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Superior verbal abilities in congenital blindness

Valeria Occelli[1], Simon Lacey[1], Careese Stephens[1,2] and Krish Sathian[1,2]; [1]Department of Neurology, Emory University School of Medicine; Atlanta, GA; [2]Center for Visual and Neurocognitive Rehabilitation; Atlanta VAMC, Decatur, GA

Abstract

Numerous studies have found that congenitally blind individuals have better verbal memory than their normally sighted counterparts. However, it is not known whether this reflects a superiority of verbal abilities or of memory abilities. In order to distinguish between these possibilities, we tested congenitally blind participants and age-matched, normally sighted control participants on verbal and spatial memory tasks, as well as on verbal fluency tasks and a spatial imagery task. Congenitally blind participants were significantly better than sighted controls on the verbal memory and verbal fluency tasks, but not on the spatial memory or spatial imagery tasks. Thus, the congenitally blind have superior verbal, but not spatial, abilities. This may be related to their greater reliance on verbal information and to the growing literature endorsing involvement of visual cortex in language processing in the congenitally blind.

Introduction

A number of studies have shown that congenitally blind people perform better than normally sighted controls on a range of verbal memory tasks, including tests of short- and long-term recall [1,2] and recognition [1,3], and memory for serial word order [4]. However, it is unknown whether this advantage of the congenitally blind on verbal memory performance generalizes to other cognitive domains. One hypothesis is that congenital blindness heightens verbal abilities generally, perhaps because of increased reliance on verbal inputs in the absence of vision. An alternative hypothesis might be that congenitally blind people develop superior memory abilities across both verbal and non-verbal domains. In order to distinguish these possibilities, we compared congenitally blind adults with sighted control participants, matched for age, on a range of verbal and non-verbal tasks. The tasks included tests of verbal and spatial memory to assess whether congenital blindness confers superiority only for verbal memory, or also for a non-verbal memory domain. To assess whether any superiority of the congenitally blind in each of these memory domains is restricted to the sphere of memory, or generalized to non-memory spheres, we included tests of verbal fluency and a test of spatial imagery. Here we present a preliminary report of our findings.

Methods

Participants

Eight congenitally blind (5 female) and eight sighted (6 female) participants took part in the study. Three of the congenitally blind participants had minimal residual light perception while the remaining had no light perception. Blindness resulted from a variety of ocular causes. Blind and sighted control participants were matched for age (mean age (±s.d.) 43.1 ± 16.6 and 43.6 ± 18.3 years, respectively, $t_{14} = -.06$, $p = .9$) but differed slightly in years of education (blind 17.4 ± 2.1 years, sighted 15.3 ± 1.8 years, $t_{14} = 2.2$, $p = .047$). All participants spoke American English as their main language and reported normal hearing. None had a history of neurological or psychiatric illness; all participants were right- or preferentially right-handed. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Emory University Institutional Review Board. All participants gave their informed consent prior to the study and received monetary compensation for their participation. Braille versions of the consent documents were provided for blind participants.

Procedures

The battery of tests was administered in three sessions. In session 1, participants performed a verbal memory task with immediate testing of recall (timepoint = T1), verbal fluency tasks, and a spatial imagery task. In session 2, after 24-48 hours, participants were tested for delayed recall on the verbal memory task (T2), and also underwent a spatial memory task. The testing took place in a quiet environment without external noise or distractions. 7-8 days after session 2, participants performed a further delayed recall test of verbal memory (T3) on the phone. Each task is described in detail below.

