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Thesis Report toward a
Master of Arts Degree in Cognitive Science

Auditory Discrimination of Highly Similar L2 English Consonant Sounds by Blind Compared to Sighted Adult Spanish Speakers

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I would like to dedicate this thesis report to my husband, Rodrigo Segovia, my family and friends, as well as the people at the Biblioteca Central para Ciegos in Santiago, Chile, who supported me throughout the entire process of this study,

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Table of Contents

ABSTRACT

Objective: To carry out a pilot experiment so as to draw results and research design improvements supporting the hypothesis that sight deprivation, both for long periods of time and only during moments where auditory information is presented (blindfolding), can lead to better auditory discrimination of highly similar L2 English sounds.

Method: 8 late blind adults (age M=36), 8 sighted and blindfolded adults (age M=26), and a control group of 8 sighted and not blindfolded adults (age M=31) participated in this study. All participants were Spanish native speakers of Chilean origin, with little knowledge of the English language. The participants attended five sessions, in which they underwent training stages where they were exposed to English words and nonsense words frequently containing 3 pairs of highly similar English consonant sounds. Two types of minimal pair discrimination tests were administered at the end of each session, with and without background noise. All participants' levels of exposure to street noise, as well as blind participants' years of blindness and ages of blindness onset were correlated with their test scores.

Results: The three groups showed increases in their scores on the minimal pair discrimination tests throughout the five sessions. The Blind Group tended to outperform the two Sighted Groups, especially in the tests with background noise. A strong correlation was found between the levels of exposure to street noise and the average scores on the auditory discrimination tests with background noise for the Blind and Sighted Blindfolded Groups. A tendency for the B Group's ages of blindness onset to correlate with their test scores was observed, but no correlation was seen for their number of years of blindness.

Conclusions: As expected, blind adults exhibited an enhanced potential to auditorily discriminate the highly similar English consonant sounds selected for this study, compared to the blindfolded and not blindfolded sighted groups. Blind participants' performance on the minimal pair tests with background noise was higher than any other score in this pilot study, which may be mediated by the levels at which they are generally exposed to street noise, their enhanced capacity for Auditory Scene Analysis

(Bregman, 1990) and selective attention, which, in turn, are supported by the neural remodeling that they undergo, as reported in the literature. Although the experimental design yielded results that tend to support the hypothesis of this pilot study, further studies with larger population samples should be carried out to validate these findings.

Keywords**:** blindness, phonetic discrimination, TESOL, auditory attention, crossmodal plasticity

RESUMEN

Objetivo: Llevar a cabo un experimento piloto, con el fin de obtener resultados y mejoras en el diseño experimental que apoyen la hipótesis de que la privación de la vista, tanto por períodos extensos como por momentos transitorios mientras se presenta información auditiva, puede resultar en una mejor discriminación auditiva de sonidos altamente similares del inglés como lengua extranjera (L2).

Método: 8 adultos no videntes (edad M=36), 8 adultos videntes vendados (edad M=26), y un grupo control de 8 adultos videntes no vendados (edad M=31) participaron en este estudio. Todos los participantes eran chilenos, hablantes nativos del español, y tenían poco conocimiento del inglés. Los participantes asistieron a cinco sesiones. Cada sesión contempló una etapa de entrenamiento, en que los participantes fueron expuestos a palabras inglesas y pseudopalabras que frecuentemente contenían 3 pares de sonidos altamente similares del inglés. Al final de cada sesión los participantes respondieron a dos tipos de pruebas de discriminación de pares mínimos, con y sin ruido de fondo. Los niveles de exposición al ruido callejero de todos los participantes, como también los números de años de ceguera de los participantes ciegos se correlacionaron con sus resultados.

Resultados: Los tres grupos mejoraron en cuanto a sus resultados en las pruebas de discriminación de pares mínimos a lo largo de las cinco sesiones. Los participantes ciegos tendieron a obtener resultados más altos que los grupos de videntes, especialmente en las pruebas con ruido de fondo. Se encontró una fuerte correlación entre los niveles de exposición al ruido de la calle de los ciegos y videntes vendados con sus puntajes en las pruebas con ruido de fondo. Hubo una tendencia de correlación entre la edad de inicio de ceguera de los participantes ciegos y sus puntajes, pero no del número de años de ceguera.

Conclusiones: De acuerdo a lo esperado, los participantes no videntes demostraron un potencial superior para distinguir los pares de sonidos consonánticos del inglés seleccionados para este estudio, en comparación con los participantes videntes vendados y no vendados. Además, los puntajes de los participantes ciegos en las pruebas auditivas con ruido de fondo fueron los más altos de todos los puntajes promedios obtenidos por todos los participantes. Esto podría tener raíces en los altos niveles de exposición al ruido de calle reportados por el grupo de no videntes, como también una capacidad incrementada de análisis del escenario auditivo (Bregman, 1990) y atención selectiva, que a su vez se encuentran apoyados por la remodelación neuronal que ocurre después de la privación de la vista, cuya evidencia ha sido reportada en la literatura. A pesar de que los resultados tendieron a apoyar la hipótesis de este estudio, experimentos con mayores números de participantes son necesarios para validar estos resultados.

Palabras claves: ceguera, discriminación fonética, inglés como lengua extranjera (ILE), atención auditiva, plasticidad intermodal

INTRODUCTION

It has been a long-standing observation that visually impaired individuals have better hearing perception than those who do not have any sensory aberrations. Recently, mounting scientific evidence has supported such conviction through neurocognitive studies, which have shed light on the neural substrates underlying the superior auditory processing capacities of the blind. Basically, the main neurological explanation that has been proposed for the compensatory behavioral adaptations of blind individuals is that of synaptic remodeling. Thus, evidence indicates that certain functional areas of the visual cortex reorganize to process non-visual information faster and more accurately (Rauschecker, 1997; Ranganath & Paller, 2000; Neville & Bavelier, 2001; Bach-y-Rita & Kercel, 2003; Duffau, 2006; Kim & Zatorre, 2008).

Regarding the enhanced auditory skills that may result from neural remodeling, as well as the greater use of the auditory sensory system following blindness, several results have been reported, specifically related to auditory short term (Hull & Manson, 1995; Juurma, 1967; Smits & Mommers, 1976; Tillman & Bashaw, 11968) and long term memory (Amedi et al., 2003; Roder & Rosler, 2003), auditory attention (Liotti, Ryder, & Woldorff, 1998; Muchnik et al., 1991; Niemeyer & Starlinger, 1981; Roder et al., 1996; Roder, Rosler, & Neville, 1999), as well as acoustic frequency discrimination (Gougoux et al., 2004), sound localization (Gougoux et al., 2005; Lessard et. al., 1998), and L1 speech perception (Hugdahl et al., 2004; Muchnik et al., 1991; Starlinger & Niemeyer, 1981).

Such compensation is quite relevant if analyzed from the language acquisition point of view, particularly, in the case of this study, from that of foreign language learning and second language acquisition. Questions have been raised to whether the lack of visual input would hinder the language learning process or if the enhanced auditory capacity due to blindness (and, thus, due to neural remodeling) would favor language learning if taught through the auditory mode. Now, there is a sufficient amount of evidence that favors the latter hypothesis. However, the vast majority of the behavioral, neuroimaging and neurophysiological studies reported to the present date have focused on first language (L1) acquisition and skills in the blind population, without looking into second language acquisition (SLA) or foreign language acquisition (FLA). Furthermore, information regarding superior auditory processing skills in late blind individuals in still obscure, since the majority of the available findings focus on congenital and early blindness. Therefore, it would be interesting to assess if the auditory perception capacities (particularly, in relation to speech perception) observed in congenital and early blind individuals could also apply to late blind populations, when learning a foreign language through the auditory mode, specifically when acquiring the sound system of the L2.

Based on the above, this theoretical and experimental study aims at analyzing the hypothesis that blind individuals can learn to auditorily perceive and distinguish pairs of highly similar consonant sounds of English as a foreign language (L2) better than those with access to all sensory information. Additionally, the effects of blindfolding (in sighted individuals) on learning to distinguish between such consonants will also be explored. Auditory perception and discrimination of the L2 English sounds selected for this study are considered, rather than their production.

In support of the above, arguments based on neurological evidence of brain plasticity that may explain the blind’s enhanced auditory perception are exposed herein. Additionally, evidence of greater auditory memory, auditory attention and speech perception in the visually impaired is examined in relation to the reorganization occurring at the cortical level, as well as the greater use and dependence on the auditory sensory mode in everyday life. The general discussion focuses on whether these compensation underpinnings can lead to greater auditory speech perception of a foreign or second language in the absence of visual input and after the brain undergoes the cortical reorganization recently reported for visually impaired individuals. Additionally, observations are made with regards to temporal visual deprivation, by means of blindfolding, during speech perception.

Following the information above, a pilot experiment carried out to test whether native Spanish speaking blind individuals can learn to distinguish highly similar L2 English sounds faster and more accurately than sighted participants is reported. Considering the growing amount of evidence indicating that blind individuals have higher auditory perception, memory and attention, possibly due to underlying crossmodal compensation as well as greater auditory training and use, the pilot experiment expected the blind participants to learn to perceive and discriminate L2 English sounds faster and more accurately than those with no sensory aberrations.

Finally, this study may have a positive impact on how foreign languages are taught to people with visual impairments, if based on techniques and activities that are adapted to cater their higher auditory processing capacities.

