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How blind individuals discriminate braille characters: An identification and comparison of three discrimination strategies

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Abstract

This study investigated (1) how blind individuals describe discriminating braille characters, including ranking braille features in importance – their discrimination strategy: explored qualitatively, and (2) whether exploration time, accuracy, and after-decision certainty in detecting one target among distractors depend on discrimination strategy: tested quantitatively. In all, 23 blind individuals participated. Three discrimination strategies and their phases of attention when processing information were identified: the figure identity strategy with two phases of focused attention, the global characteristics strategy with one pre-attentive phase, and the touch vision strategy with one phase of semi-focused and one of narrowly focused attention. The figure identity strategy and the global characteristics strategy were equally fast, accurate, and used with equal amounts of after-decision certainty. Exploration time, accuracy, and after-decision certainty of the touch vision strategy varied according to visual experience. In teaching, the pupil's nonobligatory pattern of decisions needs to be recognised, whether occasional or signalling a discrimination strategy.

Keywords

Attention, blind, braille, discrimination strategy, haptic touch

Introduction

The question of how blind individuals discriminate braille characters has thus far been approached from two main directions. One investigates hand movement and collaboration (e.g., Millar, 1984, 1987b, 1997). Ideally, the left hand moves across one-third of the line and the right hand across the last two-thirds. With the right hand continuing across the line, the left hand returns to the left margin and moves one line down. The hands collaborate in a highly coordinated zigzagging movement. The index finger discriminates the braille characters, the middle and ring finger scanning over them.

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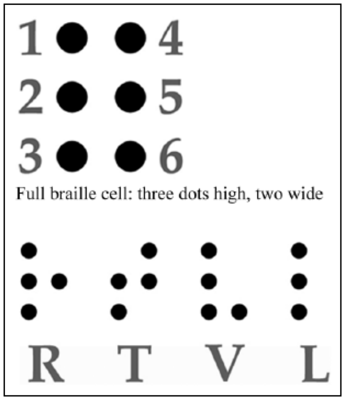

Figure 1. Braille cell and example of non-redundancy in braille.
Move Dot 1 in R and it becomes a T; Dot 5 and R become a V; remove Dot 5 from R and it becomes an L. (R = Dots 1, 2, 3, 5; T = Dots 2, 3, 4, 5; V = Dots 1, 2, 3; 6. L = Dots 1, 2, 3).

The other approach investigates what is coded: outline shapes or dot patterns (e.g., Millar, 1977, 1985, 1987a; Newman, Hall, Foster, & Gupta, 1984; Nolan & Kederis, 1969)? Nolan and Kederis (1969) found that exploration time increased according to number of dots and that children confused characters when differing in just one dot. They concluded that beginners code outline shape. Conversely, Millar (1977, 1985, 1987a) found that this was because of poor discrimination skills early in learning: discrimination was easy when dot patterns differed greatly (Millar, 1997). Newman et al. (1984) also found that the learning of names of braille characters was a function of character discriminability.

Braille characters derive from one to six dots arranged in a 2 × 3 matrix, that is, the braille cell. The dots are labelled, left downwards: 1, 2, 3 and right downwards: 4, 5, 6. Braille is a non-redundant system (Millar, 1997). For instance, move one dot in R and it becomes a T; another dot and R become a V; remove the very same dot from R and it becomes an L (see Figure 1). A missing dot is labelled 'gap', for example, the missing Dot 4 in R is Gap 4. Indeed, a braille character consists of both dots and gaps.

In line with Nolan and Kederis (1969), T and V should be easy to discriminate from one another, T resembling two dot triangles and V one dot angle, whereas R and T are difficult since both resemble two dot triangles. Outline shapes, because of the braille cell's 2 × 3 anatomy, cannot comprise curves or circles but only dot angles, straight lines, triangles, and so on. As regards the braille cell dot pattern, in line with Millar (1977, 1985, 1987a), R and T and R and V differ in dot location only and thus are difficult to discriminate. V and L differ in both dot location and quantity; thus, V is easy to discriminate from L and vice versa. Braille characters cannot differ in dot quantity only. Adding or removing one dot also involves locating it in the braille cell. It seems none of this research has investigated how braille cell gaps are coded.

Clearly, research until now has been concerned with identifying a strategy for discriminating braille characters: one for hand movement and collaboration, and one for coding. Previous research has not investigated, however, how blind individuals themselves would describe discriminating braille characters. Indeed, Treisman and Paterson (1984) suggested that sighted individuals, using vision to detect two-dimensional targets among distractors, may adopt different, even personal, strategies for ranking features in order of importance. Is this the case also for blind individuals who use haptic touch to target a specific braille character? Which features do they rank as the most important – one separate feature, for example, dot location or gap quantity, or a conjunction of features, for example, dot location and quantity or dot quantity and gap location (cf., Treisman, 1995)?

This study was designed to investigate, first, how blind individuals themselves would describe discriminating braille characters, including ranking braille features in order of importance – their discrimination strategy. A discrimination strategy is 'an organized, domain-specific, nonobligatory pattern of decisions activated when confronted with [. . .] problems, and goal directed to attain the solution of the problem' (Ostad, 1997, p. 12). Second, it investigated whether exploration time, accuracy, and after-decision certainty in detecting one braille target among distractors depend on discrimination strategy. The aim was to identify and compare discrimination strategies and to shed some light on whereabouts on the continuum from pre-attention to focused attention (Treisman, 1995) blind individuals process information. Some advice is given on how to teach braille to beginners.

