Accessibility Research Group
Civil, Environmental, and Geomatic Engineering
University College London

Effective Kerb Heights for Blind and Partially Sighted People

Research Commissioned by The Guide Dogs for the Blind Association (Guide Dogs)

Childs CR, Boampong DK, Rostron H, Morgan K, Eccleshall T, Tyler N

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1. Executive Summary

1.1 Introduction

Several local authorities in the UK have redesigned town centres and high streets using the concept of shared space, or are in the process of doing so. Shared space aims to create shared ‘social’ areas for all users, reduce the dominance of motor vehicles and make streets more people-friendly.

Shared space is often delivered by means of a "shared surface design" which requires the removal of the traditional vertical upstand (kerb). The removal of the kerb takes away the vital clue used by blind and partially sighted people to help them to navigate the pedestrian environment and to identify when they have reached the edge of the footway. In response to this The Guide Dogs for the Blind Association (Guide Dogs) has carried out or commissioned research both to establish the impact on the mobility of blind and partially sighted people and to examine potential approaches to delineating a "safe space" in the shared space in which vulnerable pedestrians can move around with confidence. As part of that research programme, in 2007 UCL carried out trials with a range of potential delineators including a 30mm high kerb. In those experiments, it was found that a kerb height of 30mm was not sufficient to be reliably detected by blind and partially sighted people whilst remaining a barrier to progress for some wheelchair users. Since some local authorities want to reduce the kerb height from the traditional 120mm and 30mm is too low, Guide Dogs asked UCL’s Accessibility Research Group to run tests to determine what kerb height could be reliably detected by blind and partially sighted people.

1.2 Methods

The experiments took place in May and June 2009 at the University College London’s Pedestrian Accessibility Movement and Environment Laboratory (PAMELA). This provided a safe and comfortable environment in which to run trials with vulnerable pedestrians in order to identify which of the kerb heights were reliably detectable. These experiments involved 36 blind and partially sighted people who were positioned at set points in the laboratory and asked to walk until they were told to stop or they encountered a kerb, following the experimenter’s voice to help with orientation. If the participant did not detect a kerb where there was one, the experimenter would class the trial as a fail. If a kerb was encountered, the participant was asked to give a score relating to the confidence they had that what had been encountered was a kerb. Kerbs were tested at heights from 20mm up to 120mm and in 2 profiles - bullnose and chamfer.

1.3 Results

All the participants detected the kerbs of 60mm, 80mm and 120mm when stepping up or stepping down from the kerb as well as when approached straight on and at an oblique angle. One participant consistently failed to detect the 50mm kerb when stepping down. With heights of 40mm and lower, some participants failed to detect the kerb when stepping up or down. It made no difference if the participant approached the kerb straight on or at an oblique angle. All kerb heights were easier to detect when stepping up.

1.4 Conclusion

This research has identified the effectiveness of each kerb height in an internal controlled environment. For confidence that a kerb is detectable by blind and partially sighted people, it is recommended to install a kerb of 60mm or greater. This applies to kerb profiles approaching vertical and any profile that is significantly different from this would need to be tested. The effects of lighting, weather, additional cognitive loading, and the practicality of using the kerb to assist navigation were not considered in this trial. All these and issues relating to other groups such as children and people with learning difficulties, would need to be the subject of further research.

2. Acknowledgements

We wish to thank all the participants for their time and Marshalls Paving for supplying the kerb profiles.

3. Introduction

As a means of delineating between the pedestrian-only footway and the area of the road that vehicles can use, the vertical upstand, or kerb, is well established. Optimal height of the kerb depends on the road use. Traditionally, a kerb height of 120mm to 150mm has been considered sufficient to stop vehicles mounting the footway, thus keeping the space clear for pedestrians. To facilitate easier access to low floor buses, higher kerbs (160mm to 220mm) minimise the vertical step required to get on and off the bus from the footway and also minimise the ramp angle for wheelchair users. Some local authorities are considering implementing shared space schemes incorporating shared surface designs where the kerbs are removed allowing vehicles and pedestrians access to the same space. The main idea behind this is that by forcing motorists and pedestrians to use the same space, drivers will reduce speed because of the increased risk, thus making the area safer for everyone. From a pedestrian perspective, the creation of a level surface should be of benefit to those who use wheelchairs or with pushchairs. However, Guide Dogs research has shown that sharing space with vehicles has been identified as a problem by wheelchair users as well as other groups of disabled people including people with learning difficulties. This is in addition to the problem of the removal of a vital clue to identifying the limits of the footway for people who are blind or partially sighted..

It has been suggested (Ramboll Nyvig, 2007) that shared spaces should have a safe space for pedestrians, giving people confidence that there should be no vehicles in these areas. In traditional streetscapes safe spaces are provided by the footway, delineated by the kerb. However the traditional 120mm+ kerb makes too distinct a separation for proponents of shared space schemes. This raised the question of the possibility of finding an alternative surface as a delineator. Earlier work (GDBA, 2007) showed that the 30mm kerb suggested by Ramboll Nyvig was not sufficiently reliable for blind and partially sighted people to use as a delineator, and equally was a barrier to some people using wheelchairs. If we already know that 30mm is a barrier to some wheelchair users, any kerb of this height or greater would require dropped kerbs at crossings as is current practice. Consequently, Guide Dogs asked UCL to investigate the minimum kerb height that blind and partially sighted people can reliably detect considering kerb height rather than alternative surfaces.

The use of low kerbs has in some cases been supported by local blind and partially sighted people and societies, and access groups. Stockport Disability Alliance has written to Guide Dogs supporting the use of 50mm kerbs by Stockport Council, who have implemented them in Warren Street, Stockport.

The UCL work presented in this report was commissioned by the Guide Dogs to determine at what height the kerb becomes detectable. The ‘traditional kerb’ height of 120mm was used as a baseline, to compare with kerb heights from 20mm up to 80mm. Two edge profiles were tested, one vertical with a chamfer, the other 15° to vertical with a 20mm bullnose. The latter (the half battered kerb from Marshalls Paving) constitutes the vast majority (approximately 90%) of the kerbs supplied by Marshalls Paving. The experiments took place at the Pedestrian Accessibility and Movement Environment Laboratory (PAMELA) at University College London. The different kerb heights were recreated in this facility, where blind and partially sighted people were asked to walk as if they were in an unfamiliar street, for example heading towards the library, or a café, only stopping if they detect what they thought could be a kerb. They were then asked questions about the level of confidence they had that what they’d encountered was a kerb.

This report sets out the minimum effective kerb height that is detectable for blind and partially sighted people for use to delineate between the footway and carriageway.

