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Note

Congenital blindness leads to enhanced vibrotactile perception

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ABSTRACT

Previous studies have shown that in comparison with the sighted, blind individuals display superior non-visual perceptual abilities and differ in brain organisation. In this study, we investigated the performance of blind and sighted participants on a vibrotactile discrimination task. Thirty-three blind participants were classified into one of three groups (congenital, early, late), depending on the age at which they became blind. Consistent with previous neuroimaging data, individuals blinded after late childhood (14 years) showed no advantage over sighted participants. Both the congenitally- and early-blind participants were better than the sighted. The congenitally blind participants were even more accurate than the early-blind participants; a distinction that has not been drawn previously. Duration of blindness did not predict task performance and the effect of onset age persisted after duration of daily Braille reading was accounted for. We conclude that complete visual deprivation early in life leads to heightened tactile acuity.

1. Introduction

Deprived of any visual input, blind individuals are forced to rely on other sensory modalities, such as audition and touch. This increased reliance has been linked to superior perceptual abilities in these modalities in blind relative to sighted individuals (Goldreich & Kanics, 2003; Gougoux et al., 2004). Different patterns of brain activation have also been observed in blind individuals during audition and tactile tasks, likely underlying the superior performance of the blind (Sadato et al., 1996; Weeks et al., 2000). Similarly, blindfolding sighted individuals for a period of five-days has been shown to lead to changes in the occipital cortex (e.g., Merabet et al., 2008).

The assessment of tactile perception skills in blind individuals has posed several challenges. Most studies have used Braille or Braille-like dots (Sadato et al., 1996), which require participants to actively scan the stimuli with their fingers. One limitation of these tasks is that blind and sighted individuals may employ different motor strategies to make sense of the material. It is also challenging to match blind and sighted participants on Braille reading experience as sighted Braille instructors typically learn to read Braille visually, rather than by touch (Pascual-Leone, Theoret, Merabet, Kauffman, & Schlaug, 2006).

To address confounds associated with Braille reading experience, recent studies have used a grating orientation task to assess tactile abilities. For example, Van Boven, Hamilton, Kauffman, Keenan, and Pascual-Leone (2000) reported that grating orientation thresholds were lower in blind compared to sighted participants. Similarly, Goldreich and Kanics (2006) found that blind participants were able to perceive thinner grooves compared to their sighted participants. The perception of grating or dot patterns, however, requires judgements about the spatial properties of the stimuli, which may be superior in the blind due to Braille reading experience. As an alternative, vibrotactile discrimination tasks may allow blind and sighted participants to have similar levels of experience as they do not require spatial discrimination judgments.

Despite their advantage, vibrotactile tasks have not been commonly used and performance differences associated with varying levels of task difficulty remain unexplored. Burton, Sinclair, and McLaren (2004) tested blind and sighted participants on a task that was intended to yield near-perfect discrimination (25 Hz vs 100 Hz). Most of the participants performed at ceiling levels demonstrating that the task could be adequately performed by both blind and sighted individuals. Further investigation of vibrotactile discrimination is warranted in blind and sighted individuals using a greater range of task difficulty levels.

The timing of blindness onset during development may determine the degree of sensory enhancement in the non-visual modalities (Neville & Bavelier, 2002). Neuroimaging studies of Braille reading show that individuals blinded after 14–16 years

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show no evidence of cross-modal (occipital) activation compared to those blinded earlier (Cohen et al., 1999; Sadato, Okada, Honda, & Yonekura, 2002). Contrasting with this, however, there is evidence implicating the role of the occipital cortex in non-visual processing even among sighted individuals. After being blindfolded for five consecutive days, TMS over the occipital cortex of sighted participants disrupted Braille character recognition (Merabet et al., 2008).

Very few behavioural studies have directly examined the timing of blindness onset, and the results have been mixed. For example, Grant, Thiagarajah, and Sathian (2000) failed to find any effects of blindness onset age on the discrimination of dot patterns and gratings. Similar stimuli were used in a study by Stilla et al. (2008), who also reported no performance differences between early- and late-blind individuals. However, this study may have been underpowered due to the relatively small sample size ($n = 5$) of the groups. In contrast, Heller (1989) reported that late-blind individuals were better than congenitally blind or sighted individuals at tactile picture identification, whereas congenitally blind individuals were superior at making tactile temporal order judgments (Röder, Rösler, & Spence, 2004). Unlike previous studies, the task used by Röder et al. did not require spatial discrimination judgements and thus, was less likely to be affected by differences in practice associated with Braille reading.

The aim of the present study was to assess tactile acuity in blind and sighted individuals on an unfamiliar vibrotactile task. We also compared performance in individuals blinded at three phases of development (congenital, early-onset, late-onset) to assess whether vision during childhood influences vibrotactile perception in blind adults.

