How individuals who are blind locate targets

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Abstract

How do individuals who are blind locate, e.g. the '@' in an email address, the black king on a chessboard or their own house on a map? To locate information in peri-personal (non-rotated) tabletop space is a two-phase process: Phase 1 is to detect and identify the target; Phase 2 is to discover its position. The present study investigated the relationship between Phase 1 and Phase 2 of the location process. Twenty-three individuals who are blind participated. Their accuracy in Phase 2 was affected by what strategy they had adopted in Phase 1; their location time was not. Three location strategies were identified in Phase 2 – the routeing strategy, the global view strategy, and the touch vision strategy: the location time and accuracy not affected by which strategy had been adopted. 50% adopted the same strategy for ranking (Phase 1) target-discriminating features and (Phase 2) target-locating cues in order of importance.

Keywords: Attention, blind, discrimination strategy, haptic touch, location strategy

How do individuals who are blind locate, e.g. the '@' in an email address, the black king on a chessboard or their own house on a map? To locate information in peri-personal (non-rotated) tabletop space is a two-phase process: Phase 1 is to detect and identify the target; Phase 2 is to discover its position. A target is not located automatically, even if its identity is known (Purdy, Lederman, & Klatzky, 2004).

Previous research on the process of locating 2D tactile information bifurcates, each branch focussing on either Phase 1 or Phase 2 of the location process. One branch investigated the ability to recognise a target shape (e.g. a country) from a mass of intersecting lines or textures on a map, including the preliminary scan, the inspection of the target shape and/or the search strategy [e.g. distinctive features, scanning behaviour, and line tracing. (Cf. for example Berlá, 1981; Berlá & Butterfield, 1977; Berlá, Butterfield, & Murr, 1976; Berlá & Murr, 1975)]. This branch is focused on the ability to recognise a target shape, not on the ability to discover its position on a map: it is focused on Phase 1 of the location process – detecting and identifying the target. The other branch investigated the ability to learn and/or recall a layout of shapes/symbols, including the use of external (e.g. surrounding frame) and internal (e.g. body midline) reference cues, movements (e.g. length of arm movement from the shoulder), exploratory strategies (e.g. number of fingertips from the surrounding frame), and mental imagery strategies [e.g. spatial vs. verbal. (Cf. for example Cornoldi, Tinti, Mammarella, Re, & Varotto, 2009; Millar & Al-Attar, 2003, 2004; Ungar, Blades, & Spencer, 1995)]. This branch is focused on the ability to learn and/or recall the target's position on the display/map, not on the ability to recognise it per se: it is focused on Phase 2 of the location process – discovering the target position. (See Millar 1994, 2008 for reviews.)

Focusing on both Phase 1 and Phase 2 of the location process, Postma, Zuidhoek, Noordzij, and Kappers (2007) found that individuals who are blind were faster at (Phase 1) fitting shapes into corresponding slots on a board than were blindfolded (sighted) individuals. They were equally accurate in (Phase 2) locating the shapes and (Phase 1) naming/describing them. When describing the target position (in Phase 2), those with blindness referred more to other shapes (e.g. 'the triangle was right of the cross') than those with blindfold, who used more board referrals [e.g. 'the cross was the top left of the board' (Postma, Zuidhoek, Noordzij, & Kappers, 2007, p. 1259)]. Postma et al. (2007) suggested that individuals who are blind describe a route, and those who are blindfolded describe a map-like bird's-eye view.

Postma et al. (2007) did not investigate, however, whether Phase 1 of the location process – detecting and identifying the target – affects Phase 2 – discovering the target position. Their participants entered Phase 1, then Phase 2, then Phase 1 again, and so on.

The present study investigated the relationship between Phase 1 and Phase 2 of the location process. More specifically:

- whether (Phase 2) location time (Berlá et al., 1976) and accuracy are affected by how individuals who are blind describe (Phase 1) discriminating a target from distractors, including ranking target-discriminating features in order of importance – their discrimination strategy,
- how individuals who are blind would describe (Phase 2) discovering/locating a target position, including ranking target-locating cues in order of importance – their location strategy, and also whether location time (Berlá et al., 1976) and accuracy are affected by what (Phase 2) location strategy is adopted, and
- whether individuals who are blind use the same strategy for ranking (Phase 1) target-discriminating features and (Phase 2) target-locating cues in order of importance.

(Cf. for example Graven, 2015, 2016a, 2016b; Millar, 1994, 2008; Wolfe & Robertson, 2012.)

Method

Design

A mixed ‘qual-quan’ design was employed. Qualitative data were collected to explore what (Phase 1) discrimination strategies and (Phase 2) location strategies were used. Quantitative data were collected to test whether location time (Berlá et al., 1976) and accuracy were affected (Phase 1) by what discrimination strategy and (Phase 2) by what location strategy was adopted, and also whether the same strategy was adopted for ranking (Phase 1) target-discriminating features and (Phase 2) target-locating cues in order of importance. (Cf. for example Graven, 2015, 2016a, 2016b; Millar, 1994, 2008; Wolfe & Robertson, 2012.)

Participants

Ten males and 13 females [mean age 43.7 years (offered a remuneration to compensate for their time)] participated. Sixteen were congenitally, three early (< 4 months old), one at ~5 months old, and three recently (< 3 years ago) blinded; categories 3 to 5 in the ICD-10 (WHO, 2017): Cat. 3 = minimal visual shape perception (N = 1); Cat. 4 = minimal colour perception (N = 2), light projection [perceives where a light source is situated (N = 5)], and light perception [perceives a light source (N = 4)]; Cat. 5 = total blindness (N = 11). They were all braille readers. No one had a cognitive delay or impairment, nor any physical disabilities. Their education ranged from comprehensive school level to master’s degree.