4. Methods

4.1 Laboratory Layout

This experimental work took place in the Pedestrian Accessibility and Movement Environment Laboratory (PAMELA) at University College London. PAMELA is a laboratory used to test existing and proposed pedestrian environments under controlled conditions. The laboratory includes a computer-controlled paved platform which can be varied in terms of layout, topography and surface type (Childs *et al.*, 2007). The PAMELA modules were arranged according to Figure 1, with two baseline areas that would be the equivalent of the footway either side of a road. The edge length of each Baseline section was 7.2m. This allowed for three 2.4m kerb height sections on each side, thus six kerb heights (A to F) along the edge of the Baseline Sections. One additional kerb height section of 3.6m long (G) was located perpendicular to the edges of the Baseline Sections. As can be seen in Table 1, the height difference between A and B was 40mm, the height difference between C and D and between E and F was 10mm. The height changes occurred at either end of the 3.6m space between the Baseline Sections, consequently the surfaces between A and B, C and D and E and F can be considered level with no appreciable gradient. The entire surface was covered with 400mm x 400mm chamfered edge concrete pavers.

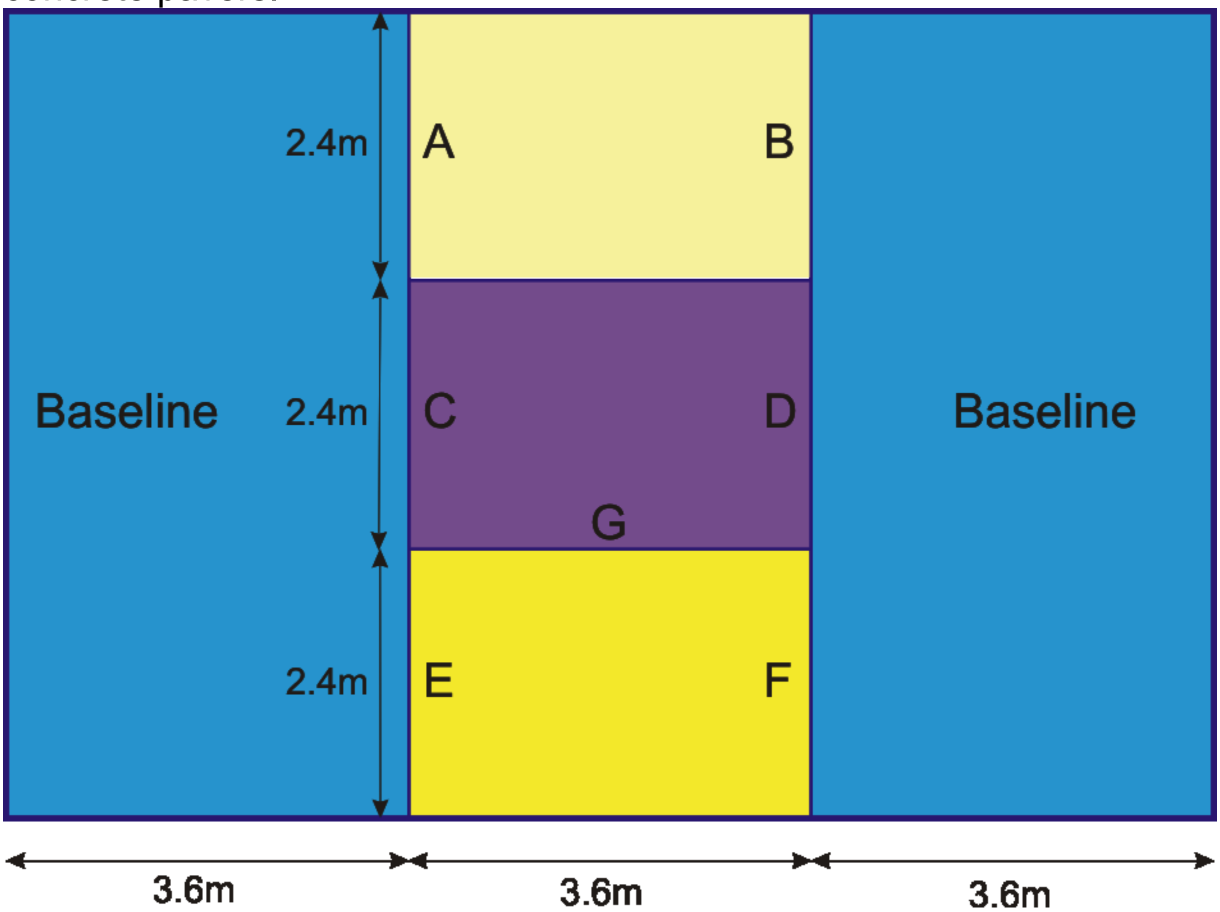

Figure 1 Laboratory layout

4.2 Kerb Characteristics

The kerb heights ranged from the traditional 120mm to 20mm (Table 1).

Kerb	Height (mm)
A	120
B	80
C	60
D	50
E	40
F	30
G	20

Table 1: Kerb heights

Two different edge profiles were tested to determine if the profile made a difference to the detectability of the kerb. The first profile to be tested was a straight vertical face with chamfered edge (Figure 2). The second profile had a straight face 15° to the vertical and a 20mm bullnose edge (Marshall's Half-Battered Kerb).

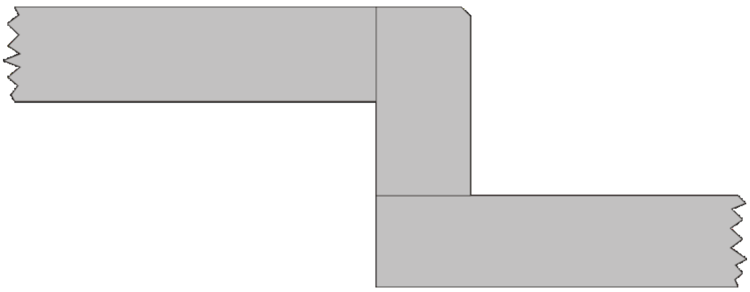

Figure 2 Chamfered edge kerb

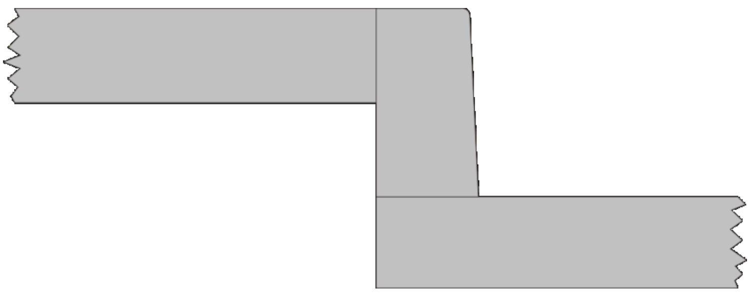

Figure 3 Bullnose edge kerb

4.3 Participants

The study was approved by the UCL Research Ethics Committee (0410/006) and all participants provided written informed consent. Only blind and partially sighted people were included in these tests as people with mobility impairments, in particular those in wheelchairs, were unlikely to overcome the kerb upstand and would need to have dropped kerbs in any design incorporating a kerb delineator. All the participants recruited reported that they use the street environment independently, either limited to local familiar areas, or for exploring new unfamiliar areas. Tables 2, 3 and 4 show the characteristics of the participants in terms of their gender (Table 2), vision/mobility aid they use (Table 3) and their age (Table 4).