Method

Design

Mixed design. Qualitative data were collected, using the think-aloud or 'aussage' method (Aanstoos, 1983), to explore how blind individuals describe discriminating braille characters, including ranking braille features in importance. Quantitative data were collected to test whether exploration time, accuracy, and after-decision certainty depend on how target is discriminated. Two pilot studies were performed.

Participants

A total of 23 paid participants (10 males and 13 females; mean age: 43.7 years) participated, 16 with congenital blindness, 4 with early-onset blindness (<4 months after birth), and 3 with recent blindness (< 3 years; Graven, 2003). All were categorised in the International classification of diseases and related health problems 10th revision (ICD-10; World Health Organization, 2013) blindness categories 3–5: Category 3 = minimal visual shape perception, Category 4 = light projection (perceives where the light source is situated) and light perception (perceives a light source), and Category 5 = total blindness. None of the participants had a cognitive delay or impairment: their education ranged from comprehensive school level to master's degree, and no one had a physical disability. The participants were assigned the main group or the mixed group based on their (1) age at onset of blindness and (2) degree of blindness.

Main group (N = 18): Onset of blindness was less than 4 months after birth. Degree of blindness was total, light perception, and light projection. Their braille experience was 10 to about 70 years, for some hours daily.

Mixed group (N = 5): Onset of blindness was after 4 months old. Degree of blindness ranged from total to minimal visual shape perception. Their braille experience was 8 months to about 30 years, some not using braille weekly, others for some hours a day.

Materials

A total of 23 arrays (210 mm × 210 mm) were used. These comprised 12 braille characters spread out randomly: 18 arrays with one target, 11 distractors (see Figure 2), and 5 catch-arrays with no target. The catch-arrays were of two types: Type 1 – 12 identical braille characters (12 Ks, 12 Ps, or 12 Ss) and Type 2 – a blend of 3 groups of 4 identical braille characters (4 Ks, 4 Ps, and 4 Ss).

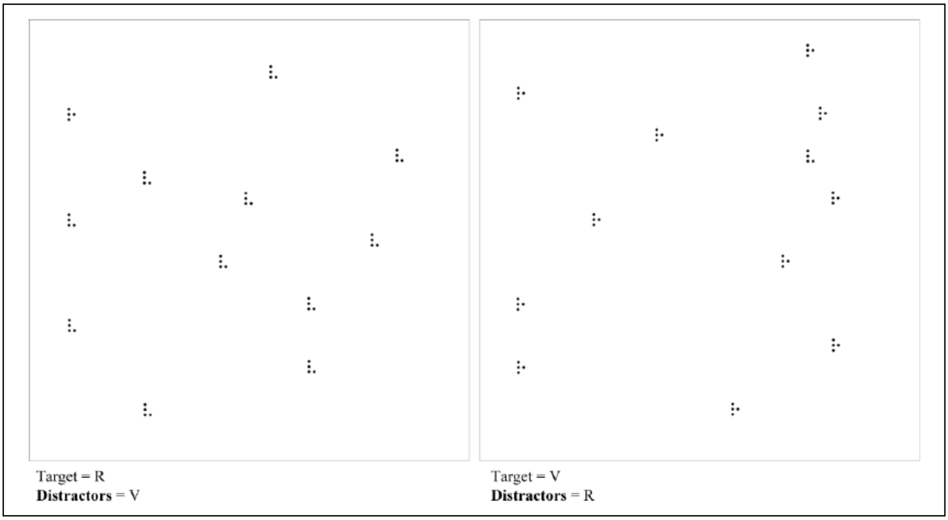

Figure 2. Array with braille target and distractors.

Six target–distractor pairs were included, with the first character as the target: RV, OM, RT, LN, UT, and YV. These were presented twice plus once in reverse (see Figures 2 and 3).

The arrays were presented one by one, inside a 210 mm × 210 mm frame. The frame was tactually smooth and visually white, and placed on a tactually rough – to prevent movement – and visually white tablecloth – to prevent visual frame contours. Frame wall height was 20 mm, that is, to prevent haptic exploring (of the tablecloth) outside the array. Surely, the frame walls strengthened the reliability of both the (1) exploration time and (2) after-decision certainty data. The height of the frame walls was, however, a threat to the reliability of the accuracy data – as it may have forced the hands into an unusual position. In order to minimise this threat, all braille characters were more than 20 mm from the frame walls.

A lifting device, that is, a white carton plate with a piece of white paper glued to its underside and folded over the frame wall furthest from the participant, ensured easy exchange of arrays. One array equals one trial (see Figure 4).

Procedure

The test materials were all white. Indeed, the participants were prevented from using any residual vision. The experiment took place in a quiet room with all interior in a neutral colour. Distinct light sources, for example, a specific lamp, were removed. Surely, visual distractions were minimised. The test materials were presented right in front of the participant. Both frame and lifting device were explained, orally and tactually. The experimenter read all test instructions out loud.