Verbal tasks

Verbal memory

Twenty concrete words and 20 abstract words were selected. Eighteen of the abstract words were included in an earlier study [1], and two additional ones with low imageability and concreteness values were chosen. Based on the MRC Psycholinguistic Database 2.0 [5,6], the abstract and concrete sets of words differed significantly in concreteness ($t_{35} = -35.57$; $p < .001$) and imageability ($t_{35} = -13.49$; $p < .001$), whereas they were comparable in length ($t_{38} = .84$; $p = .41$) and frequency ($t_{38} = .15$; $p = .88$). Two 20-word long lists were created, each consisting of 10 abstract and 10 concrete words. Each list was presented twice; the participants were asked to listen carefully and, in order to facilitate the encoding of the material, to repeat each word after they heard it. After 20-30 minutes, they were asked to recall as many words as they could remember from each list, in any order and with no time limit (T1). The scores obtained for the two separate lists at T1 were collapsed. At T2 and T3, they were asked to recall as many words as they could remember from the two lists, in any order and with no time limit. For each participant, the number of items correctly recalled for each word type (i.e., abstract vs. concrete) at each time point was scored and converted to a percentage.

Verbal fluency

Verbal fluency tests are time-limited tests, widely used in neuropsychological assessments [7], in which participants list as many words as they can beginning with a particular letter (letter fluency) or items belonging to a particular category (semantic fluency) [8]. They draw on both memory [9-12] and language [9,11,13,14] processing, although in this case the type of memory involved is rapid retrieval from long-term storage of well-learned information in the language domain.

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Participants were asked to generate, within 60 seconds, as many items as possible, starting with the letters 'F', 'A', and 'S' (letter fluency task) and, separately, belonging to the semantic categories 'animals', 'fruits', and 'musical instruments' (semantic fluency task). The total number of words produced (excluding repetitions, proper names, and same words with a different ending, i.e., ‘eat’ and ‘eating’) was scored.

Spatial tasks

Spatial memory

Spatial memory is usually assessed during neuropsychological testing using the Corsi block test [15]. We modified this test to accommodate blind participants by developing a haptic version, using a custom-built 5 x 5 matrix made of 5 x 5 removable plastic cubes (4 cm/side), with one face of each cube covered with sandpaper to facilitate easy haptic recognition. On each trial, four target cubes were arranged with the sandpapered side facing up. Participants were allowed 10 s to haptically explore the matrix with both hands and memorize the locations of the target cubes. 20 s after the exploration concluded, the participant was presented with a matrix with no target cubes and asked to point to the locations of the memorized target cubes. Each participant completed five training trials and ten experimental trials. During training and testing, the matrix was located behind a curtain, so that the task was based on purely haptic cues for both groups. A score of 1 was assigned for each target cube correctly remembered, and the percentage of recalled items was computed.

Spatial imagery

Spatial imagery is a form of mental imagery emphasizing spatial relationships [16]. We modified a spatial imagery task devised earlier in our laboratory [17]. The task used here required imagining a 5 x 5 matrix with a number (1 to 25) in each position. In order to help the participants to construct such a mental image, they underwent a training session using the haptic matrix described above, located behind a curtain so that the familiarization was based on purely haptic cues for both groups. For the actual spatial imagery task, participants completed 24 trials. They were asked to imagine the shape resulting from filling four cells in the matrix, cued by auditory four-number strings, and perform a same/different discrimination on the imagined shapes. On each trial, they heard two four-number strings, and responded whether the members of the pair were "same" or "different". Participants were prompted to base their decision on the shapes they constructed, ignoring their locations within the matrix: to this end, on "same" trials, the shapes were represented by different sequences of numbers, thus ensuring that the participants could not perform the task just by comparing the number strings. Accuracy was computed as the percentage of correct responses.

Results

Verbal tasks

Verbal memory

The percentages of items correctly recalled for each word type at each time point were calculated for each participant and submitted to a three-way repeated-measures ANCOVA with within-subjects factors of word type (abstract, concrete) and time point (T1, T2, T3) and the between-subjects factor of visual status (blind, sighted); with age and years of education as covariates. As Figure 1 shows, the blind participants had overall better performance (mean ± SEM : 35.9 ± 4.5%) than the sighted controls (20.1 ± 2.9%) ($F_{1,12}$ = 13.00, p = .004) after partialling out age (p = .02) and years of education (p = .29). There were no other main effects and no significant interactions involving visual status.

