1. Introduction

Since the 1920s, researchers studying sighted populations have demonstrated a correspondence between words and shapes. In experiments by Köhler (1929, 1947) English-speaking adults consistently matched the nonsense words “Maluma” and “Takete” with outline images of a rounded shape and a jagged, star-like shape respectively. Since then the same effect has been demonstrated across a range of populations, including English- and Swahili-speaking school children presented with the nonsense words “Uloomo” and “Takete” (Davis 1961) and Hebrew-speaking adults, shown pairs of Chinese ideograms with opposite meanings, who successfully matched them with their Hebrew equivalents based on the appearance of the ideographs alone (Koriat & Levy, 1979).

Ramachandran and Hubbard (2001) ascribe the 95% correspondence rate that has been observed between image-shape and word-choice for “Bouba” and “Kiki” to a form of synesthesia. They suggested that the “Bouba-Kiki” effect might result from contiguous areas of the brain processing the visual outline of the shape (rounded/star-shape) and the rounded or angular appearance of the speaker’s lips when enunciating the vowels. They also proposed a link between the sound contours of a word and a shape’s visual appearance. They went on to develop an explanation for auditory-visual correspondence in terms of perinatal pathways that are pruned as part of normal development, but not so heavily as to remove cross-sensory mapping completely. While in the true synesthete the pathways may not be pruned at all, in the general population pruning is such that associations are retained but at a subconscious level (Hubbard & Ramachandran, 2005)

Since then, researchers have been concerned with the relative contributions of the auditory and visual components to the “Bouba-Kiki” effect. In addition to the appearance of the rounded/spiky shapes another visual influence is the orthographic form of the words. The rounded outline of the letters B and O in “Bouba”, for example, might encourage an association with the rounded shape, while the spiky forms of the letters K and I in “Kiki” would do the same for the jagged shape. To this end, Maurer, Pathman and Mondlock (2006) asked pre-lexical toddlers to associate four pairs of rounded/spiky shapes (3 pairs of 2D drawings/cut-out shapes and one pair of 3D objects modelled in clay) with four pairs of contrasted nonsense words differing in their vowel sound. Although overall the toddlers’ bias was not as strong as that of a control group of adults, perhaps simply due to noise in the data, the youngsters still associated the rounded forms more consistently with rounded vowel sounds, and angular forms with non-rounded vowel sounds than would have been expected by chance.

Nielsen and Rendall (2011) questioned whether vowels alone were responsible for the “Bouba-Kiki” effect. They argued that most studies contain a fundamental flaw, using word-pairs where the vowels in one word resembled one of the shapes more closely than the other. To avoid this orthographic confound, they devised a number of studies swapping the vowel/consonant relationships of previously-used word-pairs (e.g. Takete/Maluma became Takouta/Malimi) and devising new ones using consonants with an incongruent orthographic form (e.g. M has a spiky appearance but a sonorant sound). When the words were presented graphically, 80% of participants made the expected associations based on the consonants, while their performance for associations based on vowels was 51% i.e. around chance level. Nielsen and Rendall also found that mode of presentation (visual/aural) affected the relative influence vowels/consonants. When the words were presented aurally, the strength of the association for both vowels and consonants was reduced. For consonants, only 58% of participants made the “expected” associations. For vowels, the “Bouba-Kiki” effect disappeared completely, with only 42% of participants mapping the words to the expected shapes.

Ozturk, Krehm & Vouloumanos (2012) also presented words aurally to adults and found a convincing “Bouba-Kiki” effect. In their study this was strongest (M = 95%) when both vowels *and* consonants matched the shape (e.g. Kiki for the spiky shape), compared with only consonants (e.g. Kuku, M = 88%) or only vowels (e.g. Bibi, M = 63%). For words containing incongruent vowels and consonants (e.g. Kuku/Bibi) 80% of mapping preferences followed the expected direction for the consonants. The researchers demonstrated a similar response in 4-month-old infants who looked longer at incongruent pairings of shapes and words, compared with congruent ones. However, the effect was only significant when both vowels and consonants matched the shape. They concluded sound-shape mapping biases are present from infancy although, in adults, exposure to language fosters lexical processing that differentiates consonants and vowels.

Taken together, these studies would seem to suggest that the sound of a word is more important than its orthographic appearance in creating the "Bouba-Kiki" effect. Support for this comes from Bremner, Caparos, Davidoff and colleagues (2012) who demonstrated sound-shape symbolism amongst the Himba people of Northern Namibia who have no written language. Nielsen and Rendall argue that the "Bouba-Kiki effect" reflects a difference in the auditory quality of consonants. Animal observation studies (e.g. Rendall, Owren & Ryan, 2009) have shown that primates and other species emit shrill and staccato (strident) sounds at moments of high arousal and aggression, and smoother, legato sounds (sonorant) in positive social situations such as grooming or foraging. The assumption here is that strident sounds are associated with spiky shapes and sonorant ones with smooth shapes, reflecting the auditory pattern of spectral density and attack.