1 THEORETICAL FRAMEWORK

1.1. Neural Reorganization

The bridge between the brain and what it can make us live through still seems to be very long and obscure. However, many researchers have been able to clarify what tends to lie on each end of that bridge. On the brain's side, its neurons create functional networks, which can change or expand due to certain stimuli. On the other side (or the cognitive side), we perceive, identify, categorize and learn. Peripheral sensory receptors are our channels to the outside world, but how we interpret the information we receive is a completely different matter; one that is highly complex and integrates many factors. How we go from electrical impulses and chemical exchange to epiphanies and emotions is still a mystery.

However, thanks to the current state of research technologies, studies have been able to reveal the activity and changes that the human brain portrays *in relation* to mental as well as physical states and processes. A fundamental aspect of the human brain is its neural plasticity, that is, the ability of the brain's synaptic networks to reorganize themselves in response to certain stimuli (or lack thereof). Thus, the synaptic remodeling that the brain undergoes is observed to occur *in relation* to mental as well as physical states and processes.

Such plasticity allows the brain to develop as the human being grows, receives stimuli, learns how to understand and use a language, masters a musical instrument, etc. Additionally, neural reorganization has also been shown to not only occur in the developing brain, but in the mature human brain as well (Kujala et al., 1995; 1997; 2000; Jain et al., 2008). For instance, neural networks may reorganize in response to an injury in a certain brain area or following sensory loss, or even when no peripheral or cortical damage has occurred, that is, simply when learning and memory take place. Moreover, recent studies have shown that neural reorganization does not only occur at the cortex level, but is also observed in early sensory processing centers that had been believed to be *hardwired*. One of these centers is the auditory brainstem, in which cellular and behavioral mechanisms for learning and memory have been revealed through recent human studies and animal models (Tzounopoulos & Kraus, 2009). However, a greater degree of neural plasticity has been reported in associative, unimodal and multisensory regions, which may partially be due to the increased sensitivity of higher level areas to crossmodal inputs (Fine, 2008).

Regarding permanent sensory loss, the neural changes occurring in the unimodal system deprived of its customary sensory input becomes functionally integrated into other circuits, thus generating changes in the brain as a whole (Bubic et al., 2010). Consequently, this ripple effect causes plasticity in multisensory areas (*multisensory plasticity*) that receive inputs from the hyper-development of the sensory modalities that remain in use, as well as within the unimodal system (*intramodal plasticity*), and also causes the reassignment of a particular sensory function to another sensory modality (*crossmodal plasticity*), and network modifications in areas that typically do not process sensory information (*supramodal plasticity*). For the purposes of this study, focus will be placed more on *crossmodal plasticity* and *supramodal plasticity*.

In light of the above, many dogmas have gradually been replaced by new discoveries. For instance, it was believed for many years that the lack of sensory input to the brain implied no cortical activity in the area(s) involved in processing such information (the *general-loss hypothesis*). For instance, in individuals who could not perceive visual stimuli, it was thought that the occipital lobe and, specifically, the primary visual cortex or the striate cortex, simply ceased to work. However, studies carried out since the 1960’s (since Wiesel & Hubel, 1963; 1965) have shown that cortical structures deprived of their normal sensory input respond to the stimulation of adjacent receptors. Moreover, studies on hemodynamic and electrophysiological variations have shown that modality-specific brain areas that are completely deprived of their normal sensory input become responsive to stimulation of other modalities.

Additionally, Burton et al. (2002) showed, using fMRI, that the cortical reorganization was observed in both *early* and *late* blind subjects, indicating that cortical reorganization might occur throughout life rather than during a limited and early period of susceptibility (Burton et al. 2002; Theoret et al. 2004; Voss et al. 2004).

These groundbreaking discoveries have been fundamental to understanding the superior auditory capacities observed in individuals who are not sensitive to visual stimuli, that is, whose vision receptors are incapable of perceiving and channeling visual information to the brain. The following section briefly summarizes some of these recent findings, which specifically pertain to the crossmodal and supramodal compensations that have been observed to take place when loss of vision occurs.

1.1.1. Crossmodal and supramodal compensation following loss of vision

As mentioned above, there has been increasing evidence that the brain undergoes neural reorganization or “rewiring” when there is sensory loss, similar to how it would in the presence of brain injury. Related studies up until now have revealed that the brain areas that were once dedicated to processing a lost sense are then used or recruited by other parts of the brain to process the remaining senses. This phenomenon has been termed *crossmodal compensation*. One of the first findings to support this recruitment of cortical areas deprived of peripheral input was seen in primates. Following transection of the median nerve to the hand in monkeys, the deprived cortical somatosensory area began to participate in processing incoming sensory information from the remaining inputs to the hand (Merzenich et al., 1983a; Merzenich et al., 1983b). Another example is the study carried out by Rauschecker et al. (1992), who found a supernormal growth of facial vibrissae and an enlarged whisker representation in the somatosensory cortical barrel field in cats and mice deprived of vision from birth.

In humans, several studies using neuroimaging techniques have shown that occipital areas in blind individuals are recruited to carry out non-visual tasks such as

Braille reading (Burton, Snyder, Conturo, et al., 2002; Sadato et al., 1996), memory retrieval (Amedi et al., 2003) sound localization (Gougoux et al., 2005; Leclerc, Saint-Amour, Lavoie, Lassonde, & Lepore, 2000; Weeks et al., 2000) or other auditory functions (Arno et al., 2001; Burton, Snyder, Diamond, & Raichle, 2002; Kujala et al., 1995; Liotti, Ryder, & Woldroff, 1998; Röder, Stock, Bien, Neville, & Rosler, 2002). A few studies have also suggested increased cortical representation in the expected areas for auditory (Elbert et al., 2002), somatosensory (Sterr et al., 1998) or motor functions (Pascual-Leone & Torres, 1993) in blind individuals.

Although large scale changes that promote full neural reorganization have been widely reported for *congenital* and *early* blind individuals, compensation occurs to a different extent in the case of *late* sensory loss. There is even evidence of short-term plasticity when sighted individuals are blindfolded (Pascuale-Leon et al., 2005), which has also been termed *expression of normal physiology* by Burton (2003). This plasticity could arise from the recruitment of existing inhibited or *masked* pathways, which are commonly not used and that become available when the source or reason for such masking (such as the availability of visual input in those who have been blindfolded) is removed. This means that there already are auditory connections to the occipital cortex, which are masked in the case of sighted individuals. However, this form of plasticity is not what is known as *plasticity de novo*, which involves the creation of new connectivity patterns (Burton, 2003), but could be the first stage toward *plasticity de novo* when injury or permanent sensory loss takes place. In this sense, quick changes that reflect the unmasking of existing connections may promote and enable subsequent slow, but more permanent, structural changes (Amedi et al., 2005; Pascual-Leone et al., 2005).

It is interesting to note that neural compensation involving the unmasking of existing pathways (in the case of sighted blindfolded individuals) and *plasticity de novo* (in the case of congenital, early and late blind individuals) both imply changes in cognitive and physiological functioning, which correlate with each other in response to certain stimuli. This is why one of the conditions in the pilot experiment reported herein involves blindfolding, so as to observe the auditory discrimination behavior that may correlate with such unmasking of existing pathways as a form of compensation for the removal of visual information, compared to late blind and sighted not blindfolded individuals. The conditions set for the pilot experiment are described in the corresponding section further in this document.

1.1.2 Evidence from brain imaging

Thanks to the information provided by functional neuroimaging, it is now known that the occipital cortex is not only neutrally active in the blind (De Volder et al., 1997), but is also *functionally* engaged in perception in other modalities, such as audition (Gougoux et al., 2005; Kujala et al., 2005) and tactile Braille reading (Büchel et al., 1998ñ Burton et al., 2002; Gizewski et al., 2003; Sadato et al., 1998, 1996). Changes have also been observed to a great extent in higher cognitive, verbal and language functions (Amedi et al., 2004; Burton et al., 2003; Burton et al., 2002; Ofan and Zohary, 2007; Röder et al., 2002) and memory processing (Amedi et al., 2003; Raz et al., 2005), which have been grouped under the term *supramodal compensation*.

Image evidence of brain activity in the blind was first related to tactile information. For example, pioneering studies by Sadato et al. (1996; 1998) reported activation of the visual cortex in early blind individuals through PET imaging while they read Braile, and also when tactically recognizing objects, but not when they passively swept their fingers on a homogenous set of Braille dots (no meaning). In relation to the latter, Hamilton et al. (2000) studied a blind adult patient who used to be fluent in Braille reading, but became unable to retrieve information from Braille after suffering posterior cerebral artery stokes. This led to the conclusion that a *functional* occipital cortex is needed for Braille reading. This was further supported through transient disruptions of occipital cortical functions by using TMS, which impaired Braille reading in the blind subjects of the experiment (Cohen et al., 1997). Moreover, transient disruptions to the left occipito-temporal cortex with rTMS also interfered with verb generation in blind subjects (Amedi et al., 2004). Therefore, the occipital cortex becomes engaged in higher-order functions through neural reorganization after loss of vision.

Concerning acoustic information processing, many brain imaging studies involving blind participants have been carried out in relation to speech perception tasks. For example, Burton et al. (2003) used fMRI to show adaptations in the visual cortex of *sighted*, *early* and *late* blind individuals as they heard lists of related words and attended to either a common meaning (semantic task) or common rhyme (phonological task). In all three groups, the semantic task elicited stronger activity in the left anterior inferior frontal gyrus and the phonological task evoked stronger activity bilaterally in the inferior parietal cortex and posterior aspects of the left inferior frontal gyrus. However, only blind individuals showed activity in occipital, temporal, and parietal components of visual cortex. The spatial extent of visual cortex activity was greatest in early blind, who exhibited activation in all ventral and dorsal visual cortex subdivisions for both tasks. Preferential activation appeared for the semantic task. Late blind individuals exhibited responses in ventral and dorsal V1, ventral V2, VP and V8, but only for the semantic task. These findings contribute to evidence of visual cortex activity in blind people engaged in auditory language processing and suggest that this activity may be related to semantic processing.