2. Method

2.1. Participants

A total of 33 blind participants participated in the study. Depending on the onset age of complete vision loss, participants were classified into one of three blindness groups: congenital-, early-, and late-onset, with 11 participants in each group. The congenitally blind participants (aged 19–63 years) were born blind or became blind soon after birth (see Table 1 for onset details). The early-blind participants (aged 25–53 years) became completely blind between the ages of 1.4–13 years. Based on the neuroimaging study by Cohen et al. (1999), we defined late-blind individuals as those who became completely blind after 14 years of age. Thus, our late-blind participants (aged 38–59 years) became completely blind between 14.5 and 54 years. Table 1 also presents the demographic characteristics and Braille reading history of the blind participants. At the time of testing, all blind participants had no pattern vision, minimal (or no) sensitivity to light, and no history of neurological disorders other than blindness. Although all of the blind participants were Braille literate, some of them relied mostly on aurally presented material through audio books and the internet (i.e., some did not read Braille daily). For each blind participant, there was an age and gender matched sighted control.

2.2. Vibrotactile device and procedures

Stimuli were suprathreshold sinusoidal vibration frequencies between 20 and 100 Hz. Peak-to-peak vibration amplitudes ranged from 0.41 mm for 100 Hz to 0.9 mm for 20 Hz and exceeded standard detection thresholds (Summers et al., 1997). Vibrotactile stimuli were produced by a vibration device that consisted of a control unit connected to two plastic response boxes (one for each hand) with three tactors mounted on each top. There was also a side mounted response button fitted to each box. Each tactor was made of a 1.5 cm diameter distensible latex rubber diaphragm. For each hand, the thumb was placed on the response button, while the index, third, and fourth fingers were placed on each rubber diaphragm. The control unit interfaced with a computer and powered six solenoids which determined the rate of vibration of the tactors. These solenoid coils activated six lightweight neodymium iron boron magnets situated under the rubber diaphragms.

Table 1
Demographic, medical, and Braille reading characteristics of the blind participants.

Participant	Cause of blindness	Age of blindness onset (years)[a]	Age at testing (years)	Gender	Years reading Braille	Daily Braille reading (hours)
Con 1	Retinopathy of prematurity	0	31	M	25	4+
Con 2	Retinopathy of prematurity	0.3	22	M	16	2–3
Con 3	Congenital cataracts	0.3	63	M	57	2–3
Con 4	Malformed eyes	0	36	F	30	1–2
Con 5	Retinopathy of prematurity	0.2	26	F	20	3–4
Con 6	Congenital detached retina	0	26	F	20	0–1
Con 7	Congenital cataracts	0	33	M	27	1–2
Con 8	Retinopathy of prematurity	0.2	21	F	15	1–2
Con 9	Retinopathy of prematurity	0.2	55	F	49	1–2
Con 10	Retinopathy of prematurity	0	19	M	13	0–1
Con 11	Retinoblastoma	0.2	35	F	29	1–2
Early 1	Retinitis pigmentosa	11	52	M	46	2–3
Early 2	Retinoblastoma	5	40	F	34	2–3
Early 3	Detached retina	1.4	48	F	42	1–2
Early 4	Retinoblastoma	1.5	36	F	30	1–2
Early 5	Retinitis pigmentosa	13	53	M	47	3–4
Early 6	Congenital glaucoma	12	38	M	25	0–1
Early 7	Detached retina	8	25	M	17	0–1
Early 8	Detached retina	9	48	M	39	2–3
Early 9	Detached retina	13	48	M	34	2–3
Early 10	Retinitis pigmentosa	12	43	F	30	0–1
Early 11	Retinopathy of prematurity	1.5	35	M	29	1–2
Late 1	Detached retina	14.5	44	M	29	0–1
Late 2	Cataracts	24	39	F	32	4+
Late 3	Retinitis pigmentosa	20	48	F	34	0–1
Late 4	Impact injury	54	59	M	33	0–1
Late 5	Impact injury	27	54	M	10	0–1
Late 6	Retinitis pigmentosa	33	46	F	13	0–1
Late 7	Retinopathy of prematurity	33	50	F	40	1–2
Late 8	Retinopathy of prematurity	25	50	F	33	1–2
Late 9	Retinitis pigmentosa	18.5	38	F	22	0–1
Late 10	Detached retina	31	40	F	20	0–1
Late 11	Glaucoma	17.5	42	M	28	0–1

Con = congenitally blind; Early = early-blind; Late = late-blind.

[a] The exact time of complete blindness for some of the ROP participants was not known, as their parents were only informed of the extent of vision loss when the participants were discharged from hospital. Thus, the blindness onset age reported for individuals with ROP reflects the age at discharge, rather than the exact time of blindness.