the most costly to implement.⁸

Another US study, prepared by ARINC Engineering Services for the Bureau of Engraving and Printing, outlined options that could assist people with vision impairment to recognise different US banknote denominations (ARINC Engineering Services 2009). The study asked blind and low vision participants to distinguish different banknote denominations, including some banknotes from other countries that contained a mix of features. It found that high-contrast numerals made it quicker to distinguish between denominations, and that over 50 per cent of participants considered that different denomination sizes would help them distinguish banknotes, with blind participants being particularly receptive to the idea. It was also noted that as the participants became more familiar with the accessible features on banknotes from

other countries, their accuracy with distinguishing different banknotes improved.

In addition to the merits of high contrast numerals and different-sized banknotes, the ARINC study also reported results related to other accessible features:

- *Printed intaglio dots*: The banknotes tested with this feature achieved high accuracy when the banknotes (and the feature) were new, with 84 per cent of participants distinguishing denominations correctly. However, when using worn banknotes, accuracy decreased to only 49 per cent. The study concluded that the 'ease of use in transaction scenarios would therefore decrease as the features experience wear from circulation' (ARINC Engineering Services 2009, p 88).
- *Printed intaglio bars*: The banknotes tested with this feature achieved high accuracy when they were new, with an average of 85 per cent of participants successfully distinguishing denominations. As with the raised dots, when using worn banknotes, the accuracy decreased to only 42 per cent on average.
- *Notches cut into the top and bottom edges*: This feature also had high accuracy with an average of 89 per cent of participants correctly distinguishing denominations. In this case, it was a prototype feature and worn samples were not reported on.
- *Different sizes*: The banknotes with the most distinct size differences were distinguished most quickly during the usability test.

In 2009, De Nederlandsche Bank published the results of a comprehensive study into banknote design features for the vision impaired (de Heij 2009). The study considered a number of categories of vision impairment (colour blind, partially sighted and blind). Varying the lengths of banknote denominations was noted to be an effective method for the blind to distinguish between denominations. The study also observed a preference by the blind community for maintaining a common banknote

⁸ This cost relates mainly to the alterations needed for all cash handling equipment in the community to accommodate a shift to denominations with different sizes.

height, in conjunction with increasing denomination lengths.

The Bank of Canada has also conducted considerable research into banknote features for the vision-impaired community (Lederman and Hamilton 2002; Samuel 2010). A variety of options were investigated including different-sized banknotes, clipped corners, tactile features, handheld readers and design enhancements such as larger numerals and stronger colour contrast between denominations.

The Bank of Canada concluded early in its research that varying the sizes of different banknote denominations, while common in many industrialised countries, would substantially increase the cost of handling banknotes for businesses and individuals. Similarly, clipping corners was also judged to cause issues for processing and assessing banknote quality in circulation. These two options were therefore ruled out and the Bank of Canada concentrated on designing an electronic reader and developing a raised tactile feature.⁹ The reader was introduced in 1989 and an embossed tactile feature was included on the Canadian banknote series from 2001.

Another relevant body of work was conducted by the Federal Reserve Bank of St. Louis, which highlighted the difficulties a banknote issuer faces when attempting to conduct a cost-benefit analysis of including accessible features on banknotes. In this study, it was noted that benefits accrue to a diverse group and at very different levels. For example, some low-cost features that assist the vision-impaired

community (colours and numerals) also assist normal-sighted people to distinguish banknotes. On the other hand, the high-cost features (sizes and tactile features) that benefit the people with vision impairment may be extremely costly to implement for many other stakeholders (Williams and Anderson 2007).

International experience

Supplementing the review of international literature, the Reserve Bank sought information from 23 central banks about the features included on their banknotes to assist people with vision impairment with distinguishing denominations and the performance, efficacy and durability of those features (Table 2).

The feedback suggested some common themes. First, different sizes, supported by large, high-contrast numerals, were noted as key features used by people with vision impairment, even for the currencies that also had a tactile feature. Second, intaglio tactile features are popular as most issuing authorities are familiar with the technology but they often do not last well in circulation, reducing the degree of reliance the vision-impaired community can place on the feature once the banknotes become worn. Finally, the feedback indicated that it is desirable to have more than one feature to accommodate the wide range of vision impairments that exist. It was also noted by a number of central banks that there was not a strong preference within the vision-impaired community for the provision of a mechanical banknote reading device.

Table 2: Countries with Accessibility Characteristics on Banknotes^(a)

Countries	Size	Colour	Numeral size	Intaglio feature	Emboss feature	Device
Australia	✓	✓	✓	–	–	✓
Other	18	21	22	19	1	4

(a) Information was sought from 23 central banks as of July 2014
Source: RBA

⁹ Handheld electronic banknote readers are made available free of charge and distributed by a registered charity, CNIB, to blind individuals on behalf of the Bank of Canada.