A more recent study that provides evidence that visual cortex activity in the blind reflects language processing was carried out by Bedny et al. (2001). They found that the left visual cortex of congenitally blind individuals behaves similarly to classic language regions, in that it showed more activity when subjects heard semantically meaningful segments (sentences or single words) compared to nonsense ones. Specifically, in congenitally blind adults, the left occipital cortex is active during sentence comprehension, even when the control tasks are more difficult and memory-intensive. Basically, functional connectivity with language regions in the left prefrontal cortex and thalamus are increased in congenially blind relative to sighted individuals. Both the left medial and the left lateral occipital ROIs had increased connectivity with the left thalamus, specifically the ventral lateral and medial dorsal nuclei. These thalamic nuclei are anatomically connected with the prefrontal cortex and have been implicated in higher cognitive functions, including language (Johnson & Ojemann, 2000).

Most results drawn from experiments of the abovementioned type have led to the idea that shared multisensory feedback across the visual and the auditory areas that code for the same supramodal skill could guide cross-modal plasticity across homologous areas, as proposed by Lomber et al. (2010).

It is important to note that imaging studies, such as those mentioned above, have focused on detecting the brain areas that process *first language* of congenitally, early and late blind versus sighted participants. However, imaging studies that involve foreign or second language tasks are extremely scarce. One study involving English as the L2 and Hebrew as the L1 was carried out by Ofan & Zohary, (2006). These researchers showed that active usage of the second language generates fMRI activation in the occipital cortex of the congenitally blind, similar to what is seen when they actively use their mother tongue. Furthermore, they found that similar activation patterns arise when contrasting active production of verbs with inactive repetition of the same words, similar to the contrast between identifying meaning and receiving input with no meaning (such as nonsense words). In agreement with previous studies, activation in the brains of the blind was found in the left occipital cortex, spanning the majority of the ventral and dorsal parts of the visual retinotopic areas, including V1, and expanding to the areas related to object recognition in the occipito-temporal cortex.

1.1.3 Findings through EEG studies

During the last decades, electrophysiological data have reported faster processing of auditory and somatosensory stimuli in blind compared sighted individuals. Thus, results from these studies indicate shorter latencies of event-related potentials (ERPs) in auditory and somatosensory tasks in the blind in contrast to the sighted, suggesting more efficient processing in former population. For example, Niemeyer & Starlinger (1981) showed shorter N1 latencies in blind participants, and Woods et al. (1985) reported larger N1, P2 and P3 amplitudes in blind compared to sighted participants.

Moreover, identified differences in topographies of ERP components in the sighted and the blind suggest reorganization in the neural implementation of nonvisual functions, so as to engage the occipital cortex of the blind. For instance, Kujala et al. (1992) found an N2b component at a posterior distribution of the scalp in early blind participants when processing auditory space (reacting to changes in sound localization). The study carried out by Alho et al. (1993) revealed greater MMN amplitudes in posterior scalp regions of blind participants.

Later, in a study carried out by Röder et al. (1999), congenitally blind subjects responded to targets faster than sighted controls when listening to a series of pure tones. The peak amplitude of N1 (100–150 ms) and P2 (150–250 ms) components were significantly larger in blind than in sighted individuals at temporal (T5/6), frontal–central (FC5/6) and parietal–occipital (P3/4) electrodes.

In the same line as the above, Kujala et al. (1995) recorded magnetic responses in early-blind, late-blind and sighted adults, while they were asked to distinguish changes in a pattern of sounds. They found that the activity elicited by the detection of an occasional higher pitch sound (infrequent 660 Hz tones among repetitive 600 Hz tones) had a generator source in the occipital cortex. In both groups of blind individuals (early and late), the scalp location of maximum electrical activity in response to higher frequency deviant tones was significantly posterior to that in sighted subjects when deviant tones were to be discriminated by subjects (but not when the tones were to be ignored). These results thus suggest the participation of posterior brain areas in active sound-change detection both in early- and late-blind subjects.

One of the aspects of speech processing that has been more extensively studied at the cortical level is that related to semantics in the participants' L1. For instance, Röder et. al. (2000) found a significant difference in cortical activity distribution between congenitally blind and sighted individuals in relation to processing meaning. When sighted participants heard the final words of an incongruous sentence, an N400 effect was observed in the fronto-central areas of the left hemisphere. However, such effect had a symmetric and broad topography in the blind. Furthermore, the N400 effect began earlier in the blind participants than in sighted ones, suggesting that the Blind Group recognized words faster than the latter group.

As mentioned previously, currently available findings from neuroimaging and electrophysiological studies that compare auditory perception processes of the blind to those of sighted controls have only considered non-linguistic sounds and L1 speech perception. Focus has not been placed on foreign or second language speech perception in blind compared to sighted individuals. Furthermore, from the majority of the available results, such as those mentioned above, no inferences can be drawn as to whether the participants were monolingual or bilingual, since the skills of processing, or learning to process an L2 have not been of principal interest to researchers. Nevertheless, shedding light onto L2 learning and acquisition in blind populations could have significant pedagogical implications.

The following section includes findings that further confirm the neurological evidence mentioned above, but from the behavioral side.

1.2 Differences in Auditory Perception between Blind and Sighted Individuals

In correlation with the neural evidence described above, several recent behavioral studies have revealed significant differences in auditory perception and discrimination accuracy between the blind and the sighted. Since significant differences have not been found from basic auditory sensory threshold measurements between blind and sighted individuals, the findings mentioned herein suggest that the blind have supranormal abilities to perform in *higher order* cognitive tasks (Niemeyer & Starlinger, 1981; Collignon et al., 2006). Furthermore, as Höting & Röder pointed out in the results they published in 2009, signs of neuroplasticity at the perceptual level also contribute to performance in other cognitive realms, such as speech perception, auditory attention and memory.

1.2.1 Auditory attention

From a structural point of view, the neurons in the dorsal area of the Medial Geniculate Body project axons to association areas in the auditory cortex, and are considered to play a pivotal role in maintaining and directing auditory attention. Further along the ascending auditory path is the Reticular Formation, of which one subsystem called the Ascending Reticular Activating System (ARAS) causes the cortex to be more alert when stimulated. It is also involved when selecting between important versus non-important auditory information, thus being related to what is known as *selective auditory attention*. Since there are so many sensory structures that project to the reticular formation and that undergo a vast number of interactions with it, it would be natural to always consider attention as an integral and fundamental part of sensory processing.

It is important to mention at this point that in order to focus auditory attention on specific acoustic objects of interest in the real world, a combination of auditory spatial cues and auditory feature cues to solve the pattern recognition problem of foreground–background decomposition (FBD) is typically used. This is illustrated by one of the best known examples of auditory attention, the *cocktail party effect*. Sound sources may vary in a wide range of acoustic dimensions, such as location, intensity, duration, etc., which facilitate grouping. Every day, listeners must develop great proficiency at what has been termed *auditory scene analysis* (ASA), which is the process of segregating and grouping sounds from the mixture of sources that typify our acoustic environment to form representations of relevant auditory streams or objects (Bregman, 1990). This process of selectively directing attention to a single auditory stream in a complex, multisource auditory scene may actually shape our perceptual organization of the elements in the scene (Shinn-Cunningham et al., 2007). Overall, the extraction of signal from noise and the separation of foreground from background is likely to be a multistage process that draws on bottom-up gestalt grouping primitives, on auditory memory, on attention, as well as other forms of top-down control (Alain et al., 2007; Xiang et al., 2007).

Although bottom-up saliency certainly plays a vital role, voluntary auditory attention is the key to highlighting foreground over background and switching attentional focus to different features, objects, or streams of interest within the acoustic scene. With that said, several studies have supported the notion of a more efficient top-down attention modulation of non-visual sensory events in participants who are blind. For example, Lessard et al. (1998) examined 3D sound localization in humans who were totally blind and in sighted subjects with or without their eyes covered. It was found that the totally blind could locate sounds equally well or more accurately than the sighted. Also, shorter reaction times to auditory and tactile spatial targets were also reported for congenitally blind versus sighted individuals (Collignon & De Volder, 2009) in selective (when participants had to focus attention on either the auditory or tactile stimulus) as well as divided (division of spatial attention between auditory and tactile targets) attention conditions. The superiority of the blind in auditory tasks was also found by Muchnik (1991) whose blind subjects were better than the sighted subjects in auditory gap detection and speech discrimination in noise, which, again, was attributed to the blind sample’s greater control of top-down selective attention.

1.2.2 Auditory Memory

During the last few decades, studies of short-term memory capacity in blind compared to sighted individuals have used digit-span tasks (Hull & Mason, 1995) and non-verbal tonal material (Stankov & Splisbury, 1978), and have consistently reported higher capacities for the blind (for example, Miller, 1992). Moreover, better memory for voices has been obtained for blind compared to sighted people (Bull et al., 1983), and enhanced memory scores for environmental sounds have been reported for congenitally blind and age-matched late blind humans (Röder & Rösler, 2003).