The "Bouba-Kiki" effect is not limited to bimodal links between sound and vision. In a recent small study, Fontana (2013) showed that 9 out of 11 sighted people whose hand was guided along a trajectory by means of a robotic arm, labelled a jagged trajectory as "Takete" and a smooth trajectory as "Maluma". Word associations have also been demonstrated in the modality of taste (Deroy et al., 2011; Crisinel et al., 2012). Gallace, Boschin and Spence (2012), for example, showed that crisps are deemed more 'Takete' than a soft cheese, while chocolate is rated more 'Kiki' if it is mint-flavoured. The researchers claimed that these word-food associations stemmed from differences in flavour rather than in shape or texture, and proposed that the "Bouba-Kiki" effect is independent of vision. Testing visual-flavour matches with the Himba, however, Bremner et al. (2012) had surprising results. Namely that the Himba did not map spiky shapes to carbonated water and rounded shapes to still water; nor did they map bitter chocolate to a spiky shape but preferred to match it with a rounded shape in the opposite direction to people from a Western cultural environment (Ngo et al., 2011). While the chocolate-shape choices could be explained by the sounds of the Himba words used to denote bitter and sweet, Bremner and his colleagues put the water-shape mapping down to visual conditioning. In the West, for example, brands of carbonated drinks often feature angular motifs (e.g. Spence, 2012; Spence & Gallace, 2011). If the lack of such visual associations in the Himba's environment explains their unexpected mapping choices, it is possible, then, that visual associations influenced the auditory-haptic/kinaesthetic or auditory-tactile connections cited in the studies by Gallace et al. and Fontana, even in the absence of perceptual visual stimuli. A mint leaf, for example, has a jagged outline as well as a sharp taste. The mint flavour may have brought an image of the leaf to mind, and it was this visual imagery that informed crossmodal mapping with the word 'Kiki', rather than a direct word-taste association. Similarly, participants in Fontana's study may have been visualising the jagged or smooth trajectory in their mind's eye when deciding which label to assign.

Visual conditioning may not only be determined geographically. Within Western culture, congenitally blind (CB), early blind (EB) and even late blind (LB) and partially sighted (PS) individuals are likely to be unfamiliar or at least less familiar with the appearance of letters, mint leaves or advertising graphics than people who are sighted. The current study explored the impact of visual experience on crossmodal associations by presenting haptic equivalents (2D and 3D models) of Köhler's outline drawings to people with varying types of visual impairment and to people with full sight. Participants were allowed to feel but not look at the object pairs and asked to decide which was "Kiki" or "Bouba".

Given Hubbard & Ramachandran's explanation that the "Bouba-Kiki" effect lies in cross-sensory mapping and cortical connections that develop (or are pruned) in early infancy the question then arises: what happens to such connections in the absence of sight? Röder, Focker et al. (2008) claim that crossmodal integration is only possible in the presence of the external reference frame that vision provides. Shu et al. (2009) used diffusion tensor tractography to show a decreased degree of connectivity in the cortical networks of CB, especially in the visual cortex. If blind people are less good at multisensory integration (e.g. Hötting et al., 2004), then they may be less likely to exhibit the "Bouba-Kiki effect" even in non-visual modalities. However, the same study also reported that brain areas in CB relating to motor and somatosensory function showed greater connectivity. Behavioural evidence for this comes from Collignon, Voss et al. (2009). Using the crossed-hands paradigm, they asked participants to respond to a bimodal (auditory or tactile) stimulus presented on the left or right side, by pressing a button with their left or right hand. The crossed-hands position caused difficulties for sighted and LB in response to both modalities, but only in response to the sound stimulus for CB. The researchers argued that CB rely on sound to create an external reference frame in the way that sighted (and LB) rely on vision (or visual memory). If this is the case, visual experience should have no impact on the strength of, for example, an auditory-haptic "Bouba-Kiki effect". Potentially some B&PS people might even show a stronger effect. CB and EB individuals have been shown to have a compensatory advantage in certain aspects of auditory perception, including pitch discrimination (Gougoux et al, 2004) and more efficient processing of simple auditory stimuli (Stevens & Weaver, 2009).

Further mixed evidence for the role of vision in multisensory integration comes from research with people born with binocular cataracts, who have them removed in childhood. After an initial period of visual deprivation in infancy, sight is able to develop. Putzar et al. (2007) reasoned that if such newly acquired sight developed normally, these individuals would show the benefits of bimodal (audio-visual) stimuli. This proved not to be the case for a speech perception task. Sighted participants gained from adding the visual stimulus to the auditory one; previously-blind participants did not, despite having had sight for at least 14 years at the time of the experiment. However, in a more recent study (Putzar et al., 2012) reaction times to auditory–tactile, auditory–visual, and tactile–visual stimuli were similar between sight groups. The researchers argue that some multisensory responses (and not others) can be developed by experience.

