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Guidance, mobility and auditory perception in guide dog users with visual impairment

Percepção auditiva e orientação e mobilidade em pessoas com deficiência visual usuárias de cão-guia

Oliveiros Barone Castro[1], *Teresa Maria Momensohn dos Santos*[1], *Andréa Paz de Oliveira*[1], *Maria Claudia Cunha*[1]

ABSTRACT

Purpose: To investigate the temporal auditory perception, and OM of visually impaired people. **Methods:** This is an exploratory intervention study including a convenience sample composed of nine blind or low vision subjects, aged between 23 and 64 years, guide dog users and who performed the following procedures: functional evaluation of OM, basic audiological evaluation (Pure tone audiometry, speech recognition index), temporal auditory processing assessment (random gap detection test (RGDT), frequency pattern test (FPT), dichotic digit Test (DDT), quick speech-in-noise test (QuickSIN). **Results:** Although all subjects had normal-level audiometric thresholds, one subject had a sensorineural audiometric curve and descending configuration, suggesting an age-related hearing loss. Evaluation of the temporal auditory processing showed values within the normal for all subjects, except for the RGDT, in which test subjects had lower (3.5 to 7.5 ms.) than the expected values for the adult population with normal vision and hearing. Evaluation of OM showed that all subjects require technical adjustments as problems were observed in the route taken. **Conclusion:** The temporal auditory processing of these subjects is appropriate and the evaluation of OM shows flaws that need to be corrected.

Keywords: Hearing; Auditory perception; Orientation and mobility; Spatial orientation; Limitation of mobility; Vision disorders; Dogs; Guide dogs

RESUMO

Objetivo: Investigar a percepção auditiva temporal, a orientação e a mobilidade de deficientes visuais. **Métodos:** Estudo exploratório de intervenção, com amostra de conveniência composta por nove sujeitos cegos ou com baixa visão, com idades entre 23 e 64 anos, usuários de cão-guia e que realizaram os seguintes procedimentos: avaliação funcional de orientação e mobilidade, avaliação audiológica básica (audiometria tonal limiar, pesquisa do índice de reconhecimento de fala), avaliação do processamento auditivo temporal (teste de resolução temporal (*random gap detection test* - RGDT), teste de padrão de frequência (TPF), teste dicótico de dígitos (TDD), teste rápido de sentenças no ruído (TRIS). **Resultados:** Todos os sujeitos apresentavam limiar audiométrico de grau normal, porém, um deles apresentava curva audiométrica do tipo neurossensorial e configuração descendente, sugerindo perda auditiva relacionada à idade. A avaliação das habilidades auditivas temporais mostrou valores dentro dos padrões de normalidade para todos os sujeitos, com exceção do teste RGDT, em que os sujeitos apresentaram valores menores (3,5 a 7,5 ms) do que os esperados para população de adultos com visão e audição normais. A avaliação da OM mostrou que todos os sujeitos necessitavam de adaptações técnicas, pois falhas foram observadas no percurso por eles executado. **Conclusão:** A percepção auditiva temporal dos sujeitos deste estudo está adequada e a avaliação da OM mostra falhas que necessitam ser corrigidas.

Palavras-chave: Audição; Percepção auditiva; Orientação e mobilidade; Orientação espacial; Limitação da mobilidade; Transtornos da visão; Cães; Cães-guia

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[1]Pontifícia Universidade Católica de São Paulo – PUC-SP – São Paulo (SP), Brasil.
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Corresponding author: Oliveiros Barone Castro. E-mail: baronelelo@gmail.com
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INTRODUCTION

Through the study of the effects of blindness or other forms of sensory deprivation on intact senses, it is possible to understand the role of experience in the formation of perception. Blind individuals are especially dependent on their hearing ability and there is extensive evidence that they may develop superior auditory skills, either as a result of plasticity in the auditory system or through the recruitment of functionally relevant occipital cortical areas that lack their normal visual inputs. Since spatial processing usually relies on close interactions between vision and hearing, much of the research in this area is focused on the effects of blindness on auditory localization.