Male	23
Female	13

Table 2: Participant Gender

Guide Dog	11
Long Cane	17
None	8

Table 3: Participant Vision/mobility aid used in street and during test

18-40	8
41-64	21
65+	7

Table 4: Participant age

4.4 Trial task

Figure 4 shows the layout of the PAMELA platform used for the tests. The kerb heights were arranged so that a participant would have a reasonable distance to walk before they would encounter a kerb and so that the full range of kerb heights could be encountered within the layout. Each participant was led to a randomly assigned part of the platform, then asked to follow the experimenter's voice to another part of the platform, only stopping if they detected a change (e.g. a kerb). For example, Figure 4 shows four example tests: (a) a Baseline test where the participant did not encounter a kerb; (b) a trial where the participant encountered an 80mm down kerb at approximately 45°; (c) a trial where the participant encountered a 40mm up kerb at approximately 45°, and (d) a trial where a participant encountered a 120mm down kerb at 90°.

Each experiment consisted of trials where the participant encountered each of the kerb heights as listed in Table 1; stepping down and stepping up, when approached from 90° and approximately 45°.

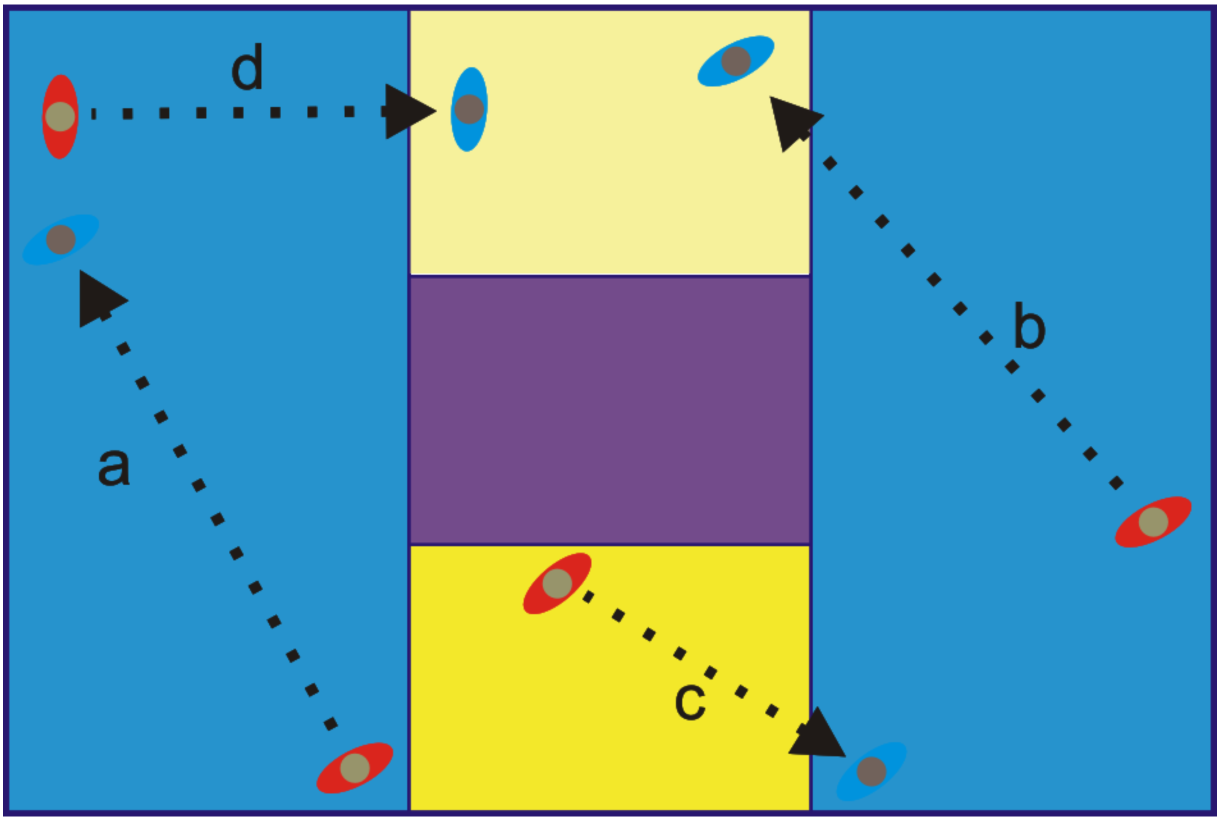

Figure 4 Trial tasks

4.5 Measurements

Each test was video recorded from cameras arranged around the laboratory. The experimenter recorded the key parameters throughout the experiment.

4.5.1 Detection

After each trial the experimenter noted whether the participant stopped having detected any kerb encountered. This was recorded as :

1) 'before' if the participant stopped before reaching the kerb, having detected it with their mobility aid,
2) 'on' if the participant reached the kerb and stopped on top of it, before placing their foot on the other side,
3) 'after' if the participant stepped over the kerb, but then stopped realising that they had encountered a kerb,
4) 'fail', if the participant stepped over the kerb and gave no indication that they had encountered a kerb.

Each participant was asked the following question after each trial :

> 'on a scale of zero to ten, how easy was it to tell that you had detected a kerb : with zero being definitely did not detect a kerb, five being detected something but unsure whether it was a kerb and with ten being definitely did detect a kerb?'

The detection scores indicate how confident the participants were that they had encountered something that could have been a kerb delineating the difference between the footway and the vehicle space of a street. These scores can be considered as follows :

10 was classed as the participant being confident that what had been encountered was a kerb,

6 to 9 was classed as the participant being sure that they had encountered something and were confident that it was a kerb,

5 was classed as the participant being confident that they had encountered something, but were not entirely confident that it was a kerb,

1 to 4 was classed as the participant being unsure that they had encountered something different to the surrounding paving, and were not confident that it was a kerb,

0 was classed as the participant being sure that they had not encountered anything different to the surrounding paving, and were confident that they had not encountered a kerb.

4.5.2 Anxiety

Each participant was asked to respond to the following question at specific times throughout their time in the laboratory :

> ‘on a scale of zero to ten, how anxious do you feel about the experiment : with one being not anxious at all and with ten being the most anxious imaginable?’