First, the participant had to make a fist with both hands – to prevent any sneak peeking at the materials. Next, guided by the experimenter, the participant placed both fists in the middle of the frame. The experimenter's left hand was placed on top of the participant's fists. Now, the participant was asked to explore the presented array: to start when the experimenter's hand was removed, to continue for as long as was needed, and to stop by tapping on the detected target (Task 1). Finally, the participant was asked to rate his or her after-decision certainty (Task 2) and to explain, in his or her own words, how target was discriminated from the distractors (Task 3).

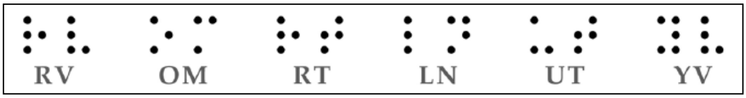

Figure 3. Target–distractor pairs.

Wooden frame: 210 x 210mm. Tactually smooth; visually white. Frame wall height: 20mm.

Figure 4. Frame, surrounding the arrays.

The participants were not told whether their detected target was correct. Neither were they told that target and distractors in fact were braille characters, nor how many characters there were in each array.

Task

Task 1: Detect target.

Task 2: Rate the after-decision certainty.

Task 3: Describe, in own words, how the target was discriminated from the distractors.

Scoring

Task 1: Target detection was scored for (1) exploration time, that is, seconds from when the experimenter's hand was removed from the participant's fists till the participant tapped on detected target, and (2) accuracy, that is, number of correct target detections (maximum = 18).

Task 2: After-decision certainty (Persaud, McLeod, & Cowey, 2007) was rated by the participants on a scale where 1 = *Not at all sure*, 2 = *Unsure*, 3 = *Not very sure*, 4 = *Fairly sure*, 5 = *Sure*, 6 = *Very sure*, and 7 = *100% sure*.

Task 3: How the target was discriminated from the distracters (Dienes & Scott, 2005) was recorded word by word in a think-aloud/'aussage' protocol (Aanstoos, 1983).

Analysis

The qualitative data (Task 3) were approached by descriptive phenomenology (Giorgi & Giorgi, 2003; Landridge, 2007). Step 1 includes reading for overall meaning. Raw data = 18 answers × 23 participants. Step 2 consists of rereading to establish meaning units and reduce and disclose what was answered, that is, both within the answers of each participant (Giorgi & Giorgi, 2003) and also across all 414 answers – first the main and then the mixed-group answers. Moreover, in Step 2, the most important target-discriminating feature was acknowledged as the one answered first, that is, the most spontaneous. Features answered in addition to this and/or after encouragement were acknowledged as not being spontaneous and requiring the participants' focused attention. Step 3 transformed meaning units from idiosyncratic detail to more general meaning and showed how the target was discriminated from distractors. Step 4 described the most invariant connected meanings, that is, the general structure of identified discrimination strategies.

Thus, the general structure of identified discrimination strategies can be presented. Six individuals are chosen to typify details in the main group: those varying the most within (Landridge, 2007) and the least between discrimination strategies in terms of onset and degree of blindness, braille experience, and gender (see Figures 5 and 6). All individuals in the mixed group are presented (see Figure 7).

The quantitative data (Tasks 1 and 2) were approached in two steps. In Step 1, three separate *t*-tests were conducted with the main group to test whether (1a) exploration time, (1b) accuracy, and (1c) after-decision certainty depend on discrimination strategy. In Step 2, each one of the five mixed-group individuals was compared with the main group.

Results

Discrimination strategy

Braille letter → dot analysis.

Nine individuals (four males and five females; mean age: 49.1 years) reported treating the target and distractors as braille letters. They were also eager to analyse them in dots. Moreover, they never analysed gaps without an analysis of dots (see Figure 5).

These individuals answered, very spontaneously, 'location of dots', 'quantity of dots', or 'location and quantity of dots'. One individual was persistent in answering 'braille letter', but when encouraged specifically to analyse the braille letter (in ± 35% of these trials, selected randomly), concentrated on dot location and quantity. Of the remaining correct target detections (N = 139), the features were ranked as follows: most important, dot location and quantity (49.64%); second, dot location (38.13%), and finally, dot quantity (12.23%). Ranking of features depended more on target–distractor pairs than on different, even personal, strategies (see Figure 5).

They then answered less spontaneously: for example, after dot location and quantity (RV) – 'R's Dot 5 equals V's Dot 6'; after dot location and quantity [NL] – 'Vertical straight line of dots vs dots more spread out'; after dot location (MO) – 'M has two dots in a horizontal straight line on top and O has a dot in the middle'; and after dot quantity (UT) – 'U has more dots than T'.

A total of six incorrect target detections were made, that is, the target was not discriminated from distractors, but rather 12 identical braille characters were detected.

These nine individuals described the very same discrimination strategy:

- *Figure Identity.* Phase 1: Recognising braille letters, including preliminary analyses of dots. The ranking of features in order of importance depends on target–distractor pairs:

	Trials 1-18																	
	LN	**RV**	**OM**	**UT**	**VR**	**TU**	**VY**	**RT**	**MO**	**NL**	**TR**	**YV**	**UT**	**LN**	**RV**	**OM**	**RT**	**YV**
I1	Dot qua. + Gap loc.	Dot loc. & Dot qua.	Dot loc.	—	Dot loc.	Dot loc. & Dot qua. + Gap loc.	Dot qua.	Dot loc. & Dot qua.	Dot loc.	Dot qua.	Dot loc.	Dot qua.		Dot loc. & Dot qua.	Dot loc.			Dot qua.
I2	Dot loc. & Dot qua..	Dot loc.		Dot qua.	—		Dot loc. & Dot qua.	Dot loc.		Dot loc. & Dot qua.	Dot loc.	Dot loc. & Dot qua.			Dot loc.			
I3	Dot loc. & Dot qua.	Dot loc.		—	Dot loc.	Dot loc. & Dot qua.		Dot loc.		Dot loc. & Dot qua.	Dot loc.	Dot qua.		Dot loc. & Dot qua.	Dot loc.			Dot qua.