It has been shown that the blind, compared to the sighted, possess superior verbal memory, when the verbal elements are presented acoustically (D'Angiulli and Waraich, 2002; Hull and Mason, 1995; Pozar, 1982; Pring, 1988; Raz et al., 2007; Röder et al., 2001; Smits and Mommers, 1976; Tillman and Bashaw, 1968). For instance, in a study by Amedi et al. (2003) robust left-lateralized V1 activation seen through fMRI was correlated with the subjects' verbal memory abilities. Subjects were tested on the percentage of words they remembered 6 months after the scan. In general, blind subjects remembered more words and showed greater V1 activation than the sighted controls. Only blind subjects also showed a significant correlation of V1 activity and performance. Notably, blind subjects showed superior verbal memory capabilities compared not only with age-matched sighted controls, but also with reported population averages (using the Wechsler verbal memory test).

In another study by Röder et al. (2001), congenitally blind participants had more hits at correctly recognizing old words, which they had heard in a previous study phase, than age-matched sighted participants.

Language processing has been closely linked to working memory functions (Just & Carpenter, 1992) and therefore, faster speech processing in the blind (as shown through ERP and reaction time studies, such as those mentioned previously) might, to some extent, be due to higher working memory capacities as well. In agreement with the studies mentioned above, higher working memory capacities for auditorily presented words and digits have been observed in congenitally blind as compared to sighted individuals (Hull & Mason, 1995; Röder & Neville, 2003).

1.2.3 Speech perception

Despite the evidence reported in support of crossmodal and supramodal compensation and higher auditory perception capacities in the blind, there have also been reports on deficient performance on language and auditory tasks in this population (Stankov & Spilsbury, 1978; Hollins, 1989; Miller & Diderot, 1992). However, such studies have not accounted for important variables such as blindness etiology in their samples, the age of blindness onset and the quality of the sighted controls. Moreover, many of such studies have involved blind children, whose performance on language and auditory tasks are characterized by development aspects that adults do not share. For example, some studies support the idea that the lack of visual sensory input at an early age deteriorates learning the phonetic system of the mother tongue. It has also been proposed that blind children tend to use words in an imitative way, without adequately understanding the meaning of what they are saying (Andersen, Dunlea, & Kekelis, 1993). Vision seems to play an important role in establishing early communication patterns in sighted children, who usually use visual context information, such as gestures, to make sense of the speech they are perceiving (Mills, 1988). In this sense, there are some researchers that claim that blind children could be slower at learning the sounds that are not directly represented in Braille orthography. Furthermore, since blind children cannot see orofacial pronunciation models from others, they wouldn't know where to place their tongues or how to shape their lips in order to produce the sounds of their mother tongue through imitation.

However, several researchers and scholars have argued that linguistic experience can be more significant to blind children than sighted ones, since blind children can focus more auditory attention to spoken language (Chomsky, 1990; Perez-Pereira & Castro, 1997). Based on the studies carried out recently, there is enough evidence to suggest that blind children have advantages in what is called *phonological memory*, which refers to the capacity to recognize and remember phonological elements and their order of occurrence (O'brien et. al., 2007). Reports have also suggested an advantage in this population with regards to *phonological fluency*, which is the capacity to generate words when given a letter or sound (for example, words starting with 'F'). For example, Lucas (1984) showed that blind children identified words that were pronounced incorrectly in a story better than sighted children.

There is mounting evidence that blind adults have the same or a higher level of phonological memory, as well as semantic, syntactic and phonological fluency than sighted individuals. For instance, as mentioned previously, it has been reported that blind adults can detect inconsistent endings in sentences better than sighted controls in their L1 (Röder, Rosier, & Neville, 2000). Moreover, improved auditory speech discrimination abilities have been reported in the blind, again for their L1, especially in the context of a noisy background (Muchnik et al., 1991; Niemeyer and Starlinger, 1981). Since there was no difference in absolute thresholds for simple auditory stimuli in these studies, the authors attributed the advantage of the blind to a more efficient language processing. Röder et al. (2003) directly tested semantic and syntactic processing in the blind in their L1. They measured lexical decision times in a priming paradigm. In each trial, an adjective preceded a noun or a pseudo-word. Participants had to decide as fast as possible whether or not the second word was a real German word. The adjective was or was not semantically related to the subsequent noun. Moreover, in half of the trials, the adjective was either correctly or incorrectly inflected for gender with respect to the following noun. Both blind and sighted participants gained similarly from semantic and syntactic priming. The blind, however, had shorter reaction times than sighted participants for both words and pseudo-words. Thus, it was concluded that the advantage of the blind was most likely due to a more efficient processing of the speech signal due to more effective auditory-perceptual skills rather than a more extensive use of semantic or morpho-syntactic information.

As mentioned previously, almost all of the studies that test speech perception abilities in the blind have focused on L1 recognition and processing, thus, integrating the influence of meaning in the recognition tasks. However, studies related to the sole capacity of the blind to distinguish between sounds of a novel language (L2) is hard to come by.

2. PILOT EXPERIMENT

2.1. Hypothesis

Blind individuals can learn to discriminate between highly similar General American English L2 consonant sounds better than people who can see, if such sounds are only presented acoustically, that is, through the auditory sensory mode.

2.2. Objective

To carry out a pilot experiment so as to draw feasibility results and research design improvements for further studies that question if sight deprivation, both for long periods of time (blind individuals) and only during moments where auditory information is presented (sighted blindfolded individuals), can lead to better auditory discrimination of highly similar L2 sounds.

2.3. Method

2.3.1 Participants

A group of 8 blind adults (B Group), a second group of 8 matched sighted and blindfolded individuals (SB Group), and a third group of 8 matched sighted individuals who were not blindfolded (S Group) participated in this study (Total = 24). The mean age of the participants was 32 (age B Group M=36, range=30-43; SB Group age M=26, range 22-40; S Group age M=31, range=19-45).

All participants were native Chilean Spanish speakers, had always lived in Chile, had completed high school education, showed basic-level knowledge of English as a foreign language (all participants were at the A1 level according to the Common European Framework of Reference (CEFR)), showed a minimum degree of daily exposure to the English language (according to the questionnaire elaborated for this study – see Annex 3), and had normal hearing capacities (according to the questionnaire elaborated for this study – see Annexes 1 and 2). It is important to note that blind participants did not present other sensory aberrations. Mental and motor deficiencies, as well as psychopathologies, obvious cerebral dysfunctions, illnesses or disorders specifically affecting the auditory sense and sociocultural deprivations were not present in the participants' profiles in all three study groups. For participants in the B group, the main causes of blindness were brain tumors, accidents leading to retinal detachment, glaucoma and cataracts.

The participants in the B Group were recruited with the help of the Biblioteca Central para Ciegos, in Santiago, Chile. The participants in Groups SB and S were recruited through random selection. This pilot study was approved by the Ethics Board of the Universidad de Chile, and all participants signed a written consent form before entering the study.

Non-native competence has been frequently estimated by self-assessment for the purpose of participant selection in previous studies related to speech perception (Hazan and Simpson, 2000; van Wijngaarden et al., 2002; von Hapsburg et al., 2004; Weiss and Dempsey, 2008; Broersma and Scharenborg, 2010; Mattys et al., 2010), which has proven to be unreliable given its intrinsic subjectivity (Cooke et al., 2010) and the potential impact of cultural differences (Hazan and Simpson, 2000). Furthermore, general non-native language competence has been proposed to be irrelevant and unrelated to phonological competence (Scovel, 1969 and 1988). However, in terms of target language sound identification, the amount of native input is an important variable (Bradlow & Bent, 2002; van Wijngaarden et al., 2002; von Hapsburg et al., 2004; Rogers et al., 2006; Gooskens et al., 2010). Therefore, in order to make sure that the participants' general auditory discrimination performances of the English phones selected for this study are not unequally influenced by their potentially varying knowledge of and contact with English as a foreign language, the variables of non-native English proficiency and daily contact with the English language were assessed as follows:

The Oxford Online Placement Test (OOPT) as well as an L2 English language questionnaire, which was specially elaborated for this study (see Annex 3), were applied to control for the abovementioned potential variables. Based on the participants' scores on the OOPT, those placed in the Beginner level (A1), according to the Common European Framework of Reference (CEFR), were selected for this study. An adapted version of the OOPT was applied to assess the English proficiency levels of the blind participants, where participants responded to the listening section of the test, and the rest of the OOPT was read aloud to each of them.

Additionally, each participant responded to a questionnaire designed to establish an approximate frequency rate at which each participant is exposed to the English language on a daily basis. Participants responded to questions such as the following: "On a scale from 0% to 100%, at what percentage do you hear people speak English every day?". Percentages were divided into three groups: 0%-25%, 26%-75% and 76%-100%, and only those who responded within the first and lowest category participated in this study.

Regarding the participants' levels of auditory perception, on average, a human ear can identify and distinguish the sound waves in the range of 20 Hz to 20 kHz (20,000 Hz). Hearing range values were not determined for each participant, since many studies have shown that there are no significant differences between the auditory thresholds of blind vs. sighted people (Collignon et al., 2006; Niemeyer and Starlinger, 1981; Starlinger and Niemeyer, 1981). However, participants were asked to indicate whether they have had any type of illness or disorder affecting their ears or auditory sense, and they were also asked to indicate the level at which they would set the volumes of their televisions or radios (from a scale of 0 to 100) under normal conditions (see questionnaires in Annex 1 and 2). Only participants who have never suffered from illnesses or disorders affecting their ears or auditory sense, and who set their TV and radio volumes within a range of 0-25 were selected to participate in this study. People with musical training were not selected to participate.