The participants were asked to respond this question in advance of the experiment, i.e. whilst they were in reception before entering the laboratory; after they were first led onto the test area prior to the first trial; after each trial; then again after being led back to the reception area just prior to leaving the building. For the participants who responded with a value greater than 5, they were asked whether this anxiety was related directly to the experiment (e.g. the risk of hurting themselves on the kerb) or to their perception of how they would be in a shared space having encountered this surface.

5. Results

The following figures show the frequency of occurrence of detection of different kerb heights. There were 36 participants in total, but not all participants completed all the trials. Had this been the case, n for each step height listed in Tables 5 and 6 would have been 144 (36 people times 2 approach angles times 2 edge profiles). For these results the angle of approach and edge profile has been combined. Sections 5.4, 5.5 and 5.6 compare the results between angle of approach, (section 5.4), stepping up or stepping down the kerb (section 5.5), and kerb edge profile (section 5.6). The data for these graphs is shown in the corresponding tables.

5.1 Experimenter scored detection

The experimenter’s classifications for all trials where the participants stepped down the kerb are summarised in Figure 5 and Table 5. The experimenter’s classifications for all trials where the participants stepped up the kerb are summarised in Figure 6 and Table 6. The figures and corresponding tables show, for each kerb height, the number of times the kerb was detected with the mobility aid before the participants stepped on the kerb (‘before’), the number of times the participants detected the kerb once they had stepped onto it, but had not yet placed their foot on the other side of the kerb (‘on’), the number of times participants detected the kerb after they had stepped up or down it (‘after’) and the number of times the participants failed to detect it at all (‘fail’).

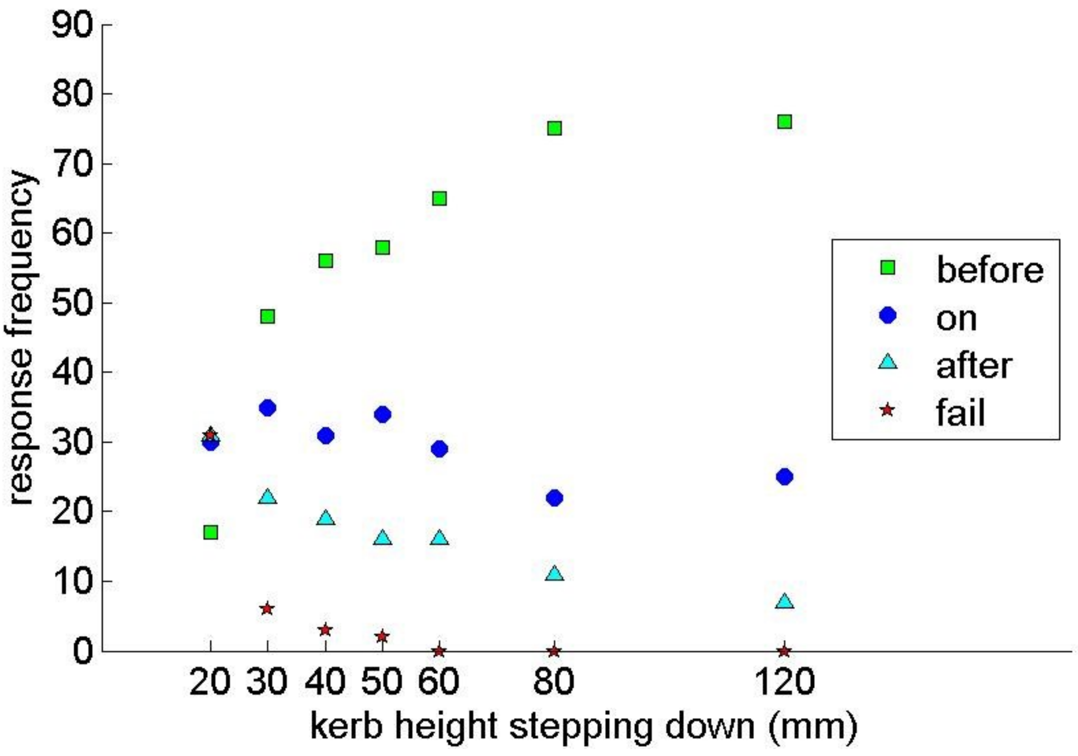

Figure 5 Experimenter scored detection for all stepping down trials

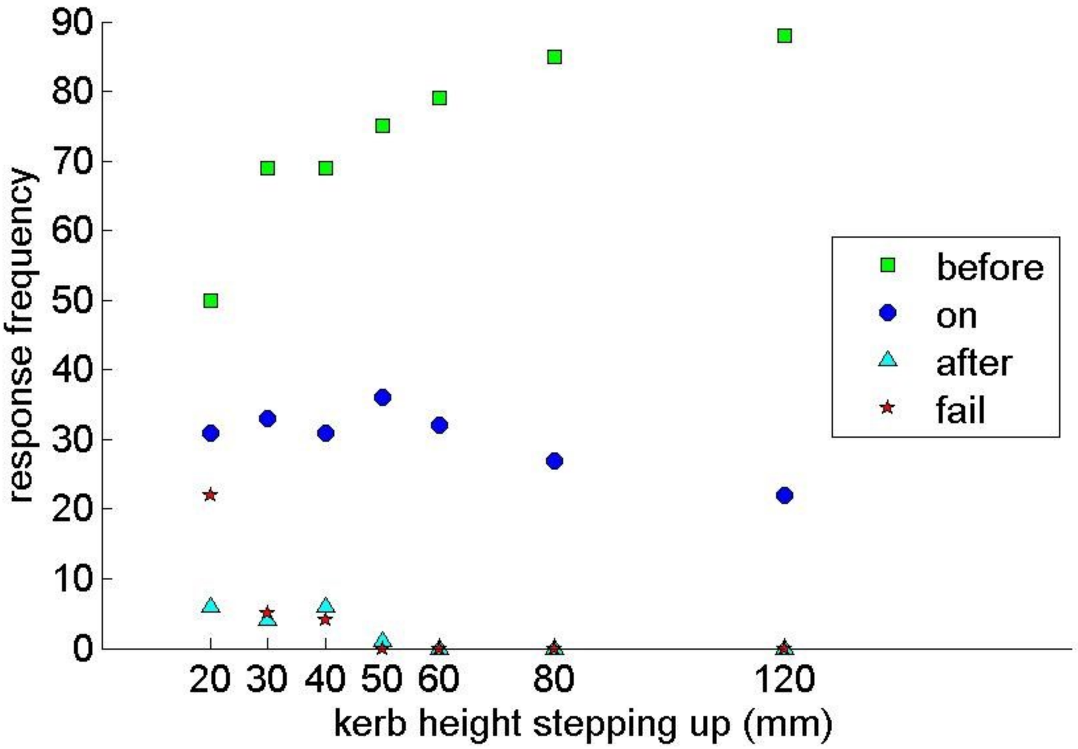

Figure 6 Experimenter scored detection for all stepping up trials

Stepping Down the kerb					
Kerb height	before	on	after	fail	n
120	75	25	7	0	107
80	77	22	11	0	110
60	65	29	16	0	110
50	58	34	16	2	110
40	57	31	19	3	110
30	48	35	22	6	111
20	17	30	32	31	110