Figure 5. Braille letter → dot analysis.
Dot loc. = dot location; Dot qua. = dot quantity; Gap loc. = gap location; & = features of equal importance; + = features ranked, consecutively, in order of importance; and — = incorrect target detection.
Individual 1: Congenitally totally blind. Braille experience ~70 years, some hours daily. Female.
Individual 2: Congenitally blind, with light projection. Braille experience ~30 years, some hours daily. Male.
Individual 3: Early totally blind. Braille experience ~20 years, some hours daily. Female.
In Trial 1, Individual 1 asked whether the experimenter required analyses of dots or gaps. When told to rely on own decision, Individual 1 analysed gaps in two trials. Individuals 2 and 3 were asked, after testing, whether they had analysed gaps in addition to dots: They answered 'No'. All three used both hands, spontaneously. No horizontal or vertical pattern appeared, although Individual 1 seemed to ignore the bottom right corner.

nevertheless with the feature conjunction dot location and quantity as the most important. Phase 2: Specific analysis of dots, that is, in both target and distractors.

Global braille letter shape → dot/gap or shape analysis.

Nine individuals (five males and four females; mean age 44.4 years) reported treating the target and distractors as global braille letter shapes: They were not eager to analyse them. Still, some did so when encouraged, specifically (in ± 35% of all trials, selected randomly); others continued answering 'global braille letter shape' (see Figure 6).

Individual 6 observed, 'When you know braille, you see them as global braille letter shapes and nothing else'. Indeed, these individuals answered, very spontaneously, 'global braille letter shape'. According to Individual 5, features were not thought of as being independent, but 'rather thought of as components of global braille letter shapes'. Individual 4 continued, 'First global braille letter shapes, then their shape similarities and, finally, their shape differences'. Example: (TU) 'Outmost left is similar in T and U' (Individual 4).

	Trials 1-18																	
	LN	RV	OM	UT	VR	TU	VY	RT	MO	NL	TR	YV	UT	LN	RV	OM	RT	YV
14	S. pro.			—		S. pro.			S. pro.			S. pro.					S. pro.	
15	GBS							—	GBS								—	GBS
16				Gap loc.		Gap loc.			Dot loc.					Gap loc.	Dot loc.		Dot loc.	

Figure 6. Global braille letter shape → dot/gap or shape analysis.
Dot loc. = dot location; Gap loc. = gap location; GBS = Global braille letter shape; S. pro. = Shape properties; and — = incorrect target detection.
Individual 4: Congenitally totally blind. Braille experience ~40 years, some hours daily. Male.
Individual 5: Congenitally blind, with light projection. Braille experience ~25 years, some hours daily. Male.
Individual 6: Early blind, with light projection. Braille experience = 45 years, some hours daily. Female.
All individuals used both hands, spontaneously. No horizontal or vertical pattern.

After being encouraged to analyse 'global braille letter shape', these individuals answered dot location and/or quantity, 'location of gaps', or 'shape property'. Of the correct and analysed target detections (N=57), the features were ranked as follows: first and most important, dot location (40.35%); second, shape property (38.60%); third, dot location and quantity (12.28%); fourth, gap location (5.26%); and finally, dot quantity (3.51%). Ranking of features depended on different, even personal, strategies: dots/gaps versus shape property, rather than target–distractor pair (see Figure 6).

Some individuals then analysed shape property: for example, (LN) 'One is a curve, while the other ones are a straight line'; (VY) 'Y is an open rectangle. V is one vertical straight line on the left, an angle in the bottom left corner, and one horizontal straight line in the bottom of the braille cell'; and (RV) 'R is a vertical line with a protuberance to the right. V is a vertical line with an angle towards the right'. No one analysed dots and/or gaps, and when encouraged to do so, they typically answered, for example, (LN) 'Probably L and N', 'Straight vertical lines and an N', 'Lots of posts and one braille N', and (NL) 'An N and some Ls, or something like that'.

Nine incorrect target detections were made, that is, the target was not discriminated from distractors: 12 identical braille characters were detected.

Also these nine individuals described the very same discrimination strategy.

- *Global characteristics.* Phase 1: Noticing different global braille letter shapes. The ranking of features in order of importance depends on different, even personal, strategies, that is, dots/gaps versus shape property, with one separate feature as the most important; for some this is dot location, for others shape property. Phase 2 (if found necessary): Specific analysis of the global braille letter shapes' shape features.

Two discrimination strategies have been identified in the main group: the figure identity strategy and the global characteristics strategy. So, how did the mixed-group individuals describe discriminating target from distractors?

Mixed-group individuals discriminating target from distractors.