Although many studies have reported enhanced auditory skills, some aspects of spatial hearing are impaired in the absence of vision. The effects of crossmodal plasticity in this case may reflect a balance between adaptive changes that compensate blindness and the role that vision normally plays, especially during development, in regulating the brain's representation of auditory space[(1)].

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Several studies have described structural and functional changes within the occipital cortex, with regions that usually would be involved in visual functions and now are responding to sound[(2-4)]. Several research lines have shown evidence suggesting that this cross modal reorganization is behaviorally relevant. Visual cortical areas that are functionally appropriate are recruited after blindness, following a principle that supports the use of sensory substitution devices that convert visual information into auditory signals[(2,3)].

From an auditory perspective, temporal processing is defined as the ability to process minimal acoustic events that are necessary for speech perception (discrimination of sound traits and consonant duration), which shows to be an important component in the ability to process speech[(5,6)]. In this sense, it also has a significant role in the ability to locate the sound source in space, a function that is essential for the individual who has low vision or blindness.

Our perceptions of the world are often determined by the way different sensory modalities interact. As for hearing, for example, the ability of human listeners to identify sounds, such as speech, especially in noisy environments, or to locate its source, can be heavily influenced by the availability of concurrent visual cues. Thus, it is not surprising that loss of vision may result in changes in auditory perceptual abilities and in the way that sounds are processed within the brain. However, the nature and extent of these changes depends on several factors, such as the age at onset, the severity and duration of blindness, the aspect of auditory perception that is measured and, almost certainly, on the degree to which visually impaired individuals have come to depend on their hearing ability in their everyday lives[(4,7)].

Vision clearly plays an important role in the development of the auditory map. Early visual impairment disrupts the topographic organization of the auditory receptive fields of neurons in the superior colliculus in different degrees. Vision is required in order to build a map of the auditory space in the brain. Rather, the availability of concurrent and often more accurate visual cues from spatial directions is likely to help overcome uncertainty and variability in the relationships between auditory location signal values and directions in space. As a result, the development of the auditory map coincides with the representation of the visual field in the superior colliculus, thus facilitating the integration of the signals provided by the eyes and ears from a common source of stimulus.

Several auditory and other sensory functions may be change as a result of blindness; however, due to the particular importance of vision and hearing for spatial perception and navigation, this study is primarily focused on the impact of blindness on sound localization abilities and the underlying neural substrates.

Given the importance of hearing in the life of a blind or visually impaired subject, this study aimed to investigate the temporal auditory processing, orientation and mobility of a group of blind or visually impaired individuals.

METHODS

Nine subjects with visual impairment (blind and low vision) participated in this study, eight of whom had acquired vision loss and one had congenital visual impairment, two female and eight male, aged between 28 and 64 years, and guide dog users for over a year.

The subjects were personally selected by the researcher, according to the following selection criteria: minimum age of 18 years, since guide dogs are only provided to users by signing a lending contract between the animal's training institution and the person with visual impairment, of legal age.

This project was approved by the Research Ethics Committee of the Pontifícia Universidade Católica de São Paulo – PUC-SP, following the guidelines and regulatory standards for research involving human subjects of the Brazilian National Health Council, Resolution 466/12, under the no. 89680517.8.0000.5482. All participants signed the Free Prior Informed consent.

Data collection procedures

Selection of subjects

Initially, 14 subjects were contacted by phone, received appropriate explanations and were invited to participate in the research. 11 of the 14 subjects accepted to participate and, later, two participants voluntarily withdrew, thus reaching the nine subjects.

Then, the participants received the Free Prior Informed consent (FPIC) by e-mail so that they could become aware of it, through a text-to-speech software or smartphone application, or reading by someone.

Then, on a previously scheduled date, individual and face-to-face meetings were held with the subjects, in which the researcher could read the FPIC again in the presence of a witness so that the participants could sign it.