Cattaneo and Vecchi (2011) argue that differences arising from varying types of visual impairment can further inform the debate. For example, Heller, Wilson et al., (2003) showed that late blind people (LB) were better than early blind (EB) or blindfolded sighted participants at identifying a target figure from a line drawing. They put this down to a combination of visual experience combining with haptic practice. However, there is little consensus as to what constitutes "Late" as opposed to "Early" blindness. Cattaneo and Vecchi reviewed 44 studies in which the cut-off ranged from 2 – 7 years. This difference is significant: a 7 year old is more likely than a 2 year old to have retained some degree of visual memory. The brain has also been shown to be highly plastic, especially in the young (e.g. Théoret, Merabet & Pascual-Leone, 2004; Huttenlocher, 2009) allowing different cortical connections to develop (Shu et al., 2009). Again, the age of cut-off is debated but there is some agreement that the phase of greatest brain plasticity ends by the age of 14-16 years (Wan et al., 2010).

For this study, blind and partially sighted (B&PS) participants were distinguished as CB (little or no light perception from birth); EB (with early visual experience but little or no light perception beyond the age of 3); LB (little or no light perception from the age of 4 years or above); or Partially Sighted (PS) (experiencing mild to moderate sight loss from birth onwards). Their responses were compared with fully sighted (FS) participants. The aim of the study was two-fold. Firstly, to establish whether the "Bouba-Kiki" effect could be demonstrated in the auditory-haptic modalities. Secondly, to ascertain whether the effect, if present, is independent of vision.

2. Method

2.1 Participants

An opportunity sample (N = 122); was drawn from staff and visitors to the offices of the Royal National Institute for Blind People (RNIB) in London and from personal contacts.

All those who took part did so on a voluntary basis. All had English as their first language. All participants with a visual impairment were registered either blind or partially sighted. Acuity of sight was judged by responses to a measure developed by Douglas, Corcoran and Pavey (2006) for the Network 1000 project. It uses a 7-point scale based on the participants' self-reported level of functional vision, judged by response to the following: Which of these best describes your sight with glasses or contact lenses if you normally use them? 1: I have no light perception; 2: I can tell by the light where the windows are; 3: I can see the shapes of furniture in the room; I can recognise a friend by sight alone if….4: I'm close to their face; 5: I'm at arms' length away; 6: I'm on the other side of the room; 7: I'm on the other side of the street. Participants were categorized as follows:

FS: N = 80 (41 male), mean age 42.88 years, range 20 – 82 years

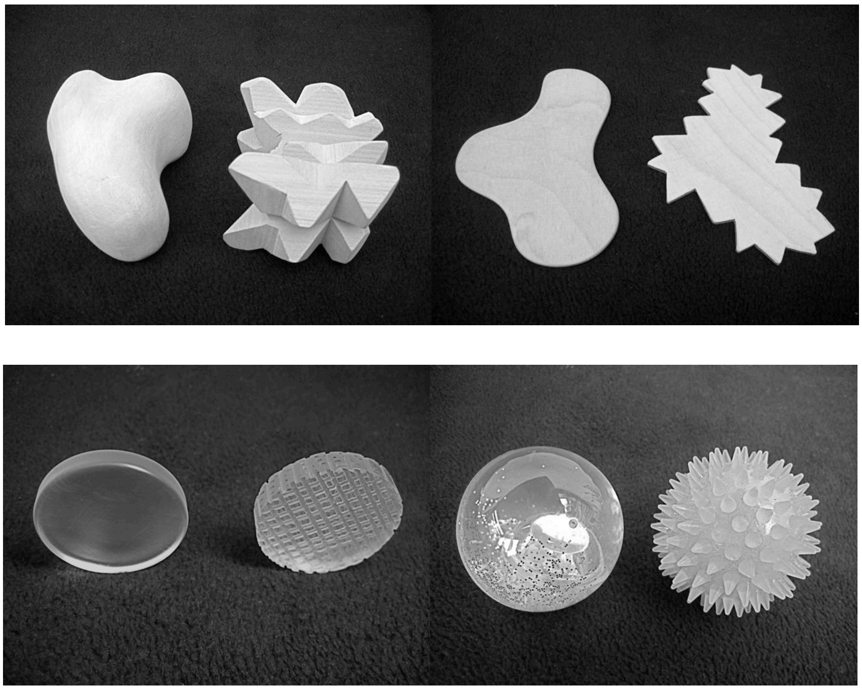
B&PS: N = 42 (24 male), mean age 48.9 years, range 24 – 80 years (CB = 6; EB = 0; LB = 17; PS = 19). One PS participant had congenital cataracts and therefore had no early visual experience. For more details see Table 1.

2.2 Stimuli

The stimuli comprised 4 pairs of shapes (Fig.1). Pairs A – C were specifically made for the experiment. The objects for Pair D were bought commercially. Pairs A and B were made from wood and designed to mimic Köhler's line drawings as closely as possible; Pair A in 3D, Pair B in outline. Pairs C and D were made of synthetic materials. The discs of Pair C were identical in shape, but differed in texture. The spheres of Pair D were consistently spiky/smooth all over. Each pair of objects was presented in a black cotton bag, measuring 250mm x 250mm, fastened by a drawstring. The bags were sufficiently loose and the fabric sufficiently thick that no outline of the shapes was visible.