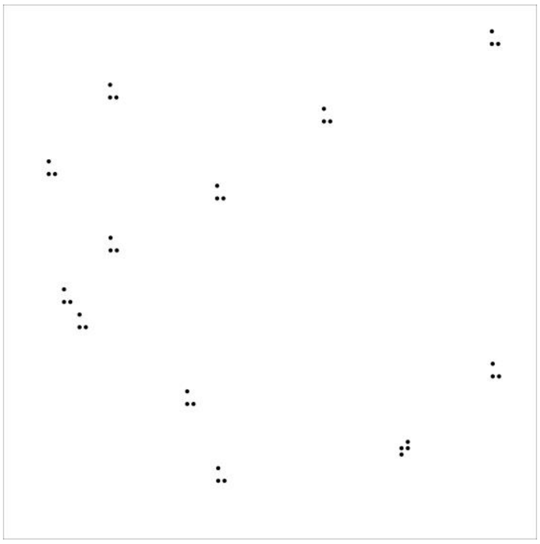
Materials

There were 18 arrays in Phase 1 and 18 record sheets in Phase 2. In addition, there were five Phase 1 catch arrays (with no target on them) and five Phase 2 ‘pretend’ record sheets.

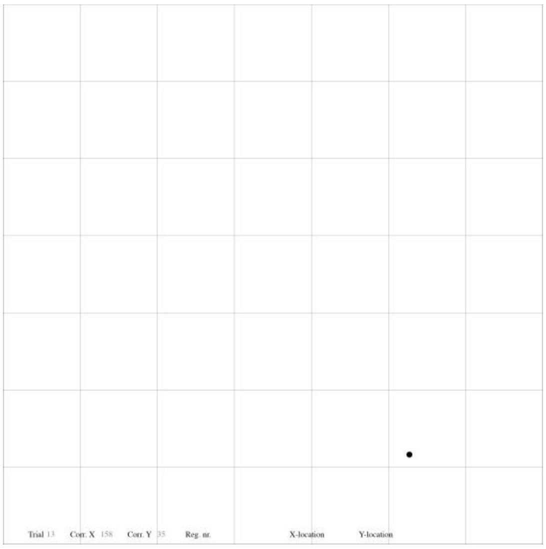
All arrays and record sheets were presented separately inside a 210 × 210 mm frame. Frame wall height was 20 mm. The frame had a lifting device for the arrays and record sheets, i.e. a carton plate with a piece of paper glued to its reverse and folded over the frame wall furthest from the participant. Locating equipment was a blue rollerball pen (Pilot V ball 0.5).

(Phase 1) detecting and identifying the target. All 18 arrays contained 12 braille characters, i.e. one target and 11 distractors, with the first character as the target: OM, RT, RV, LN, UT, and YV. These were presented twice plus once in reverse, and in random order. In half the target-distractor pairs the braille characters differed in one separate feature [i.e. dot location (OM; RT; RV)], and in the other half they differed in a feature conjunction [i.e. dot location + dot quantity (LN; UT; YV). (Cf. for example Graven, 2015, 2016a, 2016b; Treisman, 1995; Treisman & Paterson, 1984; Treisman, Vieira, & Hayes, 1992)]. The target and distractors were spread out randomly in the array.

(Phase 2) discovering/locating the target position. All 18 record sheets contained a document grid, with line space 30 mm, stroke weight 25 pt, stroke colour black, and tint 75%. A 9pt text line 3 mm above the bottom perimeter contained the trial number, correct horizontal (X) and vertical (Y) position, plus the participant’s register number. Correct target position was signalled by a 0.5 mm 100% black marker. (Cf. Figure 1 and Table 1.)



(Phase 1) Detecting and identifying the target
Target: T
Distractors: U



(Phase 2) Discovering/locating the target position
X: 158mm
Y: 35mm

Figure 1. Materials

Table 1: Target position

	Coordinates (in mm)				**Coordinates (in mm)**				**Coordinates (in mm)**	
Trial	**X**	**Y**		**Trial**	**X**	**Y**		**Trial**	**X**	**Y**
1	151	105		**7**	79	95		**13**	158	35
2	158	145		**8**	25	195		**14**	79	105
3	127	45		**9**	85	35		**15**	175	185
4	188	45		**10**	37	195		**16**	91	165
5	20	165		**11**	122	115		**17**	86	75
6	85	175		**12**	163	45		**18**	151	65

Procedure
The experiment took place in a quiet room. Both the room and the interior were neutral in colour, and all materials were white. Distinct light sources were removed. The materials were presented right in front of the participant (on a tactually rough tablecloth

to prevent it from moving around on the table). Both frame and lifting device were explained, orally and tactually. The experimenter read all instructions out loud.

There were 18 trials and five catch trials (spread out randomly amongst the 18 trials). All trials included both a Phase 1 array and a Phase 2 record sheet: Trial 1 = Phase 1 array + Phase 2 record sheet, Trial 2 = Phase 1 array + Phase 2 record sheet, and so on.

(Phase 1) detecting and identifying the target. The participant first had to make a fist with both hands. Guided by the experimenter, they placed both fists in the middle of the frame: the experimenter’s left hand now being on top. The participant started exploring the array when the experimenter’s hand was removed, and they continued for as long as they needed to. They signalled that they had detected and identified the target by tapping on it, returning both hands to their lap. The participant was not told whether their signalled target was correct, or that the target and distractors were braille characters, or how many there were. (Cf. Graven, 2015, 2016a, cf. also Graven, 2016b.)

(Phase 2) discovering/locating the target position. The participant again had to make a fist with both hands, one of them holding the rollerball pen, and to place them (guided by the experimenter) in the middle of the frame, the experimenter’s left hand being on top. The participants started locating the position of their signalled target when the experimenter’s hand was removed, continued for as long as they needed to, and completed the task by saying ‘yes’, returning both hands to their lap. The experimenter verified that the participant’s location mark was clearly visible without revealing its accuracy.

Task

(Phase 1) detecting and identifying the target. Task 1 was to detect and identify the target, quickly and accurately, and Task 2 was to describe, in the participant’s own words, how this target was discriminated from the distractors (cf. Graven, 2015, 2016a, 2016b).

(Phase 2) discovering/locating the target position. Task 1 was to locate the position of the (Phase 1) signalled target, quickly and accurately, and Task 2 was to describe, in the participant’s own words, how the position of this (Phase 1) signaled target was located.