Sample characterization

At the same meeting in which the FPIC was signed, the researcher applied a questionnaire to characterize the subjects, which is called as Subjects Questionnaire (SQ). This questionnaire was designed by the researcher, since currently there are no validated instruments covering the aspects of general health, vision, hearing, hearing/mobility and complementary information - training, professional and educational activities, time using a cane and means of locomotion used.

Functional evaluation of orientation and mobility

The instrument for Functional Evaluation of Orientation and Mobility (AFOM) was also developed by the researcher, as there are currently no validated instruments that measure the guidance and mobility of guide dog users.

A route was previously planned and standardized by the researcher for the application of the AFOM, so that the user and guide dog pair could be individually evaluated using public places and public transportation.

Each pair was followed by a research assistant, who was also a trainer of guide dogs, and remained close for any needs or guidance. The researcher remained at about two meters away, filming and timing the route, for further analysis through the AFOM.

The route taken by the pair had an average length of four kilometers and three hundred meters and an average duration of two hours. The route taken was as follows: Av. Paulista, 1313 – Rua Pamplona – Al. Santos – Praça Gusmão – Al. Casa Branca – Av. Paulista, Parque Trianon – from Consolação Metro Station to Vila Prudente Metro Station.

In the subway, the pair went through stairs, turnstiles and boarding/landing platforms. The dog received the user directions to get on the train, find an available seat, and sit under the seat. To disembark from the train, the user asked the dog to get up, position themselves in front of the landing door, get off the train, lead the user to the middle of the platform, and to find the stairs, turnstiles and exit door of the station .

Audiological evaluations

The audiological evaluations were performed by a speech-language pathologist in an acoustic booth, with supra-aural headphones and the Madsen Itera II device. The procedures performed were as follows: pure tone audiometry, temporal resolution test (random gap detection test - RGDT), frequency pattern test (FPT), Auditec version, dichotic digit test (DDT), analyzed according to the criteria established by a study[8], and the quick speech-in-noise test (Quick SIN)[9].

Analysis and interpretation of results

The results of the Functional Evaluation of Orientation and Mobility and also the audiological evaluations were described for the sample and comparatively analyzed.

RESULTS

The presentation of the results follows the following structure:

a) Sample characterization through the SQ;

b) Evaluation of AFOM test results;

c) Temporal auditory processing tests.

The subjects were identified as S1, S2, S3, S4, S5, S6, S7, S8 and S9; and ‘orientation and mobility’ was called as OM.

Sample characterization

There was a prevalence of male individuals, blind, with acquired visual impairment. The average age was 40 years and 11 months and the time of use of a guide dog in a wide spectrum was between 2 years and 6 months and 44 years (Chart 1).

Chart 1. Sample characterization

Subject N°	Gender	Age	Degree of visual loss	Etiology	Congenital or acquired impairment	Time (years) as a guide dog user	Degree of hearing loss	Audiometric configuration	Tinnitus	Dizziness	Hearing complaint
S1	F	35	LV	RD+Cat	AcI	4	Normal	Horizontal	No	No	None
S2	M	37	LV	PR	AcI	4	Normal	Horizontal	No	No	None
S3	M	63	B	PR	AcI	44	Normal	Sharp descent	Yes	No	Subject listens, but doesn’t understand
S4	M	43	B	PR	AcI	10	Normal	Horizontal	No	Sometimes	None
S5	M	36	B	SBI	AcI	4	Normal	Horizontal	No	No	None
S6	F	36	B1+LV1	CG	CoI	2.6	Normal	Horizontal	No	No	None
S7	M	51	B	PR	AcI	9	Normal	Horizontal	No	No	None
S8	M	28	B	RD	AcI	4	Normal	Horizontal	No	No	Subject understands speech in noisy environments
S9	M	32	B	PR	AcI	4	Normal	Horizontal	No	No	Subject understands speech in noisy environments