In relation to the participants' visual acuity levels, a widely accepted definition of blindness stated in government statutes around the globe defines blindness as follows: "The term *blindness* means central visual acuity of 20/200 (on the Snellen test) or less in the better eye with the use of a correcting lens." From the functional and educational point of view, the renowned educator Natalie Barraga has defined a blind person to be "one who learns through the Braille System and cannot use vision to acquire any type of knowledge, even when light perception may help him/her to move and get orientation".

According to The International Classification of Disease-10 (2009), there are four levels of visual function:

a) normal vision
b) moderate visual impairment
c) severe visual impairment
d) blindness

The average visual acuity of healthy eyes is 20/16 to 20/12, and the significance of the 20/20 standard can best be thought of as the lower limit of normal or as a screening cutoff. Functionally speaking, 20/20 is commonly used for a pilot's license and 20/40 for a driver's license, sighted participants had visual acuities within the range of 20/40 – 20/12. Based on the above, only completely blind individuals participated in the B group (Blind Group), and people with normal vision participated in the S group (sighted/not blindfolded group) and the SB group (sighted/blindfolded group).

2.3.1.1Variables Considered for Correlation Analysis

Two varying aspects of the participants' profiles were analyzed in relation to their performance on the auditory discrimination tests:

1) **Daily Exposure to Street Noise:** The participants were requested to complete a questionnaire composed of 4 questions regarding the amount of time they estimate to spend on the streets and on public transportation (see Annex 4). The

score that each participant got through this questionnaire represented the estimated frequency at which the participants are exposed to street noise in general. The reason for requesting this information was to see if this exposure influenced how well the participants could focus their attention to auditorily discriminating the phones selected for this study, under conditions in which background noise (specifically, noise recorded from the streets of downtown Santiago, Chile) could distract them from correctly perceiving the target sounds.

2) **Years of blindness and age of blindness onset:** Although behavioral studies have reported that certain auditory tasks, such as localizing sounds in the surrounding space, are equally well performed in congenitally, early and late blind individuals (Röder et al. (1999); Voss et al., 2004), neurophysiological data has revealed differences in auditory processing between congenitally and early blind humans versus late blind individuals. For instance, recent ERP studies have reported that congenitally and early blind individuals actually process locating auditory stimuli faster than late blind individuals (Fieger et al. (2006). Regarding memory for environmental sounds, this was observed to be enhanced in congenitally blind compared to age-matched late blind individuals (Röder 329 & Rösler, 2003). An underlying factor for the above which has been proposed in recent studies is that blindness onset has an impact on crossmodal plasticity. Some results suggest that crossmodal plasticity is age-dependent (Cohen et al., 1999; Sadato et al., 2002), indicating that there are different neuronal mechanisms involved in neuronal reorganization during development up to puberty, compared to those involved in adulthood. However, other studies show similar results in late blind participants (Büchel et al., 1998; Rösler et al., 1993) and even sighted humans who have been blindfolded for some days, in which short-term plasticity has been found to be induced in occipital areas (Merabet et al., 2008; Pascual-Leone & Hamilton, 2001), or the *unmasking* of existing pathways that become available when visual input is removed, as mentioned previously in this study. Considering the differences in results posed above, it is important to see whether the amount of time in which the blind participants have lacked visual input influences their auditory discrimination of foreign English

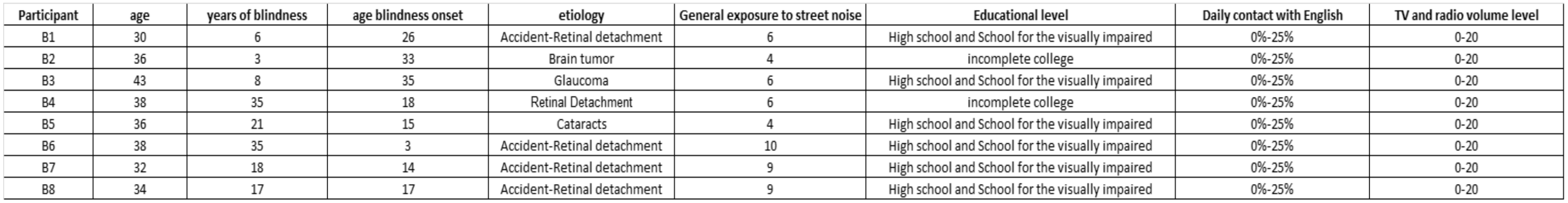
sounds. Therefore, the numbers of years in which they have been blind, along with the age of blindness onset, were analyzed in relation to their results on the auditory discrimination tests of this study (Test A-without background noise, and Test B-with background noise).

Note: It is important to mention that another varying aspect is the time in which the participants estimate to have contact with the English language on a daily basis. Contact with the language includes listening to people speak English, both live and through the media, such as movies or television, as well as listening to music in English, interacting with people in English and reading in English (be it documents, emails, publicity, etc.). Although the participants' levels of daily exposure to the target language were within a low percentage range (0%-25%), the approximate number of hours of exposure a day may vary among the participants. It would be interesting to consider the mean number of hours of daily exposure to the target language in further studies with larger sample groups.

Tables with the profiles of each participant is shown below:

Table 1.

B Group : Blind participants



Participant	age	years of blindness	age blindness onset	etiology	General exposure to street noise	Educational level	Daily contact with English	TV and radio volume level
B1	30	6	26	Accident-Retinal detachment	6	High school and School for the visually impaired	0%-25%	0-20
B2	36	3	33	Brain tumor	4	incomplete college	0%-25%	0-20
B3	43	8	35	Glaucoma	6	High school and School for the visually impaired	0%-25%	0-20
B4	38	35	18	Retinal Detachment	6	incomplete college	0%-25%	0-20
B5	36	21	15	Cataracts	4	High school and School for the visually impaired	0%-25%	0-20
B6	38	35	3	Accident-Retinal detachment	10	High school and School for the visually impaired	0%-25%	0-20
B7	32	18	14	Accident-Retinal detachment	9	High school and School for the visually impaired	0%-25%	0-20
B8	34	17	17	Accident-Retinal detachment	9	High school and School for the visually impaired	0%-25%	0-20

n = 8

Age M=36

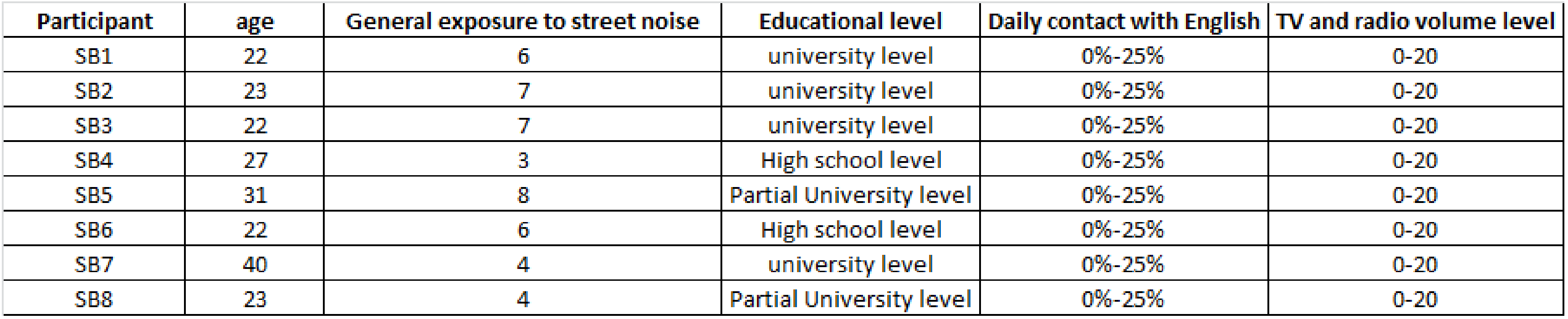
Level of exposure to street noise M=7

Years of Blindness M=18

Age of Blindness Onset M=20

Table 2.

SB Group : Sighted-Blindfolded participants



Participant	age	General exposure to street noise	Educational level	Daily contact with English	TV and radio volume level
SB1	22	6	university level	0%-25%	0-20
SB2	23	7	university level	0%-25%	0-20
SB3	22	7	university level	0%-25%	0-20
SB4	27	3	High school level	0%-25%	0-20
SB5	31	8	Partial University level	0%-25%	0-20
SB6	22	6	High school level	0%-25%	0-20
SB7	40	4	university level	0%-25%	0-20
SB8	23	4	Partial University level	0%-25%	0-20

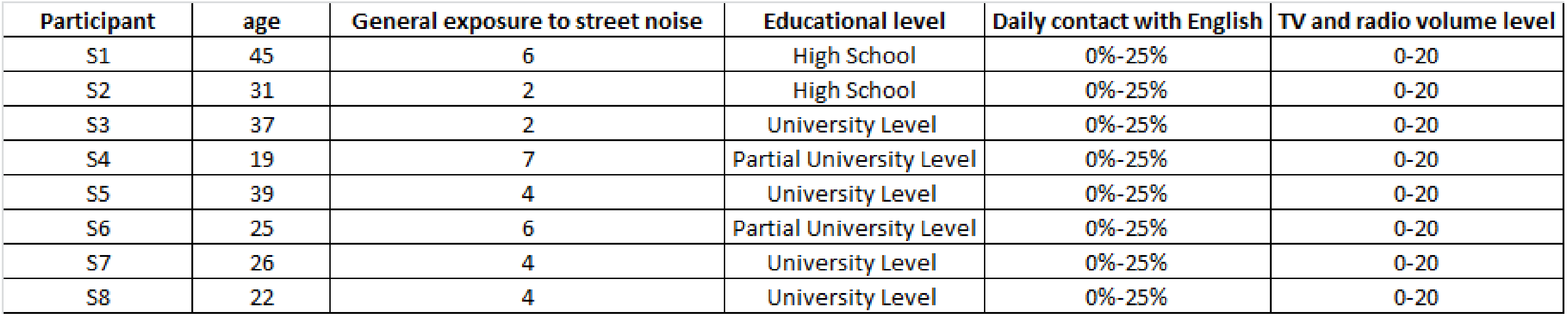
n = 8

Age M=26

Level of exposure to street noise M=5

Table 3.