Scoring

(Phase 1) detecting and identifying the target. Task 1 was scored in (a) exploration time, i.e. seconds from when the experimenter’s hand was removed from the participant’s fists to when the participant tapped on the detected and identified target, and (b) accuracy, i.e. the number of correctly signalled targets. Task 2 was recorded word by word in a think-aloud/‘aussage’ protocol [Aanstoos, 1983. (Cf. Graven, 2015, 2016a, 2016b)].

(Phase 2) discovering/locating the target position. Task 1 was scored in (a) location time (Berlá et al., 1976), i.e. seconds from when the experimenter’s hand was removed from the participant’s fists to when the participant said ‘yes’, and (b) accuracy, i.e. the distance in millimetres from the correct target position to the participant’s location mark. Task 2 was recorded word by word in a think-aloud/‘aussage’ protocol (Aanstoos, 1983). Incorrect signalling of the target in Phase 1 was scored as a missing value in Phase 2 (cf. Graven, 2015, 2016a).

Analysis

First, the qualitative data were approached using descriptive phenomenology (Giorgi & Giorgi, 2003; Landridge, 2007). Step 1 was to read for overall meaning. Raw data = 18 Phase 1 answers + 18 Phase 2 answers × 23 participants, i.e. 414 answers in Phase 1 and 414 answers in Phase 2 of the location process. Step 2 was to reread to establish meaning units, reduce and disclose what was said within the answers of each participant (Giorgi & Giorgi, 2003) and across all 414 answers in Phase 1 and all, separately, 414 answers in Phase 2 [with 28 missing values (Graven, 2015, 2016a, cf. also Graven, 2016b)]. In Step 2, the most important (Phase 1) target-discriminating feature and (Phase 2) target-locating cue was assumed to be the one answered first – the most spontaneous – and those answered later/following encouragement as not being spontaneous, thus requiring focused attention (cf. for example Graven, 2015, 2016a, 2016b; Millar, 1994, 2008; Wolfe & Robertson, 2012). Step 3 was to transform the meaning units from idiosyncratic detail to general meaning, and to show (Phase 1) how the target was detected and identified, and (Phase 2) how the target position was discovered/located. Step 4 was to describe the most invariant connected meanings, i.e. the general structure of the (Phase 1) discrimination strategies (cf. Graven, 2015, 2016a, 2016b) and (Phase 2) the location strategies identified.

Next, all participants were assigned to one of the identified (Phase 1) discrimination strategies (cf. Graven, 2015, 2016a, 2016b) and (Phase 2) location strategies based on how often they described this strategy [> 50% of all trials (Graven, 2015, 2016b; Ungar et. al. 1995)]. Indeed, a discrimination strategy (Phase 1) and a location strategy (Phase 2) 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).

The (Phase 1) discrimination strategies were identified by Graven (2015, 2016a, cf. also Graven, 2016b), thus the present study explored what strategies were used to discover/locate the target position (in Phase 2). Nine individuals were chosen in Figures

2-4 to typify details in the identified (Phase 2) location strategies: those varying the most within (Landridge, 2007) and the least between location strategies in terms of onset and degree of blindness, braille experience, and gender (Graven, 2015).

Finally, the quantitative data could be analysed. Parametric statistics were used to test whether location time (Berlá et al., 1976) and accuracy were affected (Phase 1) by what discrimination strategy (Graven, 2015, 2016a, cf. also Graven, 2016b) and (Phase 2) by what location strategy was adopted, and nonparametric statistics to test whether the same strategy was adopted for ranking (Phase 1) target-discriminating features and (Phase 2) target-locating cues in order of importance. (Cf. for example Graven, 2015, 2016a, 2016b; Millar, 1994, 2008; Wolfe & Robertson, 2012).

Results

Discrimination strategies – location time and accuracy

Graven (2015, 2016a, cf. also Graven, 2016b) identified three (Phase 1) discrimination strategies. In short, the global characteristics strategy notices different global braille letter shapes, e.g. (NL) 'An N and some L's, or something like that' (Graven, 2015, p. 87). It ranks one separate feature (i.e. dot location or shape property) as the most important target-discriminating feature. Next, if necessary, it performs a specific analysis of the global braille letter shapes' shape features, e.g. (NL) 'One is a curve, while the other ones are a straight line' (Graven, 2015, p. 87). The figure identity strategy, in contrast, recognises each braille letter, e.g. R and V, and performs preliminary analyses of the dots. It ranks a feature conjunction (i.e. dot location + dot quantity) as the most important target-discriminating feature. Next, it performs a specific analysis of the dots, e.g. (RV) 'R's dot 5 equals V's dot 6' (Graven, 2015, p. 85). The third discrimination strategy, i.e. the touch vision strategy, notices braille characters or shapes of dots and performs preliminary analyses of the dots/gaps or shape features. Next, the touch vision strategy recognises the braille letters by associating them to visual experiences, e.g. 'Braille V is "hard" because of the angle in the bottom left corner of the braille cell – equals regular print V' and (UT) 'U equals a chair in profile without legs. T equals a chair in profile with legs' (Graven, 2015, p. 88). It is not yet clear, however, what target-discriminating feature(s) the touch vision strategy ranks as the most important so this discrimination strategy was not included in these statistical analyses.

According to Treisman (cf. for example Treisman, 1995; Treisman & Paterson, 1984; Treisman et al., 1992), separate features are processed in pre-attention; fast and accurately, and feature conjunctions in focussed attention; slowly and inaccurately. The global characteristics strategy is therefore likely to carry the least attentional load from Phase 1 to Phase 2 of the location process; it will be the fastest and the most accurate in (Phase

2) discovering/locating the target position (cf. for example Graven, 2015, 2016a, 2016b; Postma et al., 2007; Treisman, 1995; Treisman & Paterson, 1984; Treisman et al., 1992).