Subtitle: S = subject; F = Female; M = Male; LV = Low vision; RD = Retinal detachment; Cat = Cataract; AcI = Acquired visual impairment; CoI = Congenital visual impairment; B = Blind; B+LV_1 = Blind in one eye and low vision in the other eye; PR = Pigmentary retinosis; SBI = Stray bullet injury; CG = Congenital glaucoma

Description of the performance of blind and low vision subjects in the Functional Assessment of Orientation and Mobility

The items evaluated in the OM evaluation covered the following axes: indoors and elevators; procedures at the subway; procedures for entering/finding a place and leaving the bus/subway/train; procedures at the corner - sidewalk orientation, street (with and without traffic lights); procedures to cross a street on intersections and in the middle of the block; adequacy of OM technique; adequacy of the remaining senses; verbal commands and volume adequacy.

The researcher rated as 'adequate' when the user and guide dog pair met the expectations previously stipulated and, if not, rated it as 'inadequate'.

If required, the researcher also made notes and observations at the AFOM (Chart 2).

Most of the subjects were assessed as 'adequate' in all aspects, with some observations. S5 and S9 were assessed as 'inadequate' in the item 'Behavior when arriving at a corner without traffic lights (crossing the road)'. S9 was also rated as 'inadequate' in the item 'Behavior when crossing a road in the middle of the block'.

Table 1 shows the performance of individuals with low vision and blindness in the temporal auditory perception tests (FPT and TGDT), quick speech-in-noise test (Quick SIN) and Dichotic digit test (DDT).

DISCUSSION

Since the dawn of mankind, some visually impaired people have spontaneously used some kind of 'cane' to get around, such as a staff, stick, bamboo stick or a tree branch. Although

Chart 2. Description of the performance of blind and low vision subjects in the Functional Assessment of Orientation and Mobility

SUBJECT Nº	S1	S2	S3	S4	S5	S6	S7	S8	S9
Entering and leaving indoors areas	A	A	A	A	A	A	A	A	A
Calling the elevator (getting in and out of it)	A	A	A	A	A	A	A	A	A
Behavior on subway platform	A	A	A	A	A	A	A	A	I
Behavior when reaching a corner (sidewalk orientation in relation to the street; identification and positioning)	A	A	A	A	A	A	A	A	A
Command and behavior when leaving the sidewalk; reaching another sidewalk and entering it	A	A	A	A	A	A	A	A	A
Behavior when arriving at a corner with traffic lights and a crosswalk (crossing the road)	A	A	A	A	A	A	A	A	A
Behavior when arriving at a corner without traffic lights (crossing the road)	A	A	A	A	I	A	A	A	I
Behavior when crossing a road in the middle of the block	A	A	A	A	A	A	A	A	I
Adequacy of the orientation and mobility technique	A	A	A	A	A	A	A	A	A
Behavior when entering, finding a seat, sitting (with the dog under the seat), staying on and leaving the bus/train/subway train	A	A	A	A	A	A	A	A	A
Evaluation of the adequate use of the remaining senses for spatial orientation in mobility (hearing, smell, touch - sensory)	A	A	A	A	A	A	A	A	A
Verbal commands. Volume adequacy	A	A	A	A	A	A	A	A	A

Subtitle: S = Subject; A = Adequate; I = Inadequate

Table 1. Performance of blind and visually impaired individuals in tests that evaluated central auditory processing

AUDITORY PERCEPTION TEST									
Subjects	QuickSIN		RGDT	FPT NAME	FPT IMITATE	DDT INTEGRATION		DDT SEPARATION	
	RE	LE	RE and LE	RE and LE	RE and LE	RE	LE	RE	LE
Subject 1	72%	80%	4.25 ms	100%	100%	100%	100%	100%	100%
Subject 2	100%	100%	3.5 ms	100%	100%	100%	97%	100%	100%
Subject 3	76%	76%	4.25 ms	100%	100%	100%	97%	100%	100%
Subject 4	88%	84%	7.5 ms	100%	100%	100%	97%	100%	100%
Subject 5	88%	80%	5 ms	100%	100%	100%	100%	100%	100%
Subject 6	88%	80%	5.5 ms	100%	100%	100%	100%	100%	100%
Subject 7	88%	92%	5 ms	100%	100%	100%	100%	100%	100%
Subject 8	92%	92%	3.5 ms	100%	100%	100%	100%	100%	97%
Subject 9	100%	100%	3.5 ms	100%	100%	100%	100%	100%	100%