Consultation with the vision-impaired community

The Bank also contacted representative groups and peak bodies of the vision-impaired community to assess how the accessibility features of the current banknotes are regarded and their appetite for additional features. In total, the Bank consulted with 10 representative bodies of the vision-impaired community¹⁰ and conducted two separate focus group studies covering a range of age groups and vision-impairment types.

These consultations confirmed that Australian banknotes do, in fact, have accessibility characteristics that are valued by people with vision impairment. Specifically, the consultations confirmed that the incremental sizing of Australian banknote denominations, together with the use of the banknote measuring device, considerably assisted with denominating banknotes.

Notwithstanding the current high level of accessibility of Australian banknotes, the feedback also highlighted the challenges that people with vision impairment face when checking their banknotes in fast-paced point-of-sale environments, such as supermarkets or fast-food outlets. In addition, many people felt heightened vulnerability when using the banknote measuring device or other commercial devices such as smart phone applications in public spaces. In this respect, the inclusion of a durable, tactile feature on Australian banknotes, allowing faster and more discrete recognition of a banknote, would be welcomed by the vision-impaired community.

Assessment of Additional Tactile Features for Australia's Banknotes

In light of this research, the Bank concluded that accessibility of the next generation of Australia's banknotes could be enhanced by the addition of a

tactile feature. It therefore undertook an investigation of alternative tactile features to assess their suitability for inclusion on the NGB series.

Information from other central banks indicated that only two types of tactile features are currently used on circulating banknotes. One is the traditional raised-print intaglio feature that is printed onto the surface of the banknote, and the second is a pattern of 'bumps' stamped or embossed into the banknote. The embossed bump is a relatively new feature for polymer banknotes and is only used on a very small number of banknotes elsewhere in the world. In fact, of the 23 other central banks that the Reserve Bank consulted with about tactile features, only one (Canada) had the embossed bumps on their banknotes.

In addition to these two features, the Bank investigated other features that had not yet been commercialised or were still under development. Due to lead times associated with bringing these features to the point of being ready for application, however, a decision was made to focus on the intaglio and emboss features, which had already been tested in circulation.

To test the viability of the intaglio and emboss features for the NGB series, the Bank established an evaluation criteria and a regime of tests was conducted to measure each feature's performance relative to these criteria.

Evaluation criteria

Ideally, any new feature being considered would need to satisfy a number of criteria:

- *Efficacy*: It must consistently meet its purpose of helping the vision-impaired community distinguish banknote denominations with higher accuracy and greater speed.
- *Durability*: It must remain functional over the life of the banknote.
- *Security*: It must not compromise the security features of the banknote.

¹⁰ These include Able Australia, Association for the Blind of WA, Blind Citizens Australia, Association of Blind Citizens of NSW, DeafBlind Association (NSW), Guide Dogs NSW/ACT, Retina Australia, The Royal Society for the Blind, Vision Australia and Vision 2020 Australia.

- *Production:* The Bank and its suppliers must have the capability to produce the feature on the banknote in a consistent, reliable and efficient manner. Production of a tactile feature should not adversely affect the other printing processes.
- *Circulation impact:* Any new feature should not impose significant costs on other stakeholders in the banknote life cycle, including the general public and industry groups.

Efficacy

Two focus group studies conducted by the Bank served as a way to test the efficacy of the two tactile features under consideration.

The primary objective of the first focus group study was to assess the efficacy and designs of the tactile features being considered. To take into account the likely impact of wear in circulation, the focus group participants were shown both pristine and worn samples of each feature.

Feedback from this study indicated that the traditional application of an intaglio tactile feature was not favoured by the vision-impaired community as an accessible feature, which is consistent with the feedback from the consultations conducted relating to the current polymer banknote series. This also aligned with international experience, where intaglio features were considered not to function well once in circulation. The emboss feature, however, was viewed favourably by the focus groups.

Over 80 per cent of participants in the first study were able to find the embossed tactile feature on the test banknotes quickly and easily, and concluded that this feature was preferred over the intaglio feature (for pristine and worn banknotes). These results were consistent with the positive feedback on the embossed tactile feature on Canada's new polymer banknotes.

Participants from the first focus group were also shown different tactile design approaches. One was based on different shapes for each denomination, and another was a scalar system, where the number of dots or characters increased per denomination. More

than two-thirds of focus group participants strongly preferred the scalar-based tactile feature design.

The second focus group study sought input on an optimal scalar-based tactile design. Focus group participants in this study were presented with two scalar-design options based on:

1. Increasing numbers of single dots.
2. Increasing numbers of rows of dots.

A clear majority of focus group participants (over 85 per cent) preferred increasing the number of single dots, primarily due to the even spacing of the tactile characters. There was also concern that participants who were familiar with braille could be confused by two rows of dots close together, as in the second option, by reading them as a single character rather than individual rows.¹¹

Durability

The Bank also conducted extensive tests to assess the durability of both tactile features being considered.