Sight status	Gender	Age	Age registered	Visual Acuity*	Aetiology	Total Score
CB	F	30	birth	1	Retinopathy of prematurity (ROP)	4
CB	M	27	birth	1	(ROP)	0
CB	M	59	birth	1	(ROP)	4
CB	M	24	birth	1	Anophthalmia	0
CB	M	65	birth	1	Retrolental fibroplasia	0
CB	M	60	birth	1	Rubella	4
PS	F	49	birth	5	Congenital cataracts	0
LB	M	45	4	1	Glaucoma with retinal detachment	4
LB	F	38	5	1	(ROP)	4
LB	M	33	5	1	Persistent hyperplastic primary vitrious	4
LB	F	30	7	1	accident	4
LB	M	58	10	1	Not stated	4
LB	M	38	13	1	Retinopathy of prematurity	0
LB	F	77	16	1	Retinitis pigmentosa	1 (C)
LB	F	42	28	1	Retinitis pigmentosa	3 (not D)
LB	M	64	50	1	Retinitis pigmentosa	4
LB	M	58	54	1	Retinitis pigmentosa	4
LB	M	30	5	2	Retinitis pigmentosa	1 (A)
LB	M	48	11	2	Autosomal recessive retinal dystrophy	0
LB	F	43	11	2	Optic atrophy	4
LB	M	30	12	2	Optic atrophy	4
LB	F	49	21	2	Glaucoma	4
LB	M	59	31	2	Optic nerve damage	3 (not A)
LB	M	44	30	2	Retinitis pigmentosa	4
LB	F	78	76	2	Retinal detachments	0
PS	F	30	birth	3	Underdeveloped macular, congenital nystagmus	4
PS	M	45	17	3	Macular degeneration	0
PS	M	41	20	3	Congenital glaucoma	0
PS	M	56	43	3	Retinitis pigmentosa	4
PS	F	47	40	4	Not stated	4
PS	M	80	78	4	Age-related macular degeneration	4
PS	F	48	5	5	Optic atrophy	0
PS	M	52	15	5	Optic atrophy, cataracts	4
PS	M	40	30	5	Retinitis pigmentosa	2 (AC)
PS	F	52	36	5	Detached retina, glaucoma	2 (CD)
PS	F	52	39	5	Retinopathy and glaucoma	0
PS	M	59	47	5	Leber's amutative neuropathy	4
PS	M	61	50	5	Retinitis pigmentosa	4
PS	F	64	52	5	Trachoma	4
PS	F	63	53	5	Retinitis pigmentosa	4
PS	F	44	21	6	Nystagmus, astigmatism	3 (not C)
PS	F	42	7	6	Double hydrocephela	1 (B)

Table 1. B&PS participants' demographic information and total score.
*Visual acuity coding after Douglas et al. (2006).



A B

C D

Fig. 1. Bouba and Kiki: Shape Stimuli.

Pair A: 3D models made from wood (jelutong) each measuring approx 100 x 70 x 60 mms. One is irregular and spiky in all dimensions; the other bulbous and smooth. Pair B: 2D plywood cut-outs, 4mm thick, 115mm x 70mm at their widest points. One has a spiky outline, the other smooth. Pair C: cast acrylic discs, 40mm in diameter x 7mm thick. Both have the same outline, but a different texture. The surface of one is smooth, with chamfered edges and the other has been cross-hatched all over so it feels rough. Pair D: commercially available plastic balls – each about the size of a tennis ball (approx 650mm in diameter). One is smooth, the other covered in rubbery plastic spikes.

2.3 Procedure

For all participants, blind or sighted, the procedure was the same. A demographic questionnaire was first read aloud by the researcher and the responses transcribed. The researcher then proceeded according to the script shown in Appendix 1. The bags were handed over one at a time. The participant was asked not to look inside the bag, but to feel the two objects inside, and to bring out either Kiki or Bouba. The sequence of bags was counterbalanced across the sample. Half the participants were asked to bring out Kiki from the first and third bags, and Bouba from the second and fourth bags. For the remaining participants, this order was reversed. After selecting from all four bags, participants were asked to give a reason for their choices.

2.4 Scoring

The presentation of each bag counted as a separate trial, making 4 trials in total. Participants scored 1 per trial if the object they took from the bag matched the expected word (e.g. the rounded object was identified as Bouba). If they took the incongruent object from the bag (e.g. rounded object identified as Kiki) participants scored 0. Thus the total score, summed across the 4 trials, ranged from 0 - 4. A total score of 2 would indicate performance at the level of chance.

3. Results

The shapes chosen as "Bouba" on each trial are shown in Fig. 2. Superimposed are the numbers of participants (FS or B&PS) who mapped the word "Bouba" to the rounded or to the spiky shape.