Individual 7, totally blind from about 5 months old, reported, simultaneous, analysing of braille character and dots/gaps. Individual 9, totally blind 22 months ago, answered, very spontaneously, 'braille letter' and then analysed dots/gaps (see Figure 7). Example: (after dot location [LN]) 'N has a gap in the middle of the left column'. These two individuals always reported in which braille cell column dots and/or gaps were positioned. Individual 9 explained, 'I associated braille characters with regular print characters in the beginning. [. . .] Not now'. Between them, Individuals 7 and 9 made eight incorrect target detections: seven in which the target was not detected and one in which Individual 9 detected three targets.

Individual 8, blind 30 months ago, with light projection, reported treating the target and distractors as braille letters. Indeed, she analysed dots/gaps in four trials: for example, after dot location and quantity (MO) – 'The braille letter, not being M, differs from M because of an extra dot in the middle', yet mostly shape property (see Figure 7) and (VY) 'V equals an angle towards the right. Y equals an angle towards the left'. Individual 8 also reported analysing shape property and, when encouraged, typically answered, for example, (RV) 'V equals an angle towards the right. R has one horizontal straight line of dots in the middle'. Individual 8 '[. . .] associated braille letters with regular print characters when learning braille, but not anymore' and answered once (OM) 'The braille O equals the regular print)'. The target was not discriminated from distractors twice: 12 identical braille characters were detected.

Individual 10, totally blind 8 months ago, reported treating the target and distractors as braille characters: eager to analyse them, at times in dots and/or gaps, mainly associating them with regular print characters. In fact, Individual 10 specified, 'I associate angles, curves, etc. in braille characters with angles, curves, etc. in regular print characters'. Example: (UT) 'Braille U is 'soft' because of the gap in braille cell position two – equals a curve, a curved regular print V. The braille T equals tall T in handwriting'. (VR) 'The braille R equals the regular print R. Braille V is "hard" because of the angle in the bottom left corner of the braille cell – equals regular print V'. (OM) 'The braille O is "soft" because of the gap in braille cell position two – equals a curve, the regular print O. Braille M equals the beginning of regular print M'. And, (YV) 'The braille V is "hard" because of the angle in the bottom left corner of the braille cell –regular print V. The braille Y is not associable with any regular print character – just with its crammed dots'. Individual 10 detected all targets (see Figure 7).

Individual 11, congenitally blind, with minimal visual shape perception, clarified, 'I associate braille characters with object shapes', for example, (UT) 'U equals a chair in profile without legs. T equals a chair in profile with legs' and (MO) 'M equals the Allen key'. Individual 11 also reported, for example, (LN) 'N equals regular print, capital, R' and (VY) 'V equals regular print, capital, L. Y equals regular print]'. Individual 11 continued, 'I analyse dots only when target and distractors are difficult to recognise'. Example: after dot location (RT) – 'T equals a chair in profile with legs' and then, less spontaneously, 'R is heavy towards the left. [. . .] Because of dots 1, 2 and 3'. Individual 11 made three incorrect target detections, that is, the target was not discriminated from distractors: 12 identical braille characters were detected (see Figure 7).

Individuals 7 and 9 seem to have described the figure identity strategy (see Figures 5 and 7). Also, Individual 8 reported treating the target and distractors as braille letters, whereas her analyses seem to suggest the global characteristics strategy (see Figures 5 to 7), as if Individual 8 was in the process of establishing discrimination strategy. Individuals 8 and 9 explained that they associated braille characters with regular print characters when first learning braille, but not anymore: Individuals 10 and 11 still associating them with visual experiences, Individual 10 with regular print characters and Individual 11 with object shape. Indeed, these four individuals described yet another discrimination strategy:

- *Touch vision.* Phase 1: Noticing braille characters or shapes of dots, including preliminary analyses of dots/gaps or shape features. Phase 2: Recognising the braille characters by associating them with visual print characters or visual object shapes, that is, both target and distractors. The ranking of features depends on different, even personal, strategies, for example, (V) 'Braille V is "hard" because of the angle in the bottom left corner of the braille