S Group : Sighted Not Blindfolded Participants



Participant	age	General exposure to street noise	Educational level	Daily contact with English	TV and radio volume level
S1	45	6	High School	0%-25%	0-20
S2	31	2	High School	0%-25%	0-20
S3	37	2	University Level	0%-25%	0-20
S4	19	7	Partial University Level	0%-25%	0-20
S5	39	4	University Level	0%-25%	0-20
S6	25	6	Partial University Level	0%-25%	0-20
S7	26	4	University Level	0%-25%	0-20
S8	22	4	University Level	0%-25%	0-20

N = 8

Age M=31

Level of exposure to street noise M=4

TOTAL PARTICIPANTS: N= 24

2.3.2. Measures

Participants took two auditory discrimination tests (Tests A and Tests B) at the end of each experiment session on minimal pair words. In each test, the participants heard a word, followed by 1 second of silence, and then heard the second word of the pair. Then, they had 10 seconds to orally indicate if the 2 words they had just heard were the same or different. Since the participants were native Chilean Spanish speakers, they were requested to say “iguales” or “distintos” for each pair they heard. The experimenter was always present in the room to take notes of the participants’ answers.

The only difference between the two tests was that the words that the participants were requested to pay attention to in Test B were heard together with a recording of street noise, whereas there was no background noise when the word pairs were heard in Test A. For Test B, the background noise had the same loudness as the voice of the English native speaker, being the signal to noise ratio (SNR) about 0 dB, as proposed by Keith Johnson (2003).

In total, the participants were tested for 14 pairs of words in Test A and 14 pairs in Test B (participants were tested for a total of 28 pairs in each of the 5 sessions). In each test of 14 pairs, the number of minimal pairs and pairs of identical words was established at random. For a detailed description of how these tests were applied, please refer to section 2.3.5. of this study.

The results on Tests A and Tests B within each group were analyzed through the Wilcoxon Signed Ranked Test. Furthermore, the results on Tests A and Tests B between groups were analyzed through the Kruskal-Wallis Test. Spearman’s correlation coefficients were calculated for the relationship between participants’ levels of exposure to street noise and their test scores, as well as for the relationships between blind participants’ numbers of years of blindness and ages of blindness onset with their scores on Tests A and Tests B.

2.3.3. Auditory Input

The design of this auditory discrimination experiment for this pilot study was done with reference to the recommendations set forth by Keith Johnson for speech perception experiments in his book *Acoustic and Auditory Phonetics* (2003), and based on certain guidelines from *Wepman's Auditory Discrimination Test* (1973).

2.3.3.1. Target sounds

Three pairs of highly similar English consonant sounds were selected for this study (6 sounds in total). The sounds in each pair only differed in their voicing aspect. A table of the pairs of consonant sounds selected for this study is shown below:

Table 4: Pairs of highly similar English consonant sounds selected for this pilot study

Pair 1	[s]	Voiceless alveolar fricative
	[z]	Voiced alveolar fricative
Pair 2	[tʃ]	Voiceless palatal-alveolar affricate
	[dʒ]	Voiced palatal-alveolar affricate
Pair 3	[ʃ]	Voiceless palatal-alveolar fricative
	[ʒ]	Voiced palatal-alveolar fricative

It is important to note that the sounds selected for this study have been observed to be difficult for native Spanish speakers to distinguish when learning English as a foreign language.

2.3.3.2. Word selection and formation with target sounds for the pilot experiment

The participants attended to 5 sessions of approximately 21 minutes each. During the first thirteen minutes of each session, the participants heard a recording of two native English speakers (one male and one female) pronouncing 156 nonsense words and 132 English words, which were generated and selected as follows:

Note: the spelling of the nonsense words below were attempts to represent the target sounds, where ‘’s’ represents [s], ‘z’ represents [z], ‘ch; represents [tʃ], ‘dge’ or ‘j’ represents [dʒ], ‘sh’ represents [ʃ], and ‘jh’ represents [ʒ]. The graphemic representations were only used by the English native speakers who recorded the words for this study. It is also worth mentioning that the nonsense words were all pronounceable according to General American English (AmE) and the target phones were in word environments, of which parts can occur in General American pronunciation.

Monosyllabic nonsense words (total = 54 words)

Five monosyllabic nonsense words were created for each sound, with the target sounds in the initial positions (eg.: ‘sa’, ‘se’, ‘si’, ‘so’, ‘su’; ‘za’, ‘ze’, ‘zi’, ‘zo’, ‘zu’; ‘cha’, ‘che’, ‘chi’, ‘cho’, ‘chu’; etc.). Thus, 30 monosyllabic nonsense words with the target sounds in the initial positions were created, which formed fifteen monosyllabic minimal pairs with the target sounds in the initial positions (eg: ‘sa’ vs. ‘za’; ‘se’ vs. ‘ze’, etc.).

Additionally, four monosyllabic nonsense words were generated for each sound, with the target sounds in the initial and final positions, separated by a vowel (eg.: ‘sas’, ‘sis’, ‘sos’, ‘sus’; ‘zaz’, ‘ziz’, ‘zoz’, ‘zuz’; ‘chach’, ‘chich’, ‘choch’, ‘chuch’; etc.). Thus, 24 monosyllabic nonsense words with the target sounds in the initial and final positions were created, which formed 12 monosyllabic nonsense minimal pairs with the target sounds in the initial and final positions (eg.: ‘sos’ vs. ‘zoz’; ‘chich’ vs. ‘jidge’; etc.).

Two-syllable nonsense words (total = 102 words)

Then, fourteen two-syllable nonsense words were created for each target sound, with the target sounds in the initial and mid positions (eg.: ‘sasa’, ‘sesa’, ‘sisa’, ‘sosa’; ‘zaza’, ‘zeza’, ‘ziza’, ‘zoza’, ‘zaza’; ‘jaja’, ‘jeja’, ‘jija’, ‘joja’, etc.). Thus, 84 two-syllable nonsense words with the target sounds in the initial and mid positions were created, which formed 42 two-syllable minimal pairs with the target sounds in the initial and mid positions (eg.: ‘sasa’ vs. ‘zaza’; ‘jeja’ vs.’checha’, etc.).

In addition, three two-syllable nonsense words were created for each target sound, with the target sounds in the initial, mid and final positions (eg.: ‘sasas’, ‘sisas’, ‘sosis’; ‘zazas’, ‘zizas’, ‘zoziz’; ‘shashash’, ‘shishash’, ‘shoshish’, etc.). Thus, 18 two-syllable nonsense words with the target sounds in the initial, mid and final positions were created, which formed 9 two-syllable nonsense minimal pairs with the target sounds in the initial, mid and final positions (eg.: ‘sasas’ vs. ‘zazaz’; ‘shishash’ vs. ‘jhijhajh’; etc.).

<u>1 - 3 syllable English words (total = 132 words)</u>

Finally, twenty-two real English words were selected for each target sound (eg.: ‘Sue’, ‘phase’, ‘allusion’, ‘catch’, hodgepodge’, etc.), that is, twenty-two words containing the sound [s], twenty-two containing [z], twenty-two containing [tʃ], twenty-two containing [dʒ], twenty-two containing [ʃ], and twenty-two containing [ʒ], thus totaling 132 real English words. These words were composed of 1 – 3 syllables and the target sounds were in the initial, mid and final positions at random. Of the 132 English words, only 102 formed minimal pairs (eg.: ‘face’ vs. ‘phase’; ‘Aleutian’ vs. ‘allusion’; ‘catch’ vs.’ cadge’), thus forming 51 minimal pairs. English-Spanish cognates and false cognates were not included in this study.

In total, the participants were exposed to 288 words (156 nonsense words and 132 English words), of which 256 words (156 nonsense words and 102 English words) formed minimal pairs (78 nonsense word minimal pairs and 51 English minimal pairs).

2.3.4. Procedure

The participants were requested to attend five sessions that lasted approximately 21 minutes each, in a room that was shielded from external noise and that included three plants, a closed closet, a 42” wide screen television (turned off), a round table, three chairs, a lap top computer (turned on, but making no noise), a pair of headphones and a window. In every session, participants were requested to sit at the round table, in one of the three chairs, put on the headphones and listen carefully to what they were going to hear. During the first thirteen minutes of each session the participants were exposed to a “training stage”, in which they heard the 156 nonsense words and 132 English words described above (total input = 288 words). Then, they were exposed to a “testing stage” that lasted approximately 8 minutes. The participants were exposed to a “training stage” and a “testing stage” in each of the five sessions of this pilot study, and were given instructions on what they were asked to do before beginning each session.