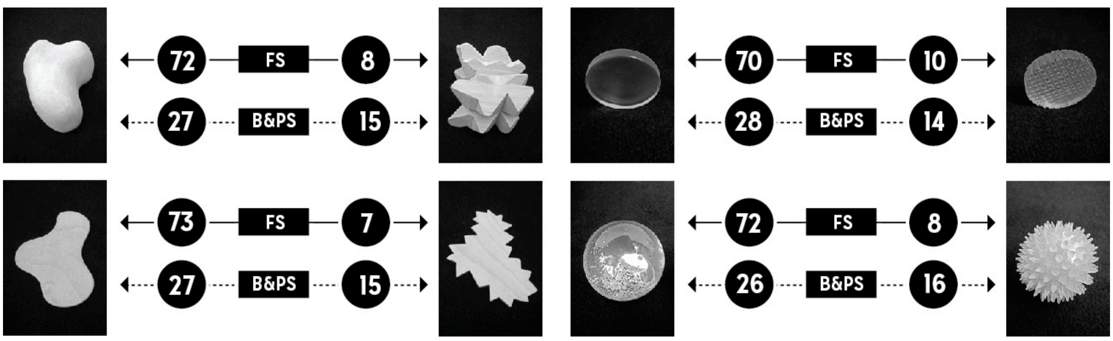


Fig. 2. 'I would like you to bring out "Bouba" for me.' *Number of participants choosing a shape as "Bouba" for the 4 object pairs. Full Sight (FS) N = 80; Blind and Partial Sight (B&PS) N = 42.*

3.1 Fully sighted participants

The FS group showed a robust "Bouba-Kiki" effect in the haptic-auditory modalities, mapping the shape to the expected word on 3.59 out of 4 trials. 84% (67/80) chose as expected for all 4 pairs, selecting rounded objects as Bouba and spiky objects as Kiki; only 5% (4/80) consistently chose in the opposite direction. The remaining 11% (9/80) were inconsistent, choosing a spiky shape sometimes as Kiki and sometimes as Bouba.
Paired samples t-tests showed no significant difference in scores between object-pairs ($p = .320$); nor between 2D (pairs B & C) versus 3D (pairs A & D) ($p = .708$); nor between wood (pairs A & B) and plastic (pairs C & D) ($p = .369$).

3.2 B&PS Participants

The B&PS group mapped the shape with the expected word on 2.57 out of 4 trials. While this was significantly higher than chance ($t\ (41) = 2.09$, $p = .043$), a one-way ANOVA showed it to be significantly lower than the score for the FS group: $F\ (1,120) = 15.68$, $p < .001$. 55% (23/42) of the B&PS participants chose in the expected direction for all 4 pairs; 26% (11/42) consistently chose the opposite, and 19% (8/42) were inconsistent. Paired samples t-tests showed no significant difference in scores between object-pairs ($p = .660$); nor between 2D (pairs B & C) and 3D (pairs A & D) ($p = .421$); nor between wood (pairs A & B) and plastic (pairs C & D) ($p = 1$).

Means for each trial are shown in Fig. 3, although these results should be interpreted with caution because of the large variation in group size. 6 of the B&PS sample were congenitally totally blind. This group performed at the level of chance: 50% (3/6) mapped words to shapes in the expected direction and 50% (3/6) in the opposite direction. Planned comparisons with Bonferroni corrections showed that the total score for the CB group was significantly different from the FS group (mean difference: -1.59, $p = .001$) but not the LB/PS group (mean difference: -.667; $p = .399$). The total score for the LB/PS group was also significantly lower than the FS group (mean difference: -.921, p = .001). Scores for the LB and PS groups showed no correlation with the percentage of life they had been visually impaired (LB r = -.277, p = .382; PS r = .080, p = .745); age at onset (LB r = .299, p = .228; PS r = .256, p = .304) nor with degree of visual acuity (LB: r = -.042, p = .872; PS r = .094, p = .702). There was no significant difference in scores between LB and PS participants (mean difference: .444, p = 443). However, of the LB participants, 65% (11/17) chose in the expected direction and 12% (2/17) the opposite. Of the PS group, only 47% (9/19) chose in the expected direction, and 32% (6/19) the opposite.