Mean location time for the global characteristics strategy was 7.4 seconds (SD = 5.46. N = 9), and for the figure identity strategy it was 7.0 seconds (SD = 3.03. N = 9). The difference between the two was tested using a t-test and found not to be statistically significant: t(16) = -0.19, *p* = 0.85. Mean diagonal distance from the correct target position to the participants’ location mark for the global characteristics strategy was 16.0 mm (SD = 3.52. N = 9), and for the figure identity strategy it was 21.5 mm (SD = 4.40. N = 9). The difference between them was tested using a t-test and found to be statistically significant: t(16) = 2.91, *p* = 0.01. More specifically, there was no statistically significant difference on horizontal accuracy; there was a statistically significant difference on vertical accuracy. Mean vertical distance from the correct target position to the participants’ location mark for the global characteristics strategy was 9.6 mm (SD = 2.20. N = 9), and for the figure identity strategy it was 14.5 mm (SD = 2.11. N = 9): t(16) = 4.77, *p* = 0.00.

Location strategies

Hands/fingers establishing a route. Four males and four females [mean age 40.3 years; congenital and early blindness; categories 4 and 5 in the ICD-10 (WHO, 2017)] reported, very spontaneously, ‘hand/finger formation’, ‘hand/finger measurement’, ‘hand/finger movement’ (including repeated hand/finger formation, measurement, and movement), ‘reasoning’, ‘gefühl’, ‘guess’, ‘intuition’, and ‘qualified guess’. One individual summed it up as: ‘You just use everything that you’ve got.’

Some individuals established their route from the target position to the surrounding frame, others from the surrounding frame to the target position, depending more on personal strategy than on the target position. They typically made one horizontal and one vertical route, starting with the shortest one: discovering/locating the target position where the two routes met. Thus, a conjunction of horizontal and vertical cues was ranked as the most important target-locating cue.

The same cue was reported horizontally and vertically in 92.9% of all trials. Hand/finger measurement (including repeated hand/finger measurement) was the most important cue conjunction (51.2%). These individuals then reported, less spontaneously, e.g. ‘Four fingers from left (frame wall). From wrist bones to index fingertip from bottom (frame wall)’, ‘Number of finger joints from right (frame wall). Number of fingertips from bottom (frame wall)’, and ‘Two finger widths from bottom (frame wall). Two finger widths from right (frame wall).’

Reasoning (including gefühl, guess, intuition, and qualified guess) was ranked as the second most important conjunction of horizontal and vertical cues (26.8%), hand/finger formation (including repeated hand/finger formation) as the third (9.4%), and hand/finger movement (including repeated hand/finger movement) as the least important (5.5%). These individuals then reported, less spontaneously, e.g. (reasoning) ‘First line, first letter in a standard braille text’, (repeated hand/finger formation) ‘It (target position) is the bottom right corner of my “finger square"’, and (repeated hand/finger movement) ‘Thumb on (target) position. Index finger (moving) from thumb to top (frame wall) and from thumb to right (frame wall).’

Different cues were reported horizontally and vertically in 7.1% of all trials, e.g. ‘hand/finger measurement and reasoning’. These individuals then reported, less spontaneously, e.g. (hand/finger measurement + reasoning) ‘Two finger widths from bottom (frame wall). In the bottom right corner (of the frame)’, (repeated hand/finger measurement + gefühl) ‘I repeated one finger length diagonally towards upper left corner of the frame. I had gefühl for the target position from bottom and from right (frame walls)’, and (hand/finger measurement + qualified guess) ‘Four fingers from left (frame wall). Fifth-sixth line from the top in a braille text.’ (Cf. Figure 2.)

<table>
<tr><th rowspan="2"></th><th colspan="18">Trials</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th><th>16</th><th>17</th><th>18</th></tr>
<tr><td>I1</td><td colspan="2">H/F ME + R</td><td>H/F ME + H/F ME</td><td>H/F ME + MP</td><td colspan="2">H/F ME + H/F ME</td><td colspan="2">H/F ME + MP</td><td colspan="2">H/F ME + R</td><td colspan="4">H/F ME + H/F ME</td><td>H/F ME + G</td><td colspan="2">H/F ME + H/F ME</td><td>H/F ME + H/F MO</td></tr>
<tr><td>I2</td><td colspan="6">Re H/F MO + Re H/F MO</td><td>Re H/F MO + Re H/F FO</td><td>Re H/F FO + Re H/F FO</td><td>Re H/F MO + Re H/F FO</td><td>Re H/F FO + R</td><td>Re H/F FO + Re H/F FO</td><td>Re H/F FO + Re H/F MO</td><td>Re H/F FO + Re H/F FO</td><td colspan="4">Re H/F FO + Re H/F MO</td><td>Re H/F FO + Re H/F FO</td></tr>
<tr><td>I3</td><td>R + R</td><td>QG + QG</td><td>H/F ME + QG</td><td>▬</td><td>H/F ME + I</td><td>R + R</td><td>H/F ME + R</td><td>QG + QG</td><td>H/F ME + H/F ME</td><td>R + R</td><td>H/F ME + H/F ME</td><td colspan="2">R + R</td><td>H/F ME + H/F ME</td><td>R + R</td><td>H/F ME + QG</td><td>H/F ME + H/F ME</td><td>R + R</td></tr>
</table>

Figure 2. Hands/fingers establishing a route

G	Guess	MP	Mental Photo
H/F FO	Hand/Finger FOrmation	QG	Qualified Guess
H/F ME	Hand/Finger MEasurement	R	Reasoning
H/F MO	Hand/Finger MOvement	Re	Repeated
I	Intuition	▬	Missing value

- I1: Congenital light perception. Braille experience ~60 years. Male.
- I2: Congenital minimal colour perception. Braille experience ~40 years. Female.
- I3: Early total blindness. Braille experience ~20 years. Female.

These eight individuals described a very similar location strategy:

- *Routeing.* Establishing a preliminary route, both horizontally and vertically, between the target position and external anchor points or vice versa, depending on personal strategy: the target position is discovered/located where the horizontal route and the vertical route meet. A conjunction of horizontal and vertical cues is ranked as the most important target-locating cue [i.e. hand/finger measurement + hand/finger measurement (including repeated hand/finger measurement)]. Next, the routing strategy performs a specific analysis of the preliminary route both horizontally and vertically, starting with the shortest one.