To test durability, banknote samples with the two potential tactile features were subjected to a range of chemical, physical and environmental durability tests to assess the resistance of the feature to circulation wear (see 'Box C: Critical Durability Tests of Tactile Features'). The intaglio feature was significantly less durable than the emboss feature, performing unsatisfactorily across the range of tests (Table 3). This result confirmed the experience of most central banks.

Some durability deficiencies of the emboss feature were observed. However, the nature of the deficiencies and the expectation that they were only likely to be manifested in extreme environments suggested that the embossed feature would be suitable in most circumstances for use on Australian banknotes. Testing also highlighted the importance of including a suite of features to assist the vision-impaired community to reduce their reliance on any one feature.

¹¹ A full braille cell is made up of two columns of three dots positioned close to each other.

Box C

Critical Durability Tests of Tactile Features

A comprehensive range of physical and chemical durability tests were conducted to assess the performance of potential tactile features in circulation. A digital micro gauge was used to assess the change in height of the tactile feature after each of the durability tests listed in the Table C1 below,

with the exception of the test for crumple resistance where, due to the complexity of the folds and crumples that are introduced to the feature, the loss in the tactile feel of the feature needs to be assessed manually.

Table C1: Critical Durability Tests of Tactile Features

Test	Description
Chemical resistance	Evaluates the resistance of the tactile elements and security features to chemical exposure. A range of chemicals that are commonly used in household and industrial applications are applied to the banknote.
Crumple resistance	Evaluates the resistance of the banknote to the folds and crumpling that are likely to occur during the lifetime of a banknote in circulation. A specialised ‘crumpling’ device is used that simulates complex folds and crumples.
Rub resistance	Evaluates the resistance of the tactile feature to abrasion using a controlled rub test where an 8 mm spot region containing the feature is continuously rubbed for 100 rub cycles.
Soil and wear	Evaluates the soil and wear resistance of the tactile feature using a specialised soil and wear tumbling apparatus that simulates likely wear in circulation.
Taber abrasion	Evaluates the abrasion resistance of the tactile feature by subjecting the feature to abrasion caused by a combination of aluminium oxide impregnated rubber wheels moving in a circular manner and the weight of the mechanical arms that are connected to these wheels.
Accelerated oven ageing	Evaluates the durability of the tactile feature to heat using a specialised oven where the feature is placed at an elevated temperature for a predetermined time. This simulates circumstances where a banknote is exposed to high heat.
Machine wash	Evaluates the progression of wear of the tactile feature during normal circulation using a specialised washing machine where the banknote is subjected to various combinations of wash cycles and temperatures.

Source: RBA

Table 3: Results of Durability Testing of Tactile Features

	Intaglio	Emboss
Chemical resistance	x	✓
Crumple resistance	x	✓
Rub resistance	x	✓
Soil and wear	x	✓
Taber abrasion	x	✓
Accelerated oven ageing	x	x
Machine wash	x	✓

Source: RBA

Security

The intaglio and emboss features were assessed at various stages of research, development, design and testing to ensure that their inclusion on a banknote did not compromise the security features of the banknote at any point. Assessment by the Bank’s scientists, designers and Note Printing Australia provided reassurance that an appropriately designed tactile feature could be incorporated into the new design without affecting other security elements of the banknote.

Production

A number of trials were conducted to assess the ability to produce both of the tactile features. Although the intaglio and emboss features had been produced on other overseas banknotes (and intaglio ink is already present on the portraits and numerals on Australian banknotes), it was essential to confirm that these features could be produced in tandem with the security features and designs that will appear on the next generation of Australian banknotes. The production trials indicated that the intaglio and emboss features could be produced consistently on the NGB series.

Circulation impact

It is estimated that in Australia more than 35 000 ATMs, 8 000 self-service checkouts, 200 000 gaming machines and 250 000 vending machines will

be affected to some extent through the upgrade of Australia’s banknotes, including the addition of a new tactile feature for the vision-impaired community (Kim and Turton 2014). The Bank is therefore working closely with the industry to minimise this impact.

Preferred Approach

In light of the research, evaluation and testing conducted by the Bank, the next generation design of Australian banknotes will include different numbers of embossed bumps on each denomination to assist people with vision impairment to distinguish between banknotes.

The accessibility features that are currently used – different-sized denominations, strong colour contrasts and large bold numerals – will also be retained.

Conclusion

The vision-impaired community has expressed a strong and consistent preference to retain the existing Australian banknote characteristics designed specifically to assist people with impaired vision – size differentials, strong colour contrasts and large bold numerals – as part of the next generation banknote design. In addition, there is substantial support for the inclusion of some form of tactile feature, that would reduce the need to use a banknote measuring device at the point of sale. Focus group feedback confirmed that this preference was sustained even with potential degradation of the tactile feature over time.

The input of the vision-impaired community, together with an extensive review and testing of two tactile features, has resulted in the Bank deciding to retain the existing accessibility features as well as add a new embossed tactile feature into the design of the next generation of Australia’s banknotes. The Bank will also continue to support the production of the banknote measuring device. ❖

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