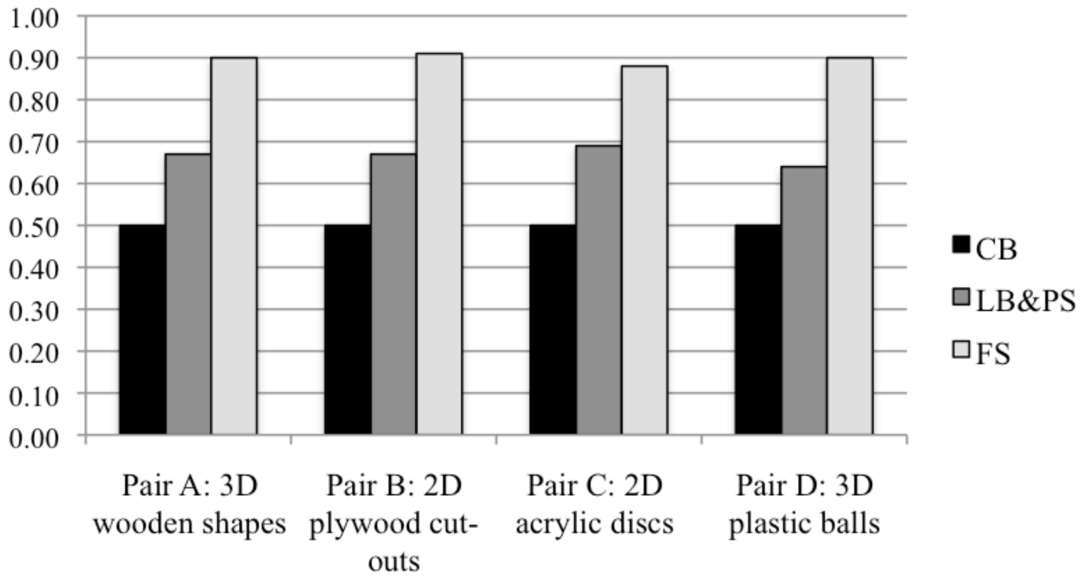


Fig. 3 Group means per trial (max = 1)

Given that the phase of greatest brain plasticity ends by the age of 14-16 years (Wan et al., 2010), one further comparison was made between blind participants who had lost their sight by the age of 16, and those who had lost it after that age. The PS participant with congenital cataracts was included in the former group. The mean score for those who lost their sight before the age of 16 was 2.78, compared with 3.67 for those who lost their sight later in life. Given the small number of participants (N = 24) and difference in group size (pre-16 = 18; post-16 = 6) scores were compared using Fisher's exact test. This was not significant (p = 1).

3.3 Strategies

81/122 participants gave a reason for their choice (Table 2). Group means for each choice strategy are shown in Table 3. Of the 58 FS participants who did so, 60% (35/58) cited the sound of the word (e.g. "Kiki sounds jaggedy; Bouba sounds smooth"; "Kiki sounds like 'kinky' – all nooks and crooks"). 3 participants specifically mentioned the vowels ("in Bouba the vowel sounds are round") and another 3 picked out the consonants ("Kiki – the consonants sound sharper"). 17% (10/58) cited orthographical appearance ("I was picturing a K in my head", "a K has prongs"; "B is rounded"); 8% (5/58) reported associating Kiki or Bouba with a name and their object choice was determined by perceived gender differences (e.g. "Kiki is a female name so I chose the rounded shape as Kiki") or attributes (e.g. "Kiki sounded like a sassy girl so I chose the object that was more prickly"; "Kiki is the awful singer who used to screech and sounds hard and angular") or other associations ("Bouba's like Pumba[1] so I chose the chunky one"). 14% (8/58) gave other reasons for their choice, (e.g. "It was the first object I picked up"; "It was a guess!"). A between-groups, one-way ANOVA showed that strategy had a significant bearing on score: F (3, 54) = 5.79, p = .002. Group means are shown in Table 3. Those who cited the sound of the word scored the maximum total: m = 4. Using Bonferroni corrections for multiple comparisons, this was shown to be significantly higher than those citing a name (mean difference = 1.60, p = .012) and those giving "other" reasons (mean difference = 1.13, p = .045). Scores for those who made an association based on visualising letter shapes were not significantly different than scores for any other strategy.

	Sound	**Letter Shape**	**Name**	**Other**	**Total**
CB	3	0	0	2	5
LB	8	0	1	4	13
PS	3	0	0	2	23
FS	35	10	5	8	58

Table 2. Choice strategy by sight group (number of participants)

[1] Pumba is the warthog character in the film The Lion King (Disney, 1994)

	Sound	Letter Shape	Name	Other
CB	2.66 (2.31)			1.60 (2.19)
LB	3.38 (1.41)		4.00 (n/a)	2.25 (1.50)
PS	1.33 (2.31)			0.50 (0.71)
FS	4.00 (0)	3.20 (1.69)	2.40 (2.19)	2.88 (1.35)

Table 3. Mean score (SD) for each choice strategy

Of the B&PS participants who gave a reason, 61% (14/23) cited sound ("the name sounded like the feel"), although unlike the FS group, these B&PS participants did not necessarily follow expected mapping patterns (e.g. "Kiki sounds softer"; "Kiki sounds rougher, curlier; Bouba sounds smoother"; "Bouba sounds bulkier, Kiki more streamlined"; "Kiki sounds more like an animal, more organic; Bouba sounds more artificial and textured"). 4% (1/23) cited a name ("Kiki sounds like an African name which I associated with crinkly hair") and 35% (8/23) gave other reasons. Some of these were similar to those given by sighted people ("It was a pure guess"; "Kiki was the first object I was asked to bring out and I liked the spiky one more"), others made a haptic association, comparing the feel of the object with one that felt similar, either in texture or outline. A blind man who felt the 2D plywood objects first, reported that the one with the rounded outline should be "Bouba" because the shape "resembled a boomerang". Another associated the feel of the textured disc with the rough skin of a kiwi fruit and made a link between "kiwi" and "Kiki". None of the B&PS group cited the look of the letters, even if their sight problems had developed late in life. However, there was no significant interaction between strategy and sight status in terms of total score: $p = .348$.