Mental photo/room establishing a global view. Five males and five females [mean age 52 years; congenital and early blindness; categories 4 and 5 in the ICD-10 (WHO, 2017)] reported, very spontaneously, ‘mental photo’ and ‘mental room’. One of them clarified this by saying: ‘You can look at and check your mental photo, while you can move around inside your mental room.’ Another individual explained the mental photo, stating: ‘I can feel the frame, the actual figure (target), and the surrounding figures (distractors) on my hands also when I remove them. Then I just copy this on to the blank sheet’.

The mental photo/room included, for some individuals, the entire array and, for others, the most important part of the array, depending more on personal strategy than on the target position. They reported the target, the surrounding frame, and sometimes the distractors – ‘The important figures and frame walls are very clear … the rest is vague, or even not included’. They also reported mental horizontal and mental vertical lines (parallel to the frame walls), mental diagonal lines and/or mental areas, e.g. ‘I’m using a mental triangle: the (mental) baseline goes from the right to the bottom frame wall. The figure (target) is the (mental) angle (i.e. the tip) mirroring the bottom right corner (tip) of the frame.’

A mental photo/room was reported in 49.7% of all trials. Two individuals summed it up as: ‘Distance is a feeling, not a movement nor a measurement by counting’, and ‘I don’t do number of fingers, length of fingers, or any of that. I’m being practical!’

If the mental photo/room was not enough by itself (50.3%), then these individuals reported, less spontaneously, ‘reasoning’, ‘gefühl’, ‘guess’, ‘intuition’, and/or ‘qualified guess’ (26.9%) or ‘hand/finger formation’, ‘hand/finger measurement’ and/or ‘hand/finger movement’ (including repeated hand/finger formation, measurement and/or movement) guided by the mental photo/room and/or by reasoning (23.4%). Examples are:

- [mental photo of (mental) horizontal midline, (mental) vertical midline, and bottom frame wall + reasoning] ‘Diagonally from the middle towards the bottom right corner (of the frame)’,

- [mental photo of all frame walls, one distractor (to the left and above the target position), and mental vertical midline + reasoning] 'A bit to the left of the (mental) midline … further down and to the right of that one (distractor)',
- (mental photo of bottom right corner of the frame + reasoning) 'In bottom half of the frame; in right corner (of the frame)',
- (mental photo of the entire array + intuition) 'I just knew where to place it!',
- (mental photo of top, right, and left frame walls + repeated hand/finger measurement guided by the mental photo) 'Both middle fingertips on top (frame wall). Left pinkie stretched out to the left (frame wall) and right pinkie to the right (frame wall). It (target) is located where my index fingertips meet', and
- (mental photo of top frame wall + hand/finger measurement guided by reasoning) 'Close to top (frame wall), in the middle (along the top frame wall). One fingertip down from top (frame wall).'

(Cf. Figure 3.)

	Trials																	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Mental photo/room +																		
I4				—														
I5						GE	—	GE	H/F FO	GE	H/F MO	GE		Re H/F MO	I	H/F MO	—	I
I6	R + GE		R + Re H/F MO	I			R + GE	I	Re H/F FO	R	I	R + GE	R	Re H/F MO + I	R	Re H/F ME	R + Re H/F MO	Re H/F MO

Figure 3. Mental photo/room establishing a global view

GE	GEfühl	I	Intuition
H/F FO	Hand/Finger FOrmation	R	Reasoning
H/F ME	Hand/Finger MEasurement	Re	Repeated
H/F MO	Hand/Finger MOvement	—	Missing value

- I4: Congenital total blindness. Braille experience ~70 years. Female.
- I5: Congenital minimal colour perception. Braille experience ~35 years. Female.
- I6: Early light projection. Braille experience ~45 years. Female.

Hands/fingers were used as external props: ‘The frame is my photo. I’m holding it in my hands, while I’m sketching in the (target) location.’ As an example, one individual placed both her left and right thumbs on the record sheet’s centre point. The other fingers were stretched out to reach the left and right frame walls. ‘This is the clock. My fingers are the time tellers.’ She then moved both hands simultaneously as time tellers; the left-hand fingers from 9 to 12 o’clock position and the right-hand fingers from 3 to 6 o’clock.

Some individuals reported that their mental photo/room might become vague, e.g. ‘… the Us (distractors) are so close together’. One individual explained that when this happens: ‘I reconstruct my mental photo by reasoning about it and estimating (the target) position. ... In bottom left corner (of the frame), I remember that, and diagonally upwards.’

These ten individuals also described the same location strategy:

- *Global view*. Establishing and retrieving a global mental photo/room of either the entire area or of its most important part, depending on personal strategy, covering the target and relevant external anchor points. One separate cue (i.e. mental photo/room) is ranked as the most important target-locating cue. Next, if found necessary, the global view strategy performs a specific analysis of the mental photo/room: now ranking a cue conjunction as the most important target-locating cue [i.e. mental photo/room + reasoning (including gefühl, guess, intuition, and qualified guess). If found ecessary, the global view strategy reconstructs the mental photo/room by reasoning about it and estimating the target position.

Visual experience. Individual 7 (congenital minimal visual shape perception) reported combining haptic touch and vision. He used haptic touch for detecting and identifying the target, and then fixated vision on his signalled target position. When locating target position, Individual 7 inserted his index finger(s) from the surrounding frame wall(s) into the record sheet until they reappeared in his fixated visual field, e.g. ‘... according to length and width of my hands, I inserted both index fingers vertically into the field that I had fixated vision on’.

Individuals 8 (recent total blindness), 9 (recent light projection), and 10 (total blindness at ~5 months old) reported, very spontaneously, ‘mental photo’. Individuals 8 and 9 also used visual mental images: Individual 8 described black spots on a white background and

Individual 9 said (in Trial 3) that 'I imagined the (target) position visually, found the centre of the frame, and looked downwards along the (mental) midline. I didn't use touch at all.' (Cf. Figure 4.)