Table 5: Experimenter scored detection for all stepping down trials

Stepping Up the kerb					
Kerb height	before	on	after	fail	n
120	88	22	0	0	110
80	85	27	0	0	112
60	79	32	0	0	111
50	75	36	1	0	112
40	69	31	6	4	110
30	69	34	4	5	112
20	50	31	6	22	109

Table 6: Experimenter scored detection for all stepping up trials

Even the traditional kerb height of 120mm cannot stop occasional instances of people walking over it before realising they have reached a delineator in the street space : indeed, some blind and partially sighted people use that "positive" step down as their warning (Figure 5, Table 5). This seems to occur when people step down the kerb: it was never observed to occur in these experiments when a participant stepped up the kerbs greater than 50mm high (Figure 6, Table 6).

There is an asymmetry in the ‘after’ score. The ‘detect on’ and ‘fail’ scores are approximately symmetrical between stepping up or stepping down, in that there are similar numbers of participants detecting the kerb once they were on top of it, or failing to detect it during the traverse. However, the number of participants who only detected the kerb after they had passed it after stepping down it was consistently higher than when stepping up for all kerb heights. Conversely, there were more detections of a kerb before reaching it when the participant was about to step up the kerb than if they were stepping down.

The number of fails is highest for participants stepping up or down the 20mm kerb and this settles to zero at around the 50mm height.

5.2 Participant perceived confidence in detection score

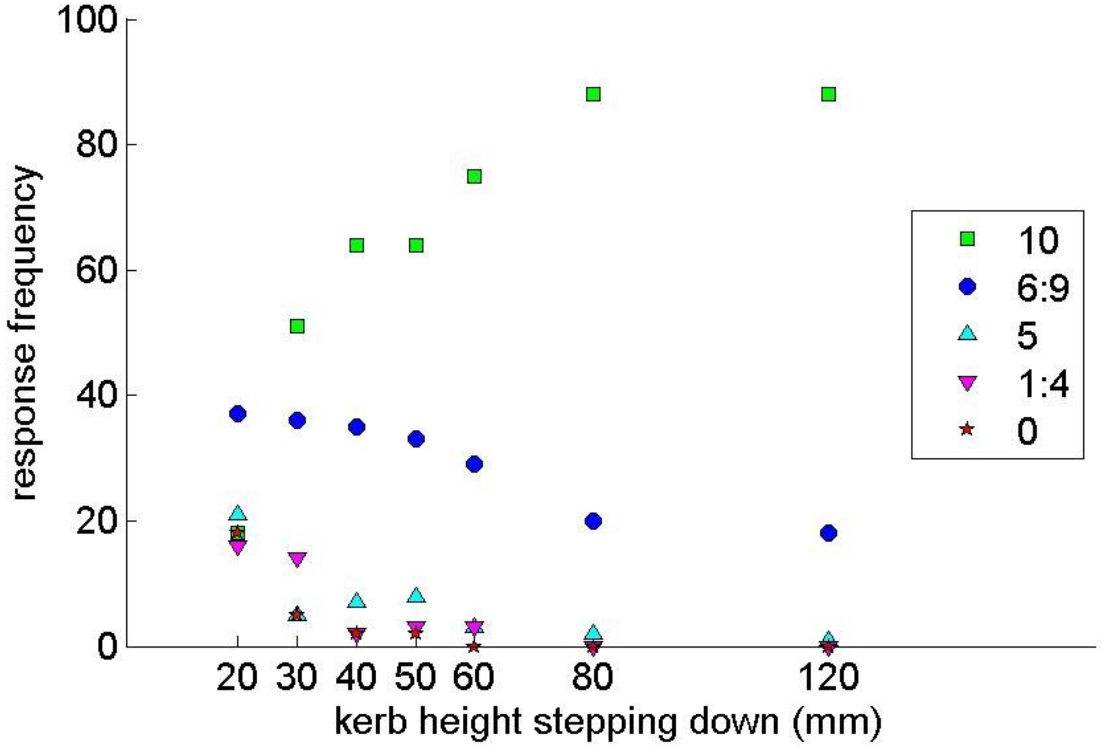

Figure 7 Participants' scored detection stepping down each kerb height

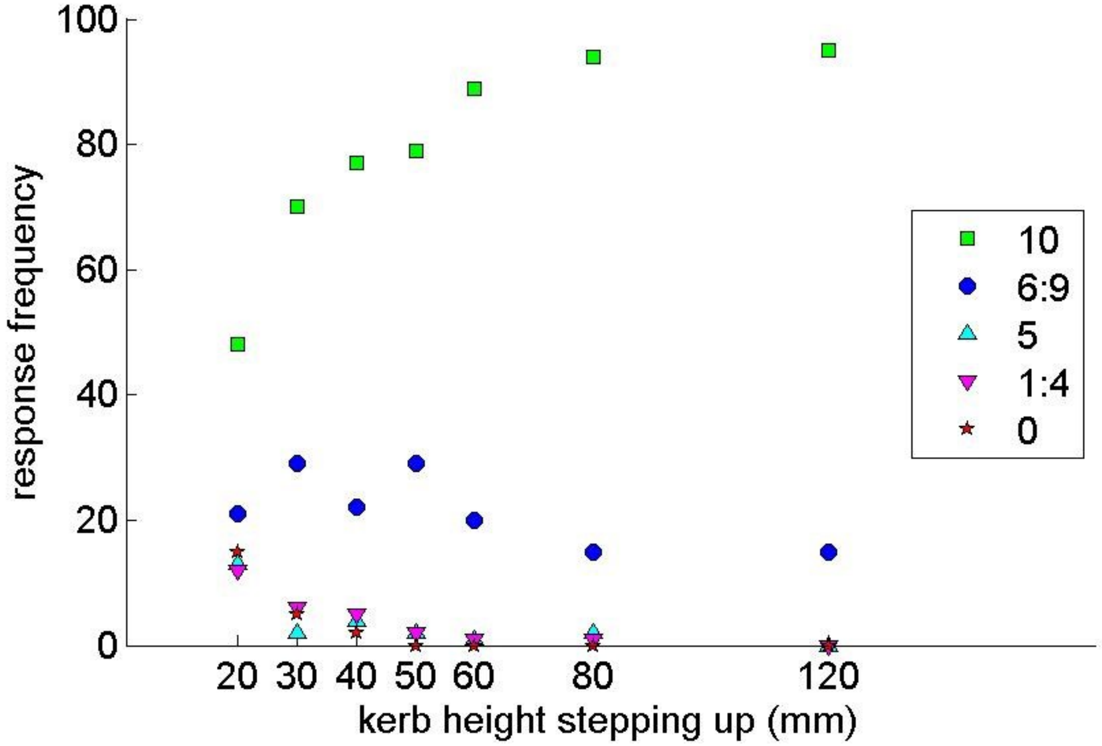

Figure 8 Participants' scored detection stepping up each kerb height

Figures 7 and 8 show the participants' scores for their confidence that they encountered something that was a kerb, grouped as described in section 5.4.1. Tables 7 and 8 show the actual frequency of responses (0 to 10) for each step height and whether the participant was stepping down (Table 7) or up (Table 8) the kerb.