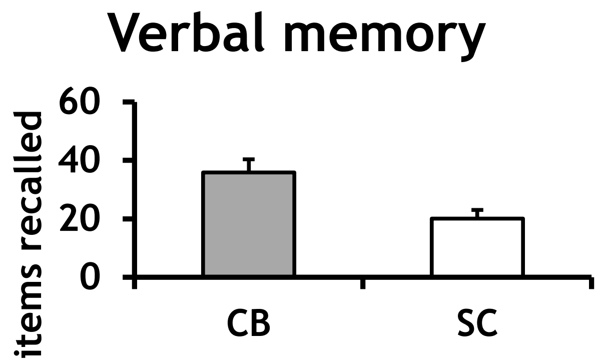

***Figure 1**. Overall verbal memory performance of congenitally blind (CB) and sighted control (SC) participants. Error bars: SEM.*

Verbal fluency

The total numbers of words generated by participants for the letter and the semantic fluency tasks were submitted to a repeated-measures ANCOVA with the within-subjects factor of task (letter, semantic) and the between-subjects factor of visual status (blind, sighted), with age and years of education as covariates. The main effect of visual status was significant ($F_{1,12}$ = 6.09; p = .03), indicating better performance of blind compared to sighted participants in both tasks (letter fluency: 55.1 ± 4.1 vs. 43.1 ± 2.0 items; semantic fluency: 64.3 ± 3.7 vs. 44.0 ± 3.5 items). There were no significant covariate effects.

Spatial tasks

Spatial memory

The scores of participants were submitted to a univariate ANCOVA with the between-subjects factor of visual status (blind, sighted), with age and years of education as covariates. The two groups did not differ significantly in the percentage of recalled items ($F_{1,12}$ = 1.32, p = .27; blind: 57.8 ± 9.3% vs. sighted: 50.0 ± 3.5%), see Figure 2. There were no significant covariate effects.

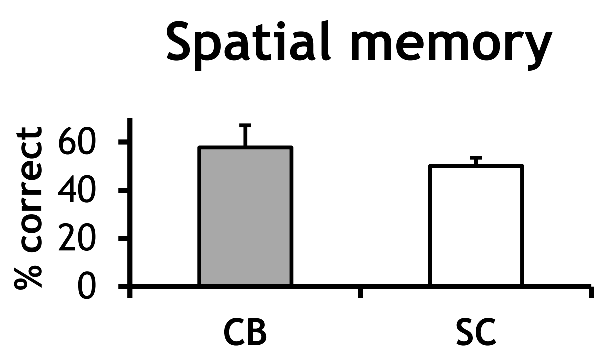

***Figure 2**. Spatial memory performance of congenitally blind (CB) and sighted control (SC) participants.*

Spatial imagery

One blind and one sighted participant were not able to perform the task due to the difficulty of keeping in mind the two series of numbers. The scores of the remaining participants were submitted to a univariate ANCOVA with the between-subjects factor of visual status (blind, sighted), with age and years of education as covariates. There was no significant difference between the accuracies of the two groups ($F_{1,10} < 1$, p = .44; blind: 81.0 ± 3.6% vs. sighted: 75.0 ± 4.3%). There were no significant covariate effects.

Discussion

In this study, congenitally blind participants did significantly better than normally sighted control participants on verbal memory and verbal fluency tasks, whereas the two groups did not differ significantly on spatial memory and spatial imagery tasks. Thus, our results favor the hypothesis that congenital blindness results in a broad superiority of verbal abilities, rather than the hypothesis that congenital blindness enhances memory ability generally. Of course, further research is necessary to replicate these findings and to confirm the conclusions by testing additional verbal and non-verbal domains of memory and other cognitive processes.