All of the words were recorded by a female native English speaker and by a male English speaker, who were both from Chicago, U.S.A. The appearance of these words, either with the female voice or the male voice, throughout the 13 minutes of the “training stage” recording was established at random. The reason for presenting the words either with a female or male voice at random was to try to keep the participants from getting used to hearing only one voice, which could influence how well they remember and identify the sounds of the words they heard.

The participants listened to the recording, which were delivered binaurally at a comfortable volume level through headphones, and were asked to pay attention to what they heard.

A. The “training stage”

The order in which the participants heard the 288 words in the 13-minute “training stage” was established as follows:

Phase 1 (total time = 4 minutes and 10 seconds; total words = 96):

During the first 2 minutes of each session, the participants heard 48 words containing the sound [s] (9 monosyllabic nonsense words, 17 two-syllable nonsense words and 22 1-3 syllable real English words). Then, they were exposed to 10 seconds of silence, after which they heard 48 words containing the sound [z] (9 monosyllabic nonsense words, 17 two-syllable nonsense words and 22 1-3 syllable real English words).

**The participants were exposed to 30 seconds of silence before moving on to the next phase.*

Phase 2 (total time = 4 minutes and 10 seconds; total words = 96):

The participants heard 48 words containing the sound [ʃ] (9 monosyllabic nonsense words, 17 two-syllable nonsense words and 22 1-3 syllable real English words) for 2 minutes. Then, they were exposed to 10 seconds of silence, after which they heard 48 words containing the sound [ʒ] (9 monosyllabic nonsense words, 17 two-syllable nonsense words and 22 1-3 syllable real English words).

**The participants were exposed to 30 seconds of silence before moving on to the next phase.*

Phase 3 (total time = 4 minutes and 10 seconds; total words = 96):

The participants heard 48 words containing the sound [tʃ] (9 monosyllabic nonsense words, 17 two-syllable nonsense words and 22 1-3 syllable real English words) for 2 minutes. Then, they were exposed to 10 seconds of silence, after which they heard 48 words containing the sound [dʒ] (9 monosyllabic nonsense words, 17 two-syllable nonsense words and 22 1-3 syllable real English words).

**End of the "training stage".*

Thus, the participants heard a list of 48 words for each of the 6 target sounds, and therefore were exposed to 6 lists of words.

Although the participants heard the same 288 words in each of the 5 sessions, the order in which the words appeared in these lists was modified at random for each session. Thus, the words were presented to the participants in a specific order in session 1, but were presented in a different order in session 2, and so on for the 5 sessions.

It is also important to highlight that the silences between each word that the participants heard lasted either 1 or 2 seconds. For example, the list of words containing the sound [s] (which corresponds to first 2 minutes of phase 1) was recorded as follows: the words were separated by 2 seconds of silence during the first 30 seconds of the recording, then were separated by 1 second during the following 20 seconds, then separated by 2 seconds during the next 33 seconds of the recording and finally were separated by 1 second during the last 37 seconds (total time = 2 minutes). These silences were assigned in this manner to the 6 lists of words containing the 6 target sounds, so as to keep the participants' attention, by not allowing them to become habituated to the rhythm with which the words were being presented.

B. <u>The “testing stage”</u>

After this “training stage”, in which the participants became familiar with the target sounds in their different word environments, the participants were exposed to a “testing stage”. This stage lasted 8 minutes, during which the participants heard word pairs (minimal pairs and pairs of identical words) and were asked to indicate whether the words in each pair were different or the same. The testing stage consisted of two tests (Tests A and Tests B). The only difference between the two tests was that the words in Test B were heard together with a recording of street noise, whereas there was no background noise when the word pairs were heard in Test A. For Test B, the background noise had the same loudness as the voice of the English native speaker, being the signal to noise ratio (SNR) about 0 dB, as proposed by Keith Johnson (2003).

At the end of phase 3 in the “training stage”, the participants were exposed to 1 minute of silence before beginning Test A. It is important to note that the participants had the headphones on during the entire 21 minutes of each session. Therefore, participants knew that Test A was going to begin when they heard a short “beep” sound at the end of the one-minute silence mentioned above. These instructions were given to the participants before beginning each session.

After the “beep”, the participants heard a word, followed by 1 second of silence, and then heard the second word of the pair. Then, they had 10 seconds to orally indicate if the 2 words they had just heard were the same or different. Since the participants were native Chilean Spanish speakers, they were requested to say “iguales” or “distintos” for each pair they heard. The experimenter was always present in the room to take notes of the participants’ answers. In total, the participants were tested for 14 pairs of words in Test A and 14 pairs in Test B (participants were tested for a total of 28 pairs in each of the 5 sessions). In each test of 14 pairs, the number of minimal pairs and pairs of identical words was established at random. Moreover, the pairs assigned for the tests were composed of the same words that the participants had heard in the first 13-minute “training stage”. The participants were tested on different word pairs (selected from the word lists they heard in the “training stage”) in each of the 5 sessions.

The following table summarizes the sequence in which the auditory input was exposed for each of the 5 sessions:

Table 5: Organization of exposure to and testing of auditory input for each session

Session Total Time: 21 minutes		
TRAINING STAGE	Phase 1 (4min. 10 sec.)	List 1: Exposure to 48 words containing the sound /s/ (2 min)
		10 seconds of silence
		List 2: Exposure to 48 words containing the sound /z/ (2 min)
	30 SECONDS OF SILENCE	
	Phase 2 (4min. 10 sec.)	List 3: Exposure to 48 words containing the sound /ʃ/ (2 min)
		10 seconds of silence
		List 4: Exposure to 48 words containing the sound /ʒ/ (2 min)
	30 SECONDS OF SILENCE	
	Phase 3 (4min. 10 sec.)	List 5: Exposure to 48 words containing the sound /tʃ/ (2 min)
		10 seconds of silence
		List 6: Exposure to 48 words containing the sound /dʒ/ (2 min)
One minute of silence		
TESTING STAGE	Test A (3 min)	
	One minute of silence	
	Test B (3 min)	
END OF SESSION		

2.4. Results

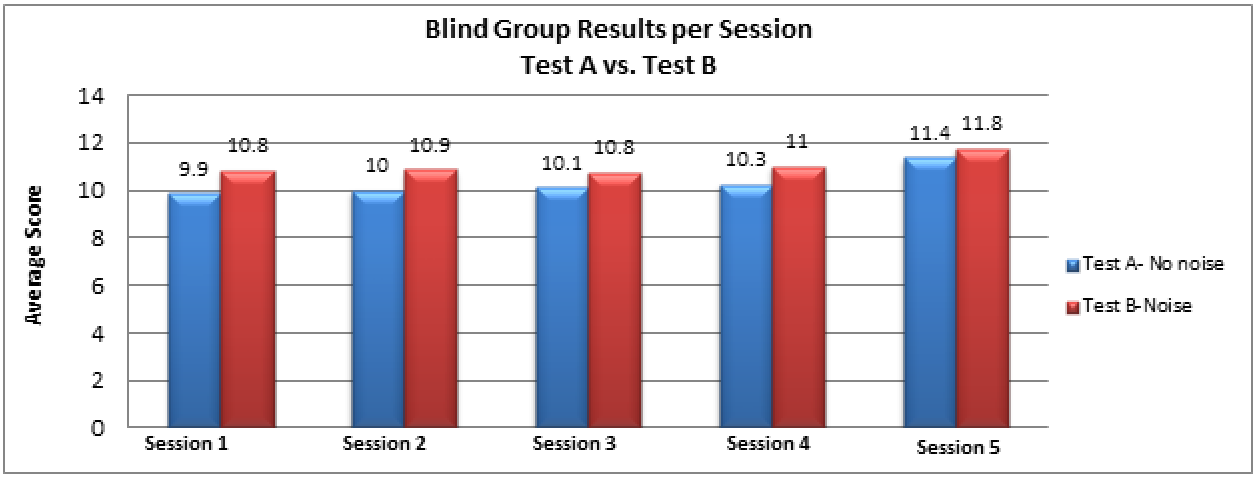
This section is divided into five subsections. The first subsection shows an examination of each group's scores on Tests A and Tests B throughout the five sessions of this pilot experiment (within-group assessment), as analyzed through simple averaging and through the Wilcoxon Signed Rank Test; subsection two compares the overall performances of the three groups on Tests A and Tests B, as analyzed through simple averaging and through the Kruskal-Wallis Test; subsection three shows the correlation between the participants' levels of exposure to street noise and their scores in Tests A and Tests B throughout the 5 sessions; the fourth subsection shows the correlation between the number of years in which the blind participants have lacked visual input and their test scores in Tests A and Tests B; and finally, the fifth subsection shows the correlation between the blind participants' ages of blindness onset, and their test scores in Tests A and Tests B throughout the 5 sessions of this pilot experiment

Subsection 1: Within-group results on Tests A and Tests B throughout the five experimental sessions

The three graphs that follow show simple averaging analyses of each group's performance on auditory discrimination Tests A (condition without background noise) and Tests B (condition with background noise). Following these graphs, the statistical analysis of the results, through the Wilcoxon Signed Rank Test, is exposed.