<table>
<tr><th rowspan="2"></th><th colspan="18">Trials</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th><th>16</th><th>17</th><th>18</th></tr>
<tr><td colspan="19">Fixated visual field +</td></tr>
<tr><td>I7</td><td>I</td><td>MP</td><td>—</td><td>MP</td><td>H/F ME</td><td>R</td><td>MP</td><td>—</td><td>G</td><td>R</td><td>H/F ME</td><td>—</td><td colspan="2">H/F ME</td><td>R + I</td><td>H/F ME</td><td>Re H/F MO</td><td>H/F ME</td></tr>
<tr><td colspan="19">Mental photo +</td></tr>
<tr><td>I8</td><td colspan="2">Re H/F FO</td><td>—</td><td>GE</td><td>R + H/F MO</td><td>H/F MO</td><td colspan="3">—</td><td>H/F MO</td><td>—</td><td>GE</td><td>I</td><td>GE</td><td>H/F MO</td><td>—</td><td>Re H/F MO</td><td>—</td></tr>
<tr><td>I9</td><td>I</td><td>H/F ME</td><td></td><td colspan="2">—</td><td></td><td>Re H/F MO</td><td>GE</td><td>H/F ME</td><td>H/F ME + I</td><td>H/F ME</td><td colspan="2">Re H/F MO + H/F ME</td><td>R</td><td>I</td><td>QG</td><td>H/F ME</td><td>R</td></tr>
</table>

Figure 4. Visual experience

GE	GEfühl	MP	Mental Photo
G	Guess	R	Reasoning
H/F FO	Hand/Finger FOrmation	Re	Repeated
H/F ME	Hand/Finger MEasurement	QG	Qualified Guess
H/F MO	Hand/Finger MOvement	—	Missing value
I	Intuition		

- I7: Congenital minimal visual shape perception. Braille experience ~25 years. Male.
- I8: Recent total blindness. Braille experience ~22 months. Female.
- I9: Recent light projection. Braille experience ~30 months. Female.

Individual 11 (recent total blindness – 8 months ago) began by reporting ‘gefühl’, ‘intuition’, and ‘reasoning’, e.g. (intuition) ‘From bottom frame wall, plus three mental vertical lines’ and (reasoning) ‘More in the middle (of the frame), than the other ones (distractors)’. She then reported (from Trial 11) repeating her hand/finger movement; using length of movement for short distances and speed for long distances, and hand/finger measurement, e.g. ‘I repeated the speed from left and right (frame walls), and the number of index fingertips from top (frame wall)’ (right plus left, right plus left etc.).

Individuals 7, 8, and 9 described yet another location strategy:

- *Touch vision.* Establishing through haptic touch either a route or a global view, depending on personal strategy. Next, the touch vision strategy fixates a visual field or mental photo/room on the target position and relevant external anchor points. If found necessary, the touch vision strategy performs a specific analysis of hand/finger formation, measurement and/or movement. It is not clear how target-locating cues are ranked in order of importance.

Location strategies – location time and accuracy. The present study identified three (Phase 2) location strategies. In short, the routing strategy establishes a preliminary route, both horizontally and vertically, between the target position and external anchor points or vice versa: the target position is discovered/located where the horizontal route and the vertical route meet. It ranks a conjunction of horizontal and vertical cues [i.e. hand/finger measurement + hand/finger measurement (including repeated hand/finger measurement)] as the most important target-locating cue. Next, it performs a specific analysis of the preliminary route both horizontally and vertically, starting with the shortest one, e.g. ‘Four fingers from left (frame wall). From wrist bones to index fingertip from bottom (frame wall)’. The global view strategy, in contrast, establishes and retrieves a global mental photo/room of either the entire area or of its most important part: ‘I can feel the frame, the actual figure (target), and the surrounding figures (distractors) on my hands also when I remove them. Then I just copy this on to the blank sheet.’ It ranks one separate cue (i.e. mental photo/room) as the most important target-locating cue. Next, if necessary, it performs a specific analysis of the mental photo/room. It now ranks a cue conjunction [i.e. mental photo/room + reasoning (including gefühl, guess, intuition, and qualified guess)] as the most important target-locating cue, e.g. [mental photo of (mental) horizontal midline, (mental) vertical midline, and bottom frame wall + reasoning] ‘Diagonally from the middle towards the bottom right corner (of the frame)’. If necessary, the global view strategy reconstructs the mental photo/room, by reasoning about it and estimating the target position, e.g. ‘In bottom left corner (of the frame), I remember that, and diagonally upwards.’ The third location strategy, i.e. the touch vision strategy, establishes through haptic touch either a route or a global view. Next, the touch vision strategy fixates a visual field or mental photo/room on the target position and relevant external anchor points. If necessary, it performs a specific analysis of the hand/finger formation, measurement and/or movement, e.g. '... according to length and width of my hands, I inserted both index fingers vertically into the field that I had fixated vision on' and 'I imagined the (target) position visually, found the centre of the frame, and looked downwards along the (mental) midline. I didn't use touch at all.' It is not yet clear, however, what target-locating cue(s) the touch vision strategy ranks as the most important so this location strategy was not included in the statistical analyses. Two more participants were also not included: Individual 10 who described the global view strategy (in 100% of all trials), but who had experience in visual shape recognition, and Individual 11 who seemed to have used the global view strategy, but who did not report 'mental photo' or 'mental room'.

Consistent with Treisman's theory [cf. for example Treisman, 1995; Treisman & Paterson, 1984; Treisman et. a.l., 1992 (See Wolfe & Robertson, 2012 for a review)], separate cues would be processed in pre-attention – fast and accurately – and cue conjunctions in focussed attention – slowly and inaccurately. The global view strategy is therefore likely to put the least load on attention; it will be the fastest and the most accurate in (Phase 2) discovering/locating the target position.

Mean location time for the global view strategy was 6.6 seconds (SD = 4.37. N = 10), and for the routeing strategy it was 7.9 seconds (SD = 4.36. N = 8). The difference between the two was tested using a t-test and found not to be statistically significant: $t(16) = -0.60$, $p = 0.56$. Mean diagonal distance from the correct target position to the participants' location mark for the global view strategy was 20.0 mm (SD = 3.88, N = 10), and for the routeing strategy it was 17.1 mm (SD = 5.60, N = 8). Also this differenc between the two was tested using a t-test and found not to be statistically significant: $t(16) = 1.29$, $p = 0.22$.