<table>
<tr><th rowspan="2"></th><th colspan="18">Trials 1-18</th></tr>
<tr><th>LN</th><th>RV</th><th>OM</th><th>UT</th><th>VR</th><th>TU</th><th>VY</th><th>RT</th><th>MO</th><th>NL</th><th>TR</th><th>YV</th><th>UT</th><th>LN</th><th>RV</th><th>OM</th><th>RT</th><th>YV</th></tr>
<tr><td>I7</td><td>Gap loc.</td><td colspan="2">Dot loc.</td><td>—</td><td>Dot loc.</td><td colspan="2">Dot loc. & Dot qua.</td><td colspan="2">Dot loc.</td><td>Dot loc. & Dot qua. + Gap loc.</td><td>Dot loc.</td><td colspan="3">Dot loc. & Dot qua. + Gap loc.</td><td colspan="3">Dot loc.</td><td>Dot loc. & Dot qua. + Gap loc.</td></tr>
<tr><td>I8</td><td colspan="2">S. pro.</td><td>BP</td><td colspan="2">—</td><td>Dot loc.</td><td colspan="2">S. pro.</td><td>Dot loc. & Dot qua.</td><td colspan="3">S. pro.</td><td>Dot loc. & Dot qua. & Gap loc. & Gap qua.</td><td colspan="2">S. pro.</td><td>Dot qua. & Gap qua.</td><td colspan="2">S. pro.</td></tr>
<tr><td>I9</td><td colspan="2">Dot loc.</td><td>—</td><td>Dot qua. + Gap loc.</td><td colspan="2">Dot loc.</td><td colspan="3">—</td><td>Dot loc. & Dot qua.</td><td>—</td><td>Dot loc. & Dot qua.</td><td>Gap loc.</td><td>Dot loc. & Dot qua.</td><td>Dot loc.</td><td>—</td><td>Dot loc.</td><td>—</td></tr>
<tr><td>I10</td><td>Dot loc. & Gap loc.</td><td>Dot loc.</td><td>Dot loc. & Gap loc. + BP</td><td colspan="3">BP</td><td>Dot qua. & Gap qua.</td><td colspan="2">BP</td><td>Dot loc. & Dot qua. & Gap loc. & Gap qua. + BP</td><td colspan="3">BP</td><td>Dot loc. & Gap loc.</td><td>BP</td><td>Gap loc. + BP</td><td colspan="2">BP</td></tr>
<tr><td>I11</td><td>S. pro.</td><td>Dot loc. & Dot. qua.</td><td>—</td><td>BO</td><td>Dot loc. & Dot qua.</td><td>BO</td><td>BP</td><td>—</td><td>BO</td><td>S. pro.</td><td>Dot loc.</td><td>—</td><td>BO</td><td>BO + BP</td><td>Dot loc.</td><td>BO + BP</td><td>BO + Dot loc.</td><td>BP</td></tr>
</table>

Figure 7. Mixed-group individuals discriminating target from distractors.

BO = Braille-(visual) Object association; BP = Braille-(visual) Print association; Dot loc. = dot location; Dot qua. = dot quantity; Gap loc. = gap location; Gap qua. = gap quantity; S. pro. = Shape properties; & = features of equal importance; + = features ranked, consecutively, in order of importance; and — = incorrect target detection.

Individual 7: Totally blind when about 5 months old. Braille experience ~30 years, some hours a day. Female.

Individual 8: Blind 30 months ago: light projection in a 2°–3° visual field. Braille experience <30 months, some minutes a day. Female.

Individual 9: Totally blind 22 months ago. Braille experience <22 months, not weekly. Female.

Individual 10: Totally blind 8 months ago. Braille experience <8 months, some minutes a day. Female.

Individual 11: Congenitally blind, with minimal visual shape perception. Braille experience ~25 years, some minutes a day. Male.

Individuals 7, 8, and 11 used both hands, spontaneously. No horizontal or vertical pattern. Also, Individuals 9 and 10 used both hands spontaneously, but (1) Individual 9 with the left index finger on the left half of the array and the right index finger on the right half, both horizontally and vertically ('I'm very keen to find symmetry') and (2) Individual 10 in a left-to-right horizontal pattern. Individual 10 was worried about not finding all braille characters and thus scanned over the array with the pinkie-side of both fists. Moreover, Individual 10 insisted on angling the array as a sighted individual would angle a sheet of paper when writing a letter by hand.

cell – equals regular print V' (Individual 10) and braille 'V equals regular print, capital, L' (Individual 11).

Exploration time, accuracy, and after-decision certainty

Because the test material consisted of six target–distractor pairs, all presented twice plus once in reverse, for example, Trial 2 RV, Trial 5 VR, and Trial 15 RV. Analysis of variance (ANOVA) was conducted to test whether, for example, Trials 5 and 15 were more or less troublesome than Trial 2 (Brennan, 2010). ANOVA confirmed that none of the trials had a target–distractor pair that was more or less troublesome than the others ($p > .05$), $N = 18$.

The figure identity strategy versus the global characteristics strategy.

Mean exploration time for the figure identity strategy was 14.7 s (with a standard deviation of 8.09), $N = 9$, and for the global characteristics strategy it was 14.3 (with a standard deviation of 12.05), $N = 9$. The difference between the two discrimination strategies was tested by means of t-tests and found not to be statistically significant: $t(16) = .09$, $p = .93$.

Next, mean accuracy for the figure identity strategy was 17.3 correct target detections (with a standard deviation of 0.71), $N = 9$, and for the global characteristics strategy it was 17.0 (with a standard deviation of 1.00), $N = 9$. The difference between the two discrimination strategies was tested by means of t-tests and found not to be statistically significant: $t(16) = .82$, $p = .43$.

Finally, mean after-decision certainty for the figure identity strategy was 6.9 on the after-decision certainty scale (with a standard deviation of 0.09), $N = 9$, and for the global characteristics strategy it was 7.0 (with a standard deviation of 0.06), $N = 9$. The difference between the two discrimination strategies was tested by means of t-tests and found not to be statistically significant: $t(13.24) = .99$, $p = .34$.

The two discrimination strategies, the figure identity strategy and the global characteristics strategy, proved to be equally fast, accurate, and used with an equal amount of after-decision certainty. So, how did each mixed-group individuals perform compared with the main group?

Mixed-group individuals versus the main group.

Because of the large variation in onset and degree of blindness as well as in braille experience, each one of the five mixed-group individuals, not identified discrimination strategies, was compared with the main group. For one-sample t-test results, see Table 1.