Subtitle: QuickSIN = quick speech-in-noise test; RGDT = Random gap detection test; FPT = Frequency pattern test; DDT = Dichotic digit test; RE = Right ear; LE = Left ear; ms = milliseconds the 'white cane' was defined in the last century as a symbol of blindness, the guide dog was the first systematized and effective way of locomotion for blind people[5,10].

The use of dogs is observed not only in the therapeutic context, but also as an aid in minimizing the effects of different types of disabilities. In this case, dogs are trained to follow individuals with visual, hearing or motor disabilities, improving the quality of life of users and acting as social assistance animals[6]. An assistance dog provides significant benefits and increased quality of life for people with physical or hearing impairment[11].

Some important aspects of visual impairment refer to the concepts of orientation and mobility. According to the directive of the Brazilian Ministry of Education and Culture (MEC), the expression of the combination of these two concepts (orientation and mobility) means to move in an oriented way, with sense, direction and using different references, such as cardinal points, stores, guides for consulting maps, asking people for information, reading information from signs with symbols or writing to get to the desired destination[12].

As for OM, this study found that most subjects had the OM course between two and 34 years before the evaluations. However, when analyzing the performance of these individuals on the route test, it was possible to notice the incorrect application of the orientation and mobility techniques, which are necessary to reduce the risk of accident with the pair. In this sense, it is essential that regular evaluations are conducted by professionals who master these techniques and the use of guide dogs; since, when properly applied, OM techniques provide the individual with greater safety and are fundamental for the achievement of their autonomy[10].

Thus, it is crucial to apply OM techniques to a person who lost the sight, so they can become aware of their body scheme and may learn to properly use the remaining senses, such as hearing, touch, smell, taste and body synesthesia, or sensory sensations (feeling of hot/cold, rough/smooth, as well as perceiving the direction of the wind or air displacements) to orient themselves in any space.

While sighted people are able to form and prove many concepts informally, people with visual impairments need a structured presentation of these concepts to ensure proper development of the principles related to them[13].

Basic concepts related to orientation and mobility are necessary for the visually impaired person to be able to move safely and efficiently, as well as body knowledge is essential, for example, with special attention to body scheme, body concept, body image, body plans and its parts, laterality and directionality. These concepts must be enhanced with others equally important, such as: position and relationship with the space, shape, measures and actions, environment, topography, texture and temperature, which, as well as body concepts, form the basis of spatial and directional concepts; which are key factors in the orientation and mobility process. Body image is equivalent to body concept and, therefore, three components must be taken into account: body plans: ability to identify the front, back, top and bottom of the body in relation to external surfaces and objects in relation to the body plans; body parts: identify; body movement: rough movements in relation to body plans and limb movements and laterality[14].

Subjects of this study reported that crossing a street at the intersection is one of the most critical situations, especially in places where there are no traffic lights. Direct observation and analysis of the videos of the technical evaluations of OM also showed that aspects of the subjects' personality, emotional state and level of anxiety directly influence the OM process. These conditions are reflected even in the dog's behavior and vice versa, that is, the temperament, emotional state and anxiety level of the dog also influence the OM process of the users. These reports were exemplified by the high level of anxiety shown by S1 and S4, by the lack of confidence of S2 and S5 in some situations of mobility, by the state of tension presented by S8 and the corresponding level of dispersion of his guide dog.

In addition, a study conducted in Australia concluded that blind subjects using guide dogs have different styles in OM procedures, which confirms the importance of this aspect for dog training[15]. Another study reported that the behavioral characteristics of the dog influence the OM process of the user, specifically reducing tensions and promoting the sense of location and decision making of the user[16].