Adopted discrimination and location strategies

In short, the (Phase 1) global characteristics strategy and the (Phase 2) global view strategy both rank one separate (Phase 1) target-discriminating feature [i.e. dot location or shape property (Graven, 2015, 2016a, cf. also Graven, 2016b)] and (Phase 2) target-locating cue (i.e. mental photo/room) as the most important. Both the (Phase 1) figure identity strategy and the (Phase 2) routing strategy, in contrast, rank a conjunction of (Phase 1) target-discriminating features [i.e. dot location + dot quantity (Graven, 2015, 2016a, cf. also Graven, 2016b)] and (Phase 2) target-locating cues [i.e. hand/finger measurement + hand/finger measurement (including repeated hand/finger measurement)] as the most important. It is not yet clear what target-discriminating feature(s) the (Phase 1) touch vision strategy ranks as the most important (Graven, 2015, 2016a, cf. also Graven, 2016b), and also not what target-locating cue(s) the (Phase 2) touch vision strategy ranks as the most important so neither the (Phase 1) discrimination strategy nor the (Phase 2) location strategy was included in the statistical analyses.

Indeed, if individuals who are blind adopt the same strategy for ranking (Phase 1) target-discriminating features and (Phase 2) target-locating cues in order of importance; they will adopt either the (Phase 1) global characteristics strategy and (Phase 2) global view strategy or the (Phase 1) figure identity strategy and (Phase 2) routing strategy.

Five of nine individuals adopted the (Phase 1) global characteristics strategy and (Phase 2) global view strategy, and four of nine adopted the (Phase 1) figure identity strategy and (Phase 2) routing strategy. Indeed, 50% adopted the same strategy for ranking (Phase 1) target-discriminating features and (Phase 2) target-locating cues in order of importance, i.e. not significantly above the chance level (of 50%): χ^2 (1. N = 18) = 0.00, *p* = 1.00 (cf. Figure 5).

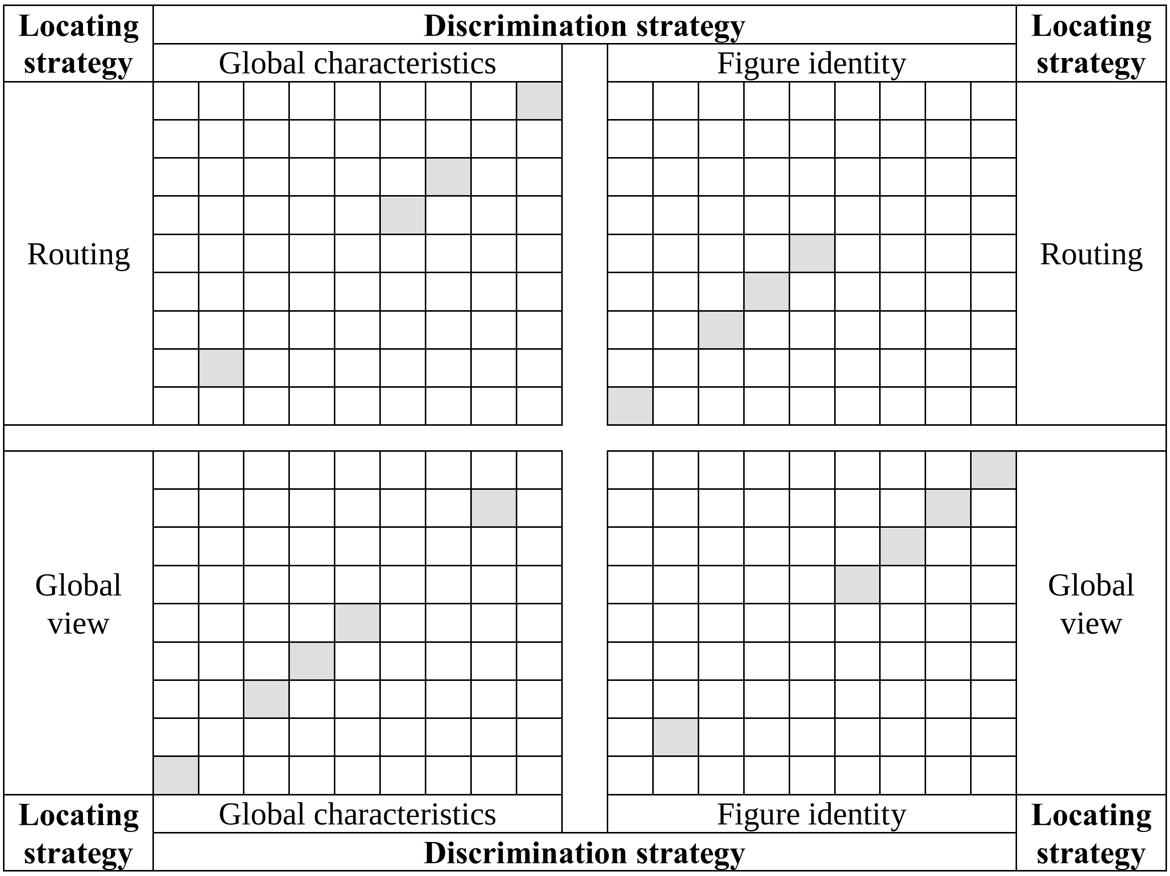


Figure 5. Adopted discrimination and location strategies

One individual. N = 18

Global characteristics strategy + global view strategy = 5 individuals

Global characteristics strategy + routing strategy = 4 individuals

Figure identity strategy + global view strategy = 5 individuals

Figure identity strategy + routing strategy = 4 individuals

Discussion

The present study investigated the relationship between Phase 1 and Phase 2 of the location process: Phase 1 is to detect and identify the target; Phase 2 is to discover its position.