	Frequency of given Detect score according to kerb height											
Kerb height	0	1	2	3	4	5	6	7	8	9	10	n
0	360	15	9	18	3	15	4	2	3	0	0	429
20	18	7	1	5	3	21	14	5	10	8	18	110
30	5	4	4	1	5	5	8	7	9	12	51	111
40	2	0	0	0	2	7	10	4	11	10	64	110
50	2	1	0	0	2	8	11	4	4	14	64	110
60	0	0	0	1	2	3	4	10	11	4	75	110
80	0	0	0	0	0	2	3	5	6	6	88	110
120	0	0	0	0	0	1	2	2	6	8	88	107

Table 7: Participant's perceived confidence detecting stepping down

	Frequency of given Detect score according to kerb height											
Kerb height	0	1	2	3	4	5	6	7	8	9	10	n
0	360	15	9	18	3	15	4	2	3	0	0	429
20	15	3	2	5	2	13	5	4	9	3	48	109
30	5	0	2	3	1	2	7	3	9	10	70	112
40	2	1	3	1	0	4	3	2	5	12	77	110
50	0	0	0	1	1	2	4	3	11	11	79	112
60	0	0	0	1	0	1	5	3	7	5	89	111
80	0	1	0	0	0	2	1	3	4	7	94	112
120	0	0	0	0	0	0	1	0	3	11	95	110

Table 8: Participant's perceived confidence detecting stepping up

A participant scoring '10' indicates that they were absolutely confident that they had encountered a kerb. Figures 6 and 7 and Tables 7 and 8 show that for the majority of trials, participants were absolutely confident that they had encountered a kerb on the trials with the 80mm (82%) and 120mm kerbs (84%). The levels of confidence drop when the kerb height is 60mm or less (participants scored '10' for 74% of trials over 60mm, 64% of trials over 50mm, 63% of trials of over 40mm, 54% of trials over 30mm and 30% of trials over 20mm).

In general, the confidence that a kerb was detected tended to be higher when the participant approached the kerb from the lower side (Table 8 compared to Table 7). For example, there was only one case where someone gave a detection confidence score lower than ‘8’ when stepping up the 120mm kerb, compared to five cases when stepping down the 120mm kerb. These numbers indicate the high level of confidence that participants had encountered a kerb when it was 120mm high.

The perceived confidence in detection score of zero corresponds to the fail from the experimenter scored detection. Correspondingly the participants who had been scored by the experimenter as a fail for a particular trial subsequently scored that trial as a zero.

No participant failed to detect the 120mm, 80mm, or 60mm kerb on any trial, from any angle tested, or for either of the edge profiles. One participant did not detect the 50mm kerb when going down approached from either straight on or at an angle. This participant was a guide dog owner. There were no failures when going up this kerb. The first failure to detect when stepping up a kerb was for the 40mm height. This participant had cone dystrophy, only using a symbol cane when walking in the street. The other participant to fail the 40mm kerb (stepping down) was someone who used a long cane. In addition to those already mentioned, two guide dog owners failed the 30mm kerb, both stepping up and down. In total, four guide dog owners, six long cane users and three people who didn’t use any aid, failed to detect the 20mm kerb.

5.3 Participant perceived anxiety score over time

The participants were asked their perceived anxiety at various points during the experiment process: (1) in the laboratory reception area prior to entering the laboratory area, (2) after having been led into laboratory area just prior to the first experiment trial, (3) after each experiment trial, and (4) at the end of the experiment, after being led back to the reception area. Figure 9 shows as an example the scores recorded by one participant at each point during the whole experiment ('anxiety') and the kerb heights in centimetres associated with these points ('kerb height/10'). The person whose anxiety scores appear in Figure 9 shows that they felt quite anxious at the beginning of the experiment experience, then as the experiment started their level of anxiety dropped. Hence this participant reduced their anxiety score from a starting level of 8 in the laboratory reception area, 8 again after first being led through to the laboratory test area, reducing to 7 prior to the first test and reducing again to 4 after the first walking trial. As they became more familiar with the test, their perceived anxiety dropped to 0.

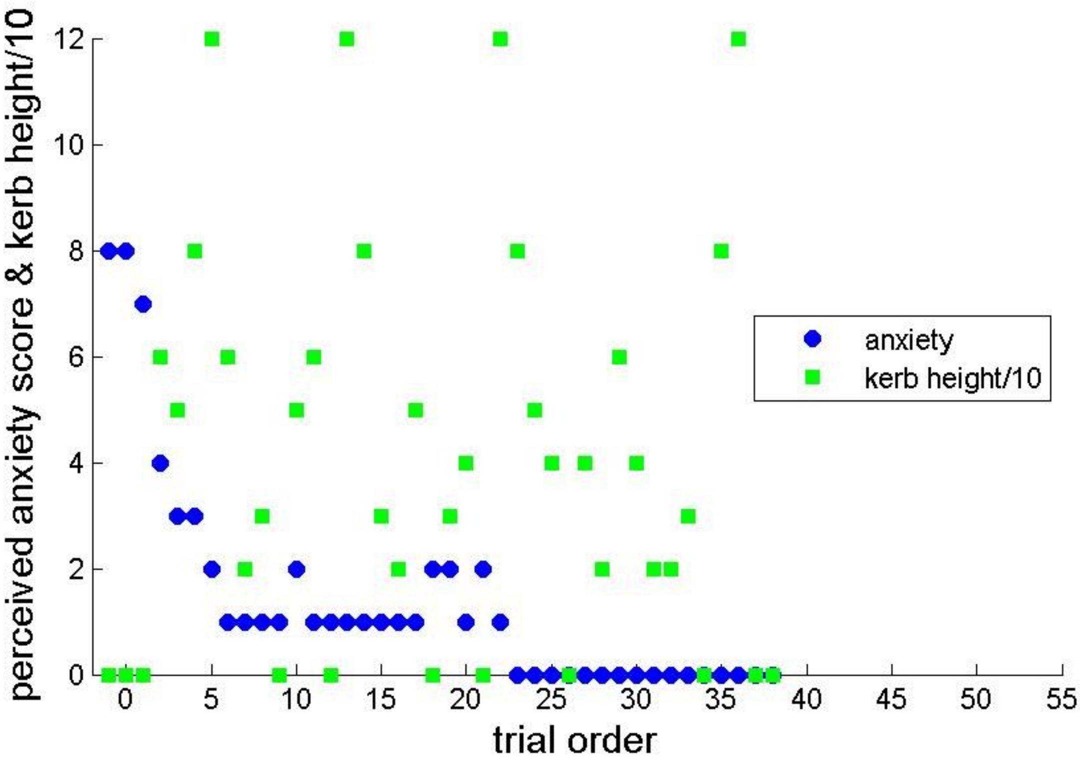

Figure 9: Example of Perceived Anxiety Score dropping over the duration of an experiment