The importance of adequate prior evaluation for the formation of the user and guide dog pair, as well as their periodic evaluation, is highlighted. As the pair will live and work together for years, these assessments go beyond technical pairing aspects. The importance of hearing, both peripheral and central, for the OM of the blind person should also be discussed. Hearing stands out when there is visual impairment due to its ability to perform the spatial analysis of the environment, which is similar to vision in many aspects and takes this function.

The practice of central auditory skills occurs in a different way in individuals with incidence of visual sensory impairment, since the lack of visual stimuli does not inactivate the visual cortices, but rather allows remaining sensory skills, such as hearing, to recruit such regions. Thus, the plasticity ability of the brain enables certain cortical regions to be designated for other purposes[3].

When comparing the results obtained (responses to the subject characterization questionnaire, results of the OM technical evaluation and audiological evaluations), it was observed that only one of the subjects had hearing problems and also did not use some OM techniques properly, due to overconfidence. Thus, the difficulties in orientation and mobility of the vast majority cannot be directly associated with hearing changes. However, there is a hypothesis that, in situations such as subway and train platforms (with a two-way path), the intensity and variety of noise, aggravated by the reverberation (or dispersion) of sounds on the walls and other agents that can interrupt or divert the sound flow, resonance and echo may lead the subjects to experience difficulties or make mistakes when trying to identify certain sounds, such as the identification of the direction of the train when it is arriving at the boarding point, through the distinctive sound of its arrival, which occurred with two of the subjects and was mentioned by everyone as a impediment in the attempt to identify the flow of the trains, through the sound identification.

Thus, auditory skills are essential for proper orientation in these spaces, being mentioned by some subjects in the responses of the identification questionnaire. However, a more accurate evaluation of this aspect would require the application of a combination of OM technical procedures, such as the identification of air displacement caused by the arrival of the trains.

Still regarding the relationship between hearing and OM, the subjects repeatedly reported the essential resource to hearing at street corners and intersections, in an attempt to identify the approach of vehicles and other urban mobility aids (such as bicycles) to locate and/or identify the direction of the traffic flow, so that they could cross the road safely. It is worth noting that, as well as vehicles that emit little noise, bicycles are complicating factors so that subjects can create references on such occasions.

Many authors[17,18] reported the difficulty that blind people face to orient themselves in situations with competitive sounds, such as those when they need to move around in noisy environments. The speech-in-noise test applied to the group of subjects in this study found that two of the nine subjects had a performance below 80% and three of the nine had a performance between 80 and 90%. These values show that these individuals were not in excellent conditions to act in situations of competitive noise. In general, a sighted listener relies on visual clues to overcome the challenges provided by the difficulty hearing in the presence of noise. But how to solve this difficulty when there is no vision?

In previous studies[9,17,18], in which the auditory localization performance in blind individuals was as good or better than the normal standard, the subjects were asked to turn to the perceived location of the sound source, from a number of speakers, or to indicate if two consecutive sounds came from the same location as the first sound, or if they came from different locations.

When evaluating the temporal resolution for consecutive sound stimuli by the RGDT, it was possible to notice that the threshold value ranged from 3.5 to 7.5 ms in the group of blind people in this study. It is interesting that these values are lower than those commonly found in the adult population. A median value of 25 ms and a minimum value of 14 ms were reported by studies[8,9,18] that investigated the temporal resolution in adults without hearing complaints and with adequate vision. So, despite the hearing ability of a blind person is more trained than that of a person who hears and sees, it can be said that many of the confusions observed when analyzing orientation and mobility are due to the uncertainty of the individual on what they hear.

CONCLUSION

The results regarding the difficulties of orientation and mobility of the subjects in this study cannot be directly associated with hearing disorders. However, it should be noted that the temporal resolution values obtained through the RGDT test for consecutive sound stimuli were lower than those found in adult listeners.

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