The accuracy in Phase 2 was affected by which discrimination strategy was adopted in Phase 1; the location time (Berlá et al., 1976) was not. In fact, the (Phase 1) global characteristics strategy was the significantly most accurate in Phase 2; ranking one separate feature (i.e. dot location or shape property) as the most important target-discriminating feature, it carries the least attentional load from Phase 1 to Phase 2 (Graven, 2015, 2016a; Postma et al., 2007; Wolfe & Robertson, 2012). Further research is needed to investigate whether location time (Berlá et al., 1976) and accuracy are affected by which separate target-discriminating feature is ranked as the most important, i.e. dot location or shape property (Graven, 2015, 2016a). Could it be that dot location is dominant over shape property – that the location process as a whole is facilitated by an overall attention to location (cf. Tsal & Lavie, 1993)? If so, then the (Phase 2) within-group variability in the global characteristics strategy may be explained by the fact that some individuals ranked shape property as the most important target-discriminating feature in Phase 1 (Graven, 2015, 2016a, cf. also Graven, 2016b).

Three location strategies were identified in Phase 2: the routeing strategy, the global view strategy, and the touch vision strategy. The routing strategy is in line with Postma et. al.’s (2007) suggestion that individuals who are blind describe a route. Moreover, the routing strategy embraces three of the five exploratory strategies observed by Ungar, Blades, and

Spencer (1995), i.e. the edge and relative strategy, the relative strategy, and the edge strategy: all of which used hand/finger measurements and hand/finger movements. Interestingly, Ungar et. al. (1995) observed that the more experienced children in using haptic touch most often adopted the relative strategy: relating the shapes to each other and not to the surrounding frame. Also Postma et. al. (2007) found that, when describing the target position, the most experienced adults in using haptic touch referred more to other shapes (e.g. 'the triangle was right of the cross') than those with little or no experience, who used more board referrals [e.g. 'the cross was the top left of the board' (p. 1259)]. In a related vein, when all individuals are experienced adults in using haptic touch, the present study found that some individuals established their route from the target position to the surrounding frame, others from the surrounding frame to the target position, depending more on personal strategy than on the target position: hand/finger measurement being the most important target-locating cue. For example, 'Four fingers from left (frame wall). From wrist bones to index fingertip from bottom (frame wall)' (congenital blindness). It is worth noticing, however, the differences in display shape, display size, and number of target positions: circle, 340 mm diameter, three and five target positions in Ungar et. al. (1995); rectangle, 455 × 302 mm, ten target positions in Postma et. al. (2007), and square, 210 × 210 mm, one target position in the present study. Further research is needed to investigate how many target positions in a route the routing strategy is capable of discovering/locating, and also whether number of positions and/or amount of experience in using haptic touch affect its ranking of target-locating cues in order of importance. (Cf. for example Millar, 1994; 2008; Postma et. al., 2007; Ungar et al., 1995; Wolfe & Robertson, 2012.)

The global view strategy seems to take a map-like bird's-eye view, thus contradicting Postma et. al.'s (2007) suggestion that individuals who are blind describe a route, and that those who are blindfolded describe a map-like bird's-eye view. Essentially, the map-like bird's-eye view taken by the global view strategy seems to be based on tactile imprints on the hands: 'I can feel the frame, the actual figure (target), and the surrounding figures (distractors) on my hands also when I remove them' (congenital blindness). It is again worth noticing the differences in display shape, display size, and number of target positions: rectangle, 455 × 302 mm, ten target positions in Postma et. al. (2007), and square, 210 × 210 mm, one target position in the present study. Further research is needed to investigate whether the map-like bird's-eye view is adopted only for displays of a certain shape, size and/or number of target positions. Moreover, the global view strategy is in line with Cornoldi, Tinti, Mammarella, Re, and Varotto (2009) who suggested that individuals with no visual experience may adopt alternative imagery strategies. Further research is needed to investigate whether these strategies are verbal (cf. for example Cornoldi et al., 2009; Schmidt, Tinti, Fantino, Mammarella, & Cornoldi, 2013), or whether they in fact could be tactile, as the present study suggests:

‘The frame is my photo. I’m holding it in my hands, while I’m sketching in the (target) location’ (congenital blindness).

When it comes to the touch vision strategy, further research is needed to investigate how it ranks target-locating cue(s) in order of importance. Additional, research is needed to investigate for how long the visual mental images are maintained and used, and also whether and, if so, how they develop into verbal and/or tactile mental imagery strategies (cf. for example Bagnara, Simon, Tagliabue, & Umiltà, 1988; Cornoldi et al., 2009; Graven, 2003, 2004, 2005; Hull, 1991; Kosslyn, 1994; Schmidt et al., 2013). As a case in point, ‘I imagined the (target) position visually, found the centre of the frame, and looked downwards along the (mental) midline. I didn’t use touch at all’ (recent blindness).

Based on how target-locating cues are ranked in order of importance, the routing strategy and the global view strategy operate on opposite ends of Treisman’s (1995) continuum of attention. The global view strategy, which ranks one separate target-locating cue as the most important, operates on the pre-attention end; and the routing strategy, which ranks a conjunction of horizontal and vertical cues as the most important, operates on the focused attention end. However, neither the location time (Berlá et al., 1976) nor the accuracy was affected by which location strategy was adopted. Then again, the global view strategy had to focus attention in half the cases, now ranking a cue conjunction as the most important target-locating cue, sliding from the pre-attention end to the focused attention end on Treisman’s (1995) continuum of attention. Further research is needed to investigate whether and, if so, how the location time (Berlá et al., 1976) and accuracy are affected when the location strategy shifts from one end to the other on Treisman’s (1995) continuum of attention.

Finally, 50% adopted the same strategy for ranking (Phase 1) target-discriminating features and (Phase 2) target-locating cues in order of importance: they needed the same amount of attention in Phase 1 and Phase 2 of the location process. However, half of those who adopted the (Phase 1) global characteristics strategy adopted the routing strategy in Phase 2: they needed focused attention when discovering/locating the target position, and half of those who adopted the (Phase 1) figure identity strategy adopted the global view strategy in Phase 2: they needed focused attention when detecting and identifying the target. (Cf. Graven, 2015, 2016a, 2016b; Wolfe & Robertson, 2012.)

In teaching, it is important to acknowledge that there are different strategies both (Phase 1) for detecting and identifying the target – and the external anchor points, and (Phase 2) for discovering/locating the target position(s), and also that which strategy is adopted in each phase depends on whether pre or focused attention is needed.

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