trial order	kerb height	anxiety score
-1	0	8
0	0	8
1	0	7
2	-60	4
3	50	3
4	-80	3
5	120	2
6	-60	1
7	20	1
8	30	1
9	0	1
10	-50	2
11	60	1
12	0	1
13	-120	1
14	80	1
15	-30	1
16	-20	1
17	50	1
18	0	2

trial order	kerb height	anxiety score
19	-30	2
20	40	1
21	0	2
22	-120	1
23	80	0
24	-50	0
25	40	0
26	0	0
27	-40	0
28	-20	0
29	60	0
30	-40	0
31	20	0
32	20	0
33	30	0
34	0	0
35	-80	0
36	120	0
37	0	0
38	0	0

Table 9: Participant’s perceived anxiety stepping down kerb heights

For the majority of the participants (61% of the participant tests) there was no change over time, with all these participants showing low levels of perceived anxiety throughout. No participant increased their perceived level of anxiety unrelated to kerb height throughout the experiment. Five of the participants who took part in the experiments with the first profile (chamfered edge) responded with a reduction in perceived anxiety over the experiment duration (for example see Figure 9). Three of these participants showed no change in perceived anxiety over the duration of their second experiment (bullnose edge). The other two participants responded in the same manner as for their first experiment, although they started from a lower initial level of perceived anxiety.

5.4 Participant perceived anxiety score

Tables 10 and 11 show the frequency of perceived anxiety scores according to the kerb height encountered immediately prior to the question when stepping down the kerb (Table 10) and stepping up the kerb (Table 11).

	Frequency of given Anxiety score according to kerb height											
Kerb height	0	1	2	3	4	5	6	7	8	9	10	n
0	260	53	43	39	12	12	1	2	1	0	6	429
20	59	13	11	13	6	5	0	0	0	0	3	110
30	59	9	15	16	6	3	1	2	0	0	0	111
40	64	13	11	15	3	3	1	0	0	0	0	110
50	61	18	3	13	6	5	2	2	0	0	0	110
60	64	17	7	11	4	2	3	1	0	0	1	110
80	64	15	9	10	5	4	1	2	0	0	0	110
120	62	18	4	13	3	4	0	2	0	1	0	107

Table 10: Participant's perceived anxiety stepping down kerb heights

	Frequency of given Anxiety score according to kerb height											
Kerb height	0	1	2	3	4	5	6	7	8	9	10	n
0	260	53	43	39	12	12	1	2	1	0	6	429
20	61	19	9	6	6	5	0	1	1	1	0	109
30	66	13	8	13	4	4	0	3	0	0	1	112
40	66	12	12	9	6	3	0	0	1	0	1	110
50	68	16	7	13	3	2	1	0	1	0	1	112
60	68	15	8	13	1	4	2	0	0	0	0	111
80	72	13	10	6	4	5	0	0	1	0	1	112
120	66	15	10	8	5	2	1	1	1	0	1	110

Table 11: Participant's perceived anxiety stepping up kerb heights

For all the trials where the perceived anxiety varied throughout the experiment, there was no apparent trend for higher anxiety scores with either lower or higher kerbs. From participant feedback during the experiments, there were some comments where people stated that they were more anxious over the lower kerb heights in the sense that they would be less confident that they were actual kerbs when encountered in an environment that meant they could be walking out into a space with vehicles.

5.5 Approach Direction and Edge Type Comparisons

In the following analysis the participants' responses have been compared for approach angle, whether stepping up or down the kerb, and between two different edge types. The participants were aligned to encounter the kerbs either from straight on (90°) or at an oblique angle (45°). The same kerb height was approached from below (stepping up) and from above (stepping down). The directional changes were incorporated into each test day. The kerb edge profile was different between test days.

For each participant that encountered both conditions their responses to the questions regarding detect confidence and anxiety were compared. For example, the response a participant gave when they approached a kerb at 45° was compared to when they approached that same kerb height at 90°. If the detect score was higher for 45° than 90°, then this was classed as 45° being easier to detect than 90°. Conversely if the detect score was lower for 45° than 90°, then this was classed as 90° being easier to detect than 45°. If the detect score was the same for both angles, this was reported as 'No Difference'. For each comparison paired 2-tailed t-tests were performed with a p-value less than 0.05 considered significant. It was expected that there would be no difference in detection confidence or anxiety for any of the conditions tested.

5.5.1 Angle of Approach

This analysis considers if there was a difference in response between when the participants approached the same kerb at different angles (same test day, same step height, different approach angle).

Table 12 shows the number of times participants reported a higher detection confidence score when approaching the kerb at 90° than at 45°, if they gave the same score or if they reported a lower detection confidence score when approaching from 45° than 90°.

Table 13 shows the number of times participants reported a higher anxiety score when approaching the kerb at 90° than at 45°, if they gave the same score or if they reported a lower anxiety score when approaching from 45° than 90°.

There was no statistical difference in detection ($p = 0.39$, paired 2-tailed t-test) or anxiety ($p = 0.66$, paired 2-tailed t-test) scores given when the participants approached the kerb straight on, compared to approaching it from an oblique angle.

	detect score
Frequency of 45° easier to detect than 90°	99
Frequency of No difference	389
Frequency of 90° easier to detect than 45°	115
Total number of responses	603

Table 12: Detection responses according to Angle of Approach

	anxiety score
Frequency of being less anxious at 45° than 90°	86
Frequency of No difference	445
Frequency of being less anxious at 90° than 45°	72
Total number of responses	603

Table 13: Anxiety responses according to Angle of Approach

5.5.2 Stepping Up or Down the Kerb

This analysis considers if there was a difference in response between when the participants stepped up the kerb or stepped down from it (same test day, same step height).

Table 14 shows the number of times participants reported a higher detection confidence score when stepping up compared with stepping down, if they gave the same score or if they reported a lower detection confidence score when stepping up compared with stepping down the kerb.

Table 15 shows the number of times participants reported a higher anxiety score when stepping up compared with stepping down, if they gave the same score or if they reported a lower anxiety score when stepping up compared with stepping down the kerb.