Congenitally blind participants were better than sighted controls on all aspects of verbal memory tested, i.e. for both abstract and concrete words, and at each time point tested: within a half-hour of encoding, a day or two later, and a week later. Thus, in keeping with prior studies [1-4], they exhibit a general superiority of verbal memory abilities compared to normally sighted people. It is not known whether the verbal memory superiority of the congenitally blind is specific for retrieval as opposed to encoding. The verbal fluency tasks we used, as pointed out in the Methods, can be considered to tap both memory and language abilities, although here the kind of memory used is of the long-term variety, i.e. memory for highly overlearned information. The present study shows that the benefits of congenital blindness are not limited to verbal memory for new information, but also extend to the ability to rapidly retrieve well-learned information from long-term storage. It would be informative to test congenitally blind people on additional aspects of language to find out if indeed they have superior language skills across the board, or whether superiority might be limited to certain aspects of language.

It is equally important to note that congenital blindness was not associated with superiority on every task tested. Specifically, blindness from birth did not seem to confer any advantage in terms of spatial skills, either for spatial memory or for spatial imagery. The relative differences between verbal and spatial domains assume importance in the context of rehabilitative approaches attempting to more fully integrate individuals with congenital blindness into society. Inter-individual differences, which were not assessed here, would be critical to consider for such approaches.

The superiority of verbal abilities conferred by congenital blindness fits with the idea that, in the absence of vision from birth, verbal inputs and cues become more important. In everyday experience, for instance, when a sighted person asks for directions, he or she can take advantage of cues offered by pointing or other gestures, in addition to the verbal information provided. In contrast, the blind person must encode and later recall the verbal material conveyed without reference to gestural cues. Thus, it seems reasonable that congenital blindness induces stronger reliance on verbal information, and that such reliance leads to better verbal memory, and potentially other verbal skills, through practice.

The stronger verbal abilities of congenitally blind, relative to normally sighted people, may be related to the reported involvement of visual cortical areas in various aspects of language in the congenitally blind. For example, covert verb generation in response to nouns presented via Braille [18] or auditory input [19] recruits activity in early visual cortex, and transcranial magnetic stimulation over the occipital pole results in semantic errors during verb generation [20]. Covert recall of a previously learned word-list (a task similar to the verbal memory task of the present study) also evoked early visual cortical activity in congenitally blind participants; interestingly, the magnitude of this activity was found to correlate with verbal memory ability [1]. Further, syntactic processing is associated with activity in various parts of visual cortex [21]. Visual cortical areas in congenitally blind people also show stronger resting-state connectivity, compared to the sighted, with language areas in inferior frontal cortex [22].

According to theories of grounded cognition, understanding of abstract concepts is grounded in the processing of related concrete concepts [23]. Thus, it is argued that metaphors are understood in terms of their sensorimotor referents [24]. For instance, when one hears metaphors pertaining to texture, such as “She had a *rough* day”, activity is evoked in parts of somatosensory cortex involved in perception of texture [25]. Preliminary data from our laboratory indicate that, when evaluating sentences containing metaphors of shape (e.g. “He *circled* the issue”), congenitally blind people demonstrate stronger activity in parts of visual cortex that are active when sighted people distinguish object shape visually. These data suggest that visual cortical activity in the congenitally blind may in part reflect semantic processes involved in grounded cognition. However, what exactly the visual cortex does in those born blind, or who become blind soon after birth, is not fully settled: not only is it active in language tasks as outlined briefly above, but it is also active in a host of other tasks, such as tactile and auditory processing [26]. Thus, it is still unclear whether the well-known involvement of early visual cortical areas in Braille reading in congenitally blind people [27, 28] reflects processing of language, the associated somatosensory input, or both. Future research on visual cortex in the congenitally blind needs to address whether a common denominator underlies the multiplicity of its proposed functions, whether these regions truly carry out multiple operations, or whether the various functions are distributed across different parts, or different neuronal pools, within this tissue.

Acknowledgements

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Author Biography

Krish Sathian (presenting author) obtained his medical degree from Christian Medical College, Vellore, India, his PhD from the University of Melbourne, Australia and postdoctoral training at Washington University in St. Louis, MO. He trained in neurology at the University of Chicago, and has been on the faculty of the Neurology Department at Emory University since 1994. His research interests comprise multisensory perception, the neural basis of metaphor, and neurological rehabilitation.