- Main group ($N = 18$): Two discrimination strategies were identified, that is, the figure identity strategy and the global characteristics strategy. These proved to be equally fast, accurate, and used with an equal amount of after-decision certainty.
- Mixed group ($N = 5$): Individuals 7 and 9 described using the figure identity strategy, Individual 8 was seemingly in the process of establishing a discrimination strategy. One more discrimination strategy was identified, that is, the touch vision strategy, described by Individuals 8, 9, 10, and 11 and still used by the latter two.
- Individual 7: Totally blind when about 5 months old. Braille experience ~30 years, some hours a day. Female.
- Individual 8: Blind 30 months ago: light projection in a 2°–3° visual field. Braille experience <30 months, some minutes a day. Female.
- Individual 9: Totally blind 22 months ago. Braille experience <22 months, not weekly. Female.
- Individual 10: Totally blind 8 months ago. Braille experience <8 months, some minutes a day. Female.
- Individual 11: Congenitally blind, with minimal visual shape perception. Braille experience ~25 years, some minutes a day. Male.

Table 1. Mixed-group individuals versus the main group.

	Descriptive statistics					
	Exploration time		Accuracy		After-decision certainty	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Main group	**14.5**	**9.96**	**17.2**	**0.86**	**7.0**	**0.08**
Mixed group						
• Individual 7	19.0		17.0		7.0	
• Individual 8	17.4		16.0		6.9	
• Individual 9	56.8		11.0		5.8	
• Individual 10	20.2		18.0		7.0	
• Individual 11	9.7		15.0		7.0	

Analytic statistics

	Exploration time			Accuracy			After-decision certainty		
	t	*df*	*p*	*t*	*df*	*p*	*t*	*df*	*p*
• Individual 7	−1.91	17	.07	0.83	17	.42	−2.38	17	.03
• Individual 8	−1.23	17	.24	5.77	17	.00	3.04	17	.01
• Individual 9	−18.01	17	.00	30.51	17	.00	62.70	17	.00
• Individual 10	−2.42	17	.03	−4.12	17	.00	−2.38	17	.03
• Individual 11	2.05	17	.06	10.72	17	.00	−2.38	17	.03

Both Individual 7 (totally blind at about 5 months old) and Individual 9 (totally blind 22 months ago) described using the figure identity strategy, and thus should be performing like the main group. Individual 7 did so for exploration time as well as for accuracy and with more after-decision certainty. Individual 9 did not. Actually, Individual 9 was slower, less accurate, and less after-decision certain. Individual 8 (blind 30 months ago, with light projection) seemed in the process of establishing either the figure identity strategy or the global characteristics strategy, and thus should also be performing like the main group. This was the case for exploration time, but not for accuracy and after-decision certainty, that is, Individual 8 was less accurate and less after-decision certain.

Individuals 8, 9, 10, and 11 all identified the touch vision strategy, and Individuals 10 and 11 were still using it. Individual 11 (congenitally blind with minimal visual shape perception) was as fast as the main group, whereas Individual 10 (totally blind 8 months ago) was less fast. As regards accuracy, Individual 10 was more accurate and Individual 11 less so. Both were more after-decision certain than the main group.

Taken together, it seems that some braille experience is needed before a discrimination strategy is established and that the global characteristics strategy takes longer to establish than the figure identity strategy. When firmly established, the figure identity strategy and the global characteristics strategy are equally fast, equally accurate, and used with equal amounts of after-decision certainty. Having vision, albeit restricted to no more than minimal shape perception, seems to improve the exploration time but worsen the accuracy: Recent vision (now total blindness) has the opposite effect. It seems the touch vision strategy is left behind at 8–22 months of total blindness and that a new discrimination strategy needs to be established: the figure identity strategy or the global characteristics strategy.

Discussion

This study investigated (1) how blind individuals themselves would describe discriminating braille characters, including ranking braille features in order of importance – their discrimination strategy, and (2) whether exploration time, accuracy, and after-decision certainty in detecting one braille target among distractors depend on discrimination strategy.

Three discrimination strategies were identified. First, the figure identity strategy, which recognises each braille character (e.g., V and L) and ranks a feature conjunction, dot location, and quantity, as the most important. Second, the global characteristics strategy, which notices global braille letter shapes (e.g., [NL] one is a curve, the other a straight line), ranking one separate feature as the most important: for some dot location, for others shape property. Third, the touch vision strategy, which notices braille characters, or shapes of dots, and then recognises them (e.g., R and T) by associating their tactile features with visual experiences (e.g., T is a chair in profile). As of yet, it is not clear which features are ranked as the most important in the touch vision strategy. Indeed, more research is needed to identify the nature of the discrimination strategies.

On a curious note, individuals using both the global characteristics strategy and the touch vision strategy described perceiving the braille N, O, and U as curves. Curves and circles are by nature impossible in a 2×3 matrix. Were the curves perceived because of how the reading finger moves? Were N, O, and U perceived as curves because of the nearby characters, that is, because of priming? Or was it because of the position of the braille cell gaps, as specified by Individual 11: (U) 'Braille U is 'soft' because of the gap in braille cell position two – equals a curve'? If so, braille characters such as S (Dots 2, 3, and 4) and Z (Dots 1, 3, 5, and 6) would also be perceived as curves. Further research is needed to understand how braille is perceived by individuals who use haptic touch.