There was a statistical difference in both detection and perceived anxiety scores ($p < 0.01$, paired 2-tailed t-test) comparing when the participants stepped up or down the kerb. There is a large number showing no difference in detection (353 trials) or perceived anxiety (402 trials). More people reported a higher detection confidence score when they stepped up (160 trials) than when they stepped down the kerb (61 trials). In addition, more participants reported a lower perceived anxiety score when stepping up the kerb (122 trials) than when stepping down. There were 50 trials where participants reported a lower perceived anxiety score when stepping down than stepping up the kerb.

	detect score
Frequency of stepping up easier to detect than down	160
Frequency of No difference	353
Frequency of stepping down easier to detect than up	61
Total number of responses	574

Table 14: Detection responses to stepping Up or Down the kerb

	anxiety score
Frequency of less anxious stepping up than down	122
Frequency of No difference	402
Frequency of less anxious stepping down than up	50
Total number of responses	574

Table 15: Anxiety responses to stepping Up or Down the kerb

5.5.3 Edge type

This analysis considers if there is a difference in response between when the participants approached the same kerb height, but with the different edge (tested on different days).

Table 16 shows the number of times participants reported a higher detection confidence score when they encountered a chamfered edge kerb compared with a bullnose kerb, if they gave the same score or if they reported a lower detection confidence score they encountered a chamfered edge kerb compared with a bullnose kerb.

Table 17 shows the number of times participants reported a higher anxiety score when they encountered a chamfered edge kerb compared with a bullnose kerb, if they gave the same score or if they reported a lower anxiety score when they encountered a chamfered edge kerb compared with a bullnose kerb.

There was a statistically significant difference ($p = 0.02$, paired 2-tailed t-test) between the detection scores on test day 1 (chamfered edge) and test day 2 (bullnose edge). However, there are only slightly more occasions (128 rather than 112) when the bullnose edge was scored higher on the detect scale than the chamfered edge.

	detect score
Frequency of chamfered easier to detect than bullnose	112
Frequency of No difference	350
Frequency of bullnose easier to detect than chamfered	128
Total number of responses	590

Table 16: Detection responses according to edge profile

Similarly, there was a statistically significant difference (p <<0.01, paired 2-tailed t-test) between the perceived anxiety scores on test day 1 (chamfered edge) and test day 2 (bullnose edge).

	anxiety score
Frequency of being less anxious at chamfered than bullnose	169
Frequency of No difference	380
Frequency of being less anxious at bullnose than chamfered	41
Total number of responses	590

Table 17: Anxiety responses according to edge profile

There were more occasions (169 compared to 41) where the chamfered edge was scored lower than the bullnose edge (for the same kerb height and direction) in terms of perceived anxiety. There is a large number showing no difference in detection or perceived anxiety.

6. Discussion

The principal outcome required from this experiment was to determine if blind and partially sighted participants could detect certain kerb heights. From the experimenters' and participants' scores of detection, no one failed to detect a kerb height of 60mm or greater and there was a high level of confidence that what had been encountered was a kerb. This detection confidence is reflected in the reduced perceived anxiety response in the higher kerb heights where there was a relationship between height and anxiety score. There was no systematic increase in perceived anxiety for kerb heights of 60mm and greater.

The highest kerb that a participant stepped up without detecting it was 40mm. On this basis it could be argued that any kerb 40mm or less is unsuitable as a detectable delineator between a pedestrian-only space and a space with vehicles. Additionally, one person (a guide dog owner) in these experiments walked down the 50mm kerb and always failed to detect it. Perhaps this height should not be used as a kerb. However, there are installations in the UK and elsewhere of 50mm kerbs, and in the case of 50mm, there has been positive feedback to Guide Dogs from some blind and partially sighted people. This indicates that further epidemiological studies are required to determine whether or not 50mm kerbs would be a problem in the wider population of people who are blind or partially sighted.

There was no statistically significant difference in the rate of detection whether the participant approached the kerb from straight on or from an oblique angle. This aspect was included in the experiments to reduce the possibility of participants becoming so familiar with the trials that they could predict what they were going to encounter. Although not a key outcome from this experiment, this result indicates that if a kerb is going to be detected straight on, it is as likely to be detected when approached from an oblique angle.

More participants reported the kerbs being easier to detect when they were stepping up rather than down them. Similarly, and perhaps consequently, more participants reported feeling less anxious when approaching the kerbs from below. It would be expected that they would feel more apprehensive leaving what they perceived as a safe space (i.e. the traditional footway) and entering a space where they may expect to encounter vehicles.

There was a statistical difference between the detection confidence scores that participants gave when they encountered the chamfered (test day 1) and the bullnose (test day 2) edge profiles. However, there were similar numbers who gave higher detection confidence scores for the chamfered edge (112 of 590) as for those who gave higher detection confidence scores for the bullnose edge (128 of 590). Considering the methods participants used to detect the kerbs and the small physical difference between the profiles, it would not be expected that one profile would be easier to detect than the other. In addition, after the second test day, many participants reported being surprised to hear that there was a different edge profile in the tests.

It is most likely that the statistically higher detect score was due to the participants being more familiar with the laboratory environment and the task they had been set, rather than a genuine difference in how they encountered each kerb type. Perhaps this understanding of the task also increased their confidence with regards what they would describe as a kerb.

It is unclear why more participants would report their perceived level of anxiety to be higher on their second visit to the laboratory. This was in contrast to a number of people who explained after they had performed the second test that they had found it easier. They ascribed this to the fact that they knew what they were coming to, they knew what they were going to be asked to do, they knew that the test did not consist of anything that would harm them (prior to the first test, they were not sure that there would not be obstacles such as lampposts in the layout).

6.1 Experiment Limitations

These experiments were designed to determine whether different kerb heights could be detected. They were not tested to see if they could be followed for any distance. All the participants knew they were in a safe, relatively quiet space with no vehicles. After the first few trials they were also aware that there were no obstacles in the space such as lamp posts (which could also be used as indicators of position). The participants knew, even allowing for distraction through conversations during the trials, that the task was to walk a short distance which may or may not include a kerb. The distance was functionally short (3.6m maximum at 90°, approximately 5m maximum at 45°), and as such it was a realistic distance from the building line to the kerb, but in reality, walking down a street someone may walk for tens of metres before encountering a kerb. Issues relating to other groups, such as people with learning disabilities, would need to be considered in other future research.

7. Conclusions

Kerb heights of 60mm and above were detectable when stepping up and stepping down and induced the greatest confidence in what they were and what they signified.

Kerb heights less than 40mm appear to be less consistent in detection rates and thus consideration should be given to avoiding them if possible.

Epidemiological tests would be required to determine if 50mm kerbs would be a problem in the wider population of people who are blind or partially sighted.

It is unlikely that the kerb edge profile makes a significant difference as long as the kerb face is approximately vertical.

8. References

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