4 Discussion

The "Bouba-Kiki" effect has been demonstrated in the visual-auditory modalities for over 80 years. It has been shown to override linguistic and cultural boundaries, and does not appear to be dependent on familiarity with particular letter shapes. Recent studies have shown the effect in 4 month old infants (Ozturk, Krehm & Vouloumanos, 2013), pre-lexical toddlers (Maurer, Pathman & Mondlock, 2006) and populations that have no written language (Bremner et al., 2012). The "Bouba-Kiki" effect has even been extended to include associations between words and taste. Our study shows that the "Bouba-Kiki" effect also embraces the haptic-auditory modalities. Aurally presented words and objects that could be touched but not seen created a robust "Bouba-Kiki" effect in sighted people. Participants were presented with 4 bags, each containing a pair of objects modelled on Kohler's original drawings (one smooth, one spiky). They were asked to feel inside the bag and bring out either Bouba or Kiki. 84% of participants consistently selected the smooth object as Bouba or the spiky object as Kiki. Only 5% consistently chose in the opposite direction. The effect was reliable across all 4 object-pairs, even though they differed in material (wood or plastic), and whether the jagged/smooth contours were global, textural or restricted to the outline.

Sighted participants reported using a range of strategies to make their choice. The most common was to match the sound of the word to the haptically-explored shape of the object resulting in a "Bouba-Kiki effect" of 100%. This was significantly more successful than making a name association or using another strategy, such as simply guessing. However, visualising the letter-shapes was equally likely to produce the "Bouba-Kiki effect".

Gallace, Boschin and Spence (2012), demonstrating the effect in sound-taste matches, have argued that it can be independent of vision. However, other researchers (e.g. Röder, Focker et al., 2008) argue that vision is essential to crossmodal integration. Having demonstrated the "Bouba-Kiki effect" in the auditory-haptic modalities in the fully sighted participants, we compared their responses of with those of people with a range of visual experience, from congenitally blind participants to individuals with more minor visual impairments acquired later in life. We reasoned that if vision played no role in crossmodal correspondence between touch and sound, there should be no difference between those with full sight and those with impaired vision. Potentially B&PS people might even show a stronger “Bouba-Kiki” effect, possibly having heightened auditory and tactile sensitivity and being necessarily more experienced in haptic exploration of objects.

The results were surprising. People with a visual impairment who had residual vision (PS) or had had some visual experience (LB) also associated sharp/jagged shapes with Kiki and rounded/smooth shapes with Bouba at a level higher than chance, although the effect was significantly less strong than in their fully sighted peers. Only 55% of the LB & PS participants chose in the expected direction for all 4 pairs. 26% consistently chose the opposite. The small number of people in this study who had no visual experience (congenitally totally blind) did not show the “Bouba-Kiki” effect, choosing at the level of chance (50%). Like the FS group, B&PS individuals reported a range of strategies. None cited the look of the letters, even though 79% developed sight problems at school age (5 years) or older, suggesting most were at least familiar with orthographical appearance. 61% (14/23) cited sound but, unlike their sighted peers, did not necessarily deem Kiki to sound harsh or angular, nor Bouba soft and smooth.

Interestingly, Oberman & Ramachandran (2008) found that children on the autistic spectrum performed poorly on the standard visual/auditory version of the Bouba/Kiki test, mapping the word to the expected shape only 56% of the time. Autistic-like traits have been identified in some (but not all) children with congenital blindness. These include echolalia, pronoun reversals and formulaic speech (Hobson & Bishop, 2003; Pring, 2004). It is possible, then, that our results reflect a high incidence of autism amongst the B&PS participants. Given that so few of our sample were congenitally blind, this seems unlikely. Perez-Pereira and Conti-Ramsden (2004) point out that autism is a genetically-based, neurodevelopmental disorder and therefore quite different from blindness, which is a peripheral sensory impairment. Pring (2002) suggests that although blind children may have delayed speech development, the majority catch up. Of the 6 congenitally blind adults in the current study, 5 had a college degree. Furthermore, there was no significant difference in results between CB, LB or PS participants, nor were scores affected by the percentage of life with a visual impairment, age at onset of that impairment, nor its severity.

Arguably the difference in responses between those with full and those with impaired sight supports Hötting et al.'s (2004) assertion that blind people exhibit a unimodal rather than a multimodal processing style. Again, the heterogeneous nature of the sample in this study makes this doubtful. In particular PS participants were no more likely than CB individuals to demonstrate the "Bouba-Kiki" effect, nor were there significant differences between those with and those without early visual experience. Collignon, Voss et al. (2009) point out that inconsistent evidence for multisensory integration in blind individuals may be the result of tasks being more relevant for one group of participants than the other. As touch is the primary way in which blind people identify objects in the world around them (Struiksma et al., 2011) it may be, then, that in this task B&PS participants were more likely to make a concrete (object-to-object) rather than an abstract (sound-shape-to-object-shape) association.