Discrimination strategies and attention

It seems that both the figure identity strategy and the touch vision strategy process information in two phases of attention, still as discrimination strategies they seem rather disparate: the figure identity strategy processes information in two phases of focused attention: the touch vision strategy in one phase of semi-focused attention and one phase of narrowly focused attention. The global characteristics strategy, on the other hand, seems to process information predominantly pre-attentively, focusing attention only if found necessary. But when necessary, the focus seems as narrowed down as that in the figure identity strategy, yet less so than that in the touch vision strategy.

Hence, because it processes information predominantly pre-attentively, the global characteristics strategy should be the fastest of the three (Treisman, 1995). This was not the case, however. The figure identity strategy and the global characteristics strategy were equally fast. The touch vision strategy was as fast as the other two when the individuals had minimal visual shape perception, the slowest when not, that is, when they were totally blind.

Moreover, and again because it processes information predominantly pre-attentively, the global characteristics strategy should be the most accurate. This was also not the case. The figure identity strategy and the global characteristics strategy were equally accurate. Then again, this study did not test the accuracy of recognition but only the accuracy of detecting targets. Some of the answers given by those who used the global characteristics strategy revealed that they were not striving to recognise the braille characters as such, for example, (LN) 'Probably L and N' and (NL) 'An N and some Ls, or something like that'. Individuals using this strategy would probably need to focus their attention during reading, at least at the beginning of a text. The touch vision strategy was the most accurate of the three when the individual was totally blind, the least when he or she had minimal visual shape perception.

Clearly, blind individuals are perfectly capable of adjusting their attention along the continuum from pre-attention to focused attention (Treisman, 1995). But, was the pre-attention in the global characteristics strategy, the semi-focused attention in the touch vision strategy, and the focused (first phase) attention in the figure identity strategy in actual fact quite similar? Were they all what Treisman (1995) calls 'early attention'? Or do the individuals shift from pre-attention, semi-focused attention, and focused (first phase) attention to focused (second phase) attention and narrowly focused attention without really being aware of doing it? Finally, the touch vision strategy was used with more after-decision certainty than both the figure identity strategy and the global characteristics strategy. This seems to suggest that after-decision certainty is related to exploration time when individuals have minimal visual shape perception and to accuracy when they are totally blind.

Further research is needed to investigate whether the exploration time, accuracy, and after-decision certainty of individuals using the vision touch strategy are affected by vision. Indeed, in this study, the participants were prevented from using any residual vision to detect target. Furthermore, research is needed to explore in more detail how attention is adjusted along the continuum from pre-attention to focused attention (cf., Treisman, 1995). To this end, further research is needed to investigate whether the features ranked as the most important for detecting target in pre-attention, semi-focused attention, and focused (first phase) attention correspond with the cues retrieved the fastest from memory (Lamberts & Kent, 2008). This seems of particular relevance when teaching braille to individuals who have some vision and/or who are recently blind, as there is a chance of a mismatch (Graven, 2009).

Discrimination strategies and teaching

The congenitally and early blind individuals used either the figure identity strategy or the global characteristics strategy. Surely, the first seems in line with Millar (1977, 1985, 1987a) and the latter with Nolan and Kederis (1969). Nolan and Kederis (1969) suggested coding of outline shape, for example, triangles, whereas the individuals using the global characteristics strategy described shape features, such as angles, curves, and straight lines. In teaching, the congenitally or early blind pupil's nonobligatory pattern of decisions needs to be recognised, whether occasional or goal directed, signalling a discrimination strategy. Braille should be taught accordingly.

Furthermore, the recently blind individuals and/or those with minimal visual shape perception used the touch vision strategy: associating braille characters with their stored visual experiences. It seems that visual experience compensates for braille experience for quite some time, but also that it decays rather quickly after total blindness. When it has decayed, the individuals re-establish their discrimination strategy, firmly establishing either the figure identity strategy or the global characteristics strategy. Research is needed to investigate which of the two is preferred when individuals are recently blind. When they are congenitally and early blind, the two strategies are preferred equally often. Research is also needed to investigate whether the recently blind individuals, using the touch vision strategy, give signals to indicate whether the figure identity strategy or the global characteristics strategy will be firmly established later on. If they give such signals, it would certainly be possible to tailor the rehabilitation programme to suit each pupil.

Indeed, it seems discrimination strategies are not static. They are constantly developed and fine-tuned, and accuracy, but not exploration time, decreases during the re-establishing or altering of discrimination strategy: in fact, the brain changes with greater experience and learning (Hamilton & Pascual-Leone, 1998; Pascual-Leone & Torres, 1993). In teaching, this does not mean that the pupil needs a break from braille. Instead, this study suggests even more braille experience is required.

Regarding all three discrimination strategies, it seems that visual stimuli, for example, light, have a negative impact on simultaneous haptic perceptions. (For an elaboration, see Driver & Spence, 2000.) In reality, do individuals with some vision expect visual stimuli also when the stimuli is tactile (Spence, Nicholls, & Driver, 2001)? Are they in a state of low, even no, perceptual readiness (Bruner, 1957): not prepared to perceive tactile information? Is vision, although minimal, their dominant sense modality (Graven, 2003, 2004, 2005)? In teaching, it seems the best approach would be to make them curious about tactile materials, for example, art, shapes, and surfaces – thereby increasing their tactile experience – before introducing the braille characters as such, and then increasing their braille experience. They should also be made aware of in which tasks and situations they would benefit from using haptic touch instead of vision.

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