This does not explain the fact that 100% of FS who adopted a "sounds like" strategy chose in the expected direction, while this dropped to 64% for B&PS participants. The alternative explanation is that what Bremner et al. (2012) refer to as visual conditioning affected the choices of the FS participants, even in the absence of direct visual input. 17% of FS participants spontaneously reported the use of visual imagery in the form of visualising the letters. Yet the auditory connection ("Bouba's reminiscent of 'baby' and fitted the rounder shape", "Kiki sounds like 'kinky' – all nooks and crooks") may also have stimulated a mental image, so FS participants were visualising, for example, the appearance of a baby or a kinked object, and then comparing that with an image triggered by the unseen object in their grasp. Zangenehpour and Zatorre (2009) found that, for sighted people, even brief habituation to visual and auditory stimuli that were presented simultaneously led to a response in the primary visual cortex being automatically triggered when participants were subsequently exposed just to the auditory stimulus. It is likely that the visuo-haptic modalities are similarly tied. Amedi et al. (2001) showed that both visual and tactile recognition of objects activates a part of the object-responsive cortex in the lateral occipital complex (the lateral occipital tactile-visual region: LOtv) where, more recently, bimodal visuo-haptic neurons have been identified (Tal et al., 2009). Lacey et al. (2009) in a review of studies on visuo-haptic convergence argue that the LOtv is supramodal, and can be driven by geometric shape information regardless of the modality it is acquired through i.e. vision or touch. However, a study by Holtby and d'Angiulli (2012) with blindfolded sighted participants, showed that identification of haptic pictures decreased in the presence of visual interference. This suggests that haptic stimuli are encoded in the memory, at least in part, via a visual code. Such bimodal associations cannot develop in CB individuals, and we suggest that in LB/PS individuals the association with vision is sufficiently weakened for the visual element of bimodal neurons no longer to be stimulated automatically. Arguably the small minority of sighted people who failed to demonstrate the "Bouba-Kiki" effect may have been individuals with below-average ability to evoke vivid visual images i.e. verbalisers rather than visualisers (Paivio, 1977). This would be interesting to test in future research.

Overall, lack of visual conditioning may explain why the "Bouba-Kiki" effect, although present, was demonstrated significantly less strongly in the B&PS group, compared with FS participants. Crossmodal associations are influenced both by perception and experience. Fully sighted individuals can pick up on regularities in their environment that are not as easily accessed by those for whom visual information is restricted. It would appear that visual impairment limits the strength of the "Bouba-Kiki" effect even when stimuli are presented in non-visual modalities.

5. Practical implications

The difference between FS and B&PS individuals does more than raise questions about the role of visual imagery in integrating non-visual modalities. There are practical implications, too. Audio Description is a verbal commentary added to make audiovisual media accessible to B&PS people (e.g. Whitehead, 2005). Describers are encouraged to use language techniques such as onomatopoeia, for example choosing short, staccato words such as "jab" and "thwack" when describing a fast movement sequence such as a fight (Fryer, 2009). Onomatopoeia is one example of sound symbolism whereby "the sign is taken to represent the object by imagic similarity to it" (Tabakowska, 2003, p.361). Tabakowska cites the example of the plosive "p", used in dismissive expressions such as "pish!" and "pooh!" that can be associated with spitting out something that tastes bad (see Wierzbicka, 1991). However, our study suggests that such sound associations, thought of as "universal", cannot be taken for granted in those with impaired sight. This may affect word choices made by audio describers. It may also be useful for teachers to be aware that such associations need to be made explicit to aid congenitally blind children, whose language development is often delayed, in catching up with their sighted peers.

6. Conclusion

This study shows that, in sighted people, sound-shape associations previously demonstrated in the visual-auditory modalities also hold for haptic-auditory associations. Choosing from pairs of objects that could be touched but not seen, 84% of fully sighted participants showed the "Bouba-Kiki" effect. However, that percentage was significantly reduced for individuals with a visual impairment. This included people blind from birth, those with partial sight, and those who lost their sight later in life. Although this was a small, exploratory study its findings cast doubt on the assertion that the "Bouba-Kiki" effect is independent of vision, even when demonstrated in non-visual modalities. It suggests that, in the absence of a direct visual stimulus, visual imagery plays a role in crossmodal integration.

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Appendix

Kiki and Bouba Script

I have 4 bags. In each bag there are 2 objects. I will hand you the bags, one at a time. I want you not to look inside, but to feel inside. [hands over the 1st bag]

Put your hand in here. You might want to use both hands. Now, one of these objects is called Kiki, and one of these objects is called Bouba. I would like you to bring out Bouba [Kiki] for me

Thank you. Put Bouba [Kiki] back in the bag. Here's the 2nd bag. Inside you'll find Kiki and Bouba again. This time I'd like you to bring out Kiki [Bouba] for me

Thank you. Put Kiki [Bouba] back in the bag. Here's the 3rd bag. Inside you'll find Kiki and Bouba again. This time I'd like you to bring out Bouba [Kiki] for me

Thank you. Put Bouba [Kiki] back in the bag. Here's the final bag. Inside you'll find Kiki and Bouba again. This time I'd like you to bring out Kiki [Bouba] for me

Thank you. Finally I'd like you to tell me why you made those choices.