B Group

Figure 1



*Maximum mean score for Test A and Test B= 14

Mean Score Test A 10.3

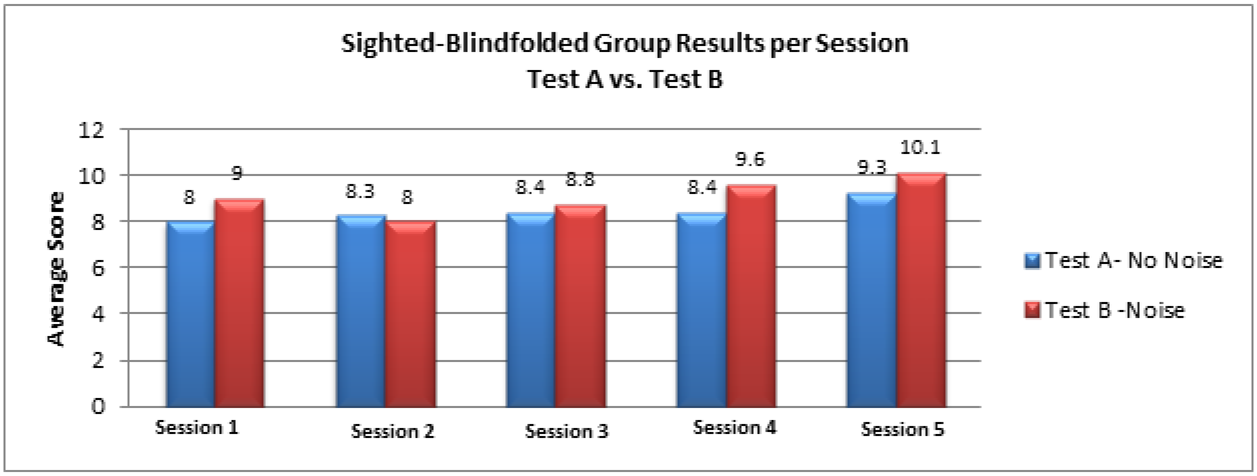
Mean Score Test B 11.0

According to the graph above, a tendency to improve in auditorily distinguishing the highly similar sounds selected for this study can be appreciated for the Blind Group. Their average test scores went up by more points on session 4, compared to the slow increase observed from session 1 to session 3. Higher performances can be observed for Tests B, in which they were asked to discriminate between minimal pairs while hearing recordings of street noise in the background, throughout the five sessions.

It is also interesting to note that this group showed a greater improvement in auditory discrimination with background noise starting at session 4 (the group scored 0.3 points more on their average score from session 3 to session 4, whereas the constant difference in score from session 1 to 3 was of only 0.1). This jump in average score on Tests B (condition with background noise) occurred earlier than the jump in scores on Tests A (condition without background noise), i.e., under background noise conditions the group showed a greater improvement starting at session 4, whereas under no background noise conditions they increased greatly in performance at session 5. Therefore, their improvement in distinguishing the L2 sounds selected for this study could have been favored by conditions that required them to focus their attention on the particular acoustic streams, while shutting out the potentially distracting background noise from their attention span. This would be related to the so called *cocktail party effect*, and the participants' proficiency at auditory scene analysis (see discussion and conclusions section 2.5).

SB Group

Figure 2



*Maximum mean score for Test A and Test B= 14

Mean Score Test A	**8**
Mean Score Test B	**9.1**

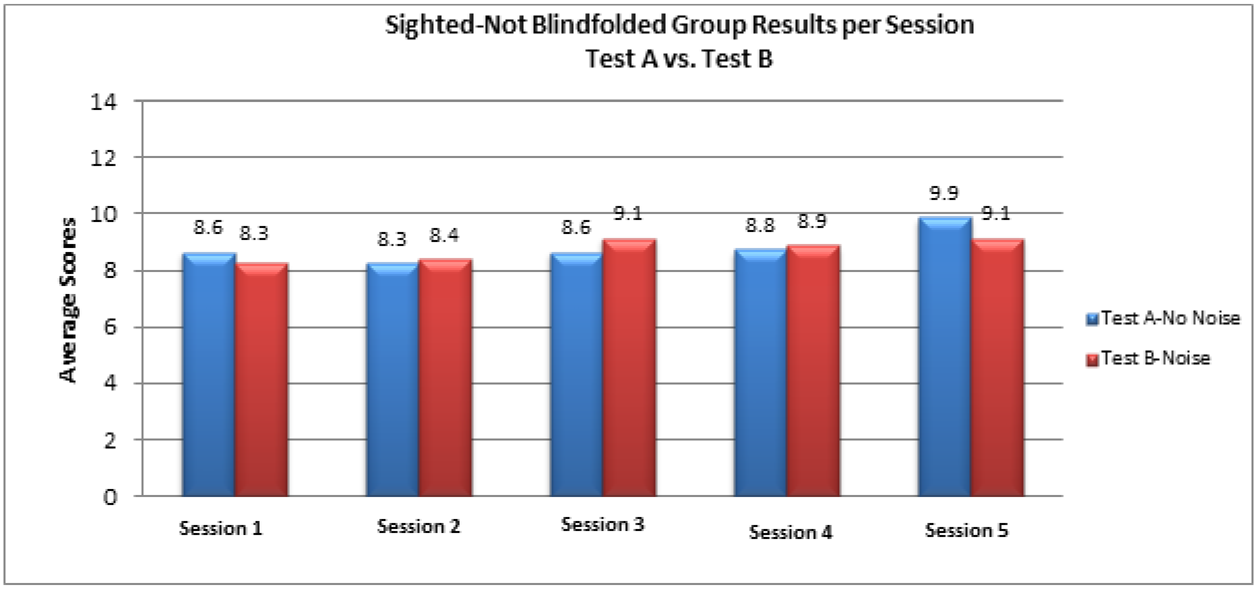
In the graph above, a tendency for the average scores to improve on Tests A and B can be seen from session 1 to session 5. However, this tendency isn't as constant as the one observed for the B group in the previous graph. For the SB Group, there was a slight decrease in performance in session 2 compared to session 1, but the average scores increased gradually from session 2 on.

Furthermore, the difference in performance between Test A (without background noise) and Test B (with background noise) is greater in the SB Group (with an average score difference of 1.1) than the difference in Test A and Test B scores in the B Group (with an average score difference of 0.7).

Additionally, just like Group B, the SB Group performed better in Test B (with background noise) than in Test A (without background noise).

S Group

Figure 3



*Maximum mean score for Test A and Test B= 14

Mean Score Test A	**8.8**
Mean Score Test B	**8.8**

Unlike the B and SB Groups, the Sighted-Not Blindfolded group did not consistently perform better on the auditory discrimination tests with background noise (Tests B) compared to the discrimination tests without background noise (Tests A). Although their performance under the background noise condition tended to increase from session 1 to session 3, it dropped in session 4 and recovered in session 5 to the same peak level it had reached in session 3.

Furthermore, the S Group’s auditory discrimination of the s English sounds was worse with background noise (Test B) than without background noise (Test A) in session 1, was better with background noise in sessions 2, 3 and 4, and finally was worse with background noise in the final session compared to their performance without background noise. In this sense, instead of improving their capacity to distinguish between the sounds under background noise conditions, as was the case for the previous 2 groups, the Sighted-Not Blindfolded participants did not improve consistently throughout the 5 sessions.

The S Group’s mean score on Tests A (without background noise) was the same as their mean score on Tests B (with background noise).

The following graphs and tables represent the statistical analyses obtained through the Wilcoxon Signed Rank Test for each group.

Statistical Analysis-Wilcoxon Signed Rank Test

Blind Group-With/without background noise

Figure 4

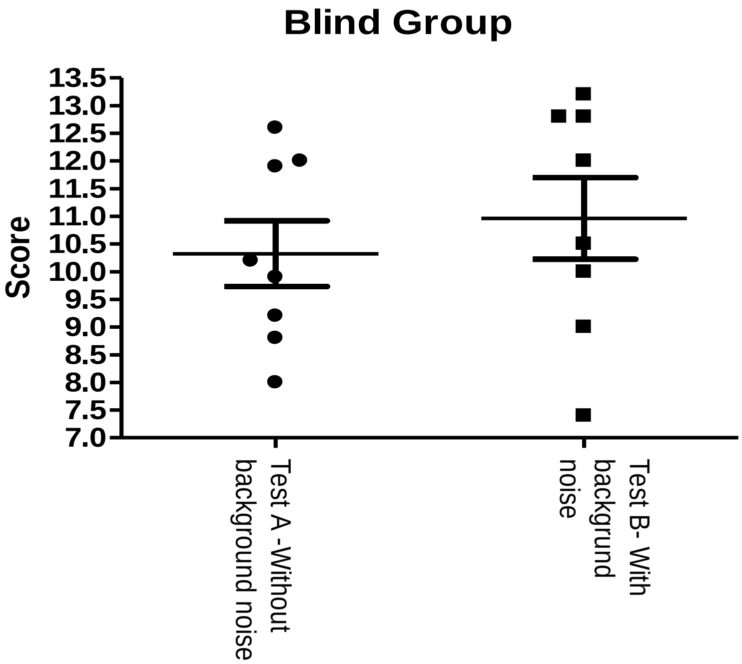


Table 6

	Test A	**Test B**
Number of values	8	8
Median	10.05	11.25
Mean	10.33	10.96
Std. Deviation	1.676	2.088
Std. Error	0.5924	0.7382
Lower 95% CI of mean	8.924	9.217
Upper 95% CI of mean	11.73	12.71
Wilcoxon Signed Rank Test		
Actual median	10.05	11.25
P value (two tailed)	**0.0078**	**0.0078**

Exact or estimate	Exact	Gaussian Approximation
Significant (alpha=0.05)	**YES**	**YES**
Sum	82.60	87.70

Statistical Analysis-Wilcoxon Signed Rank Test

Sighted Blindfolded Group-With/without background noise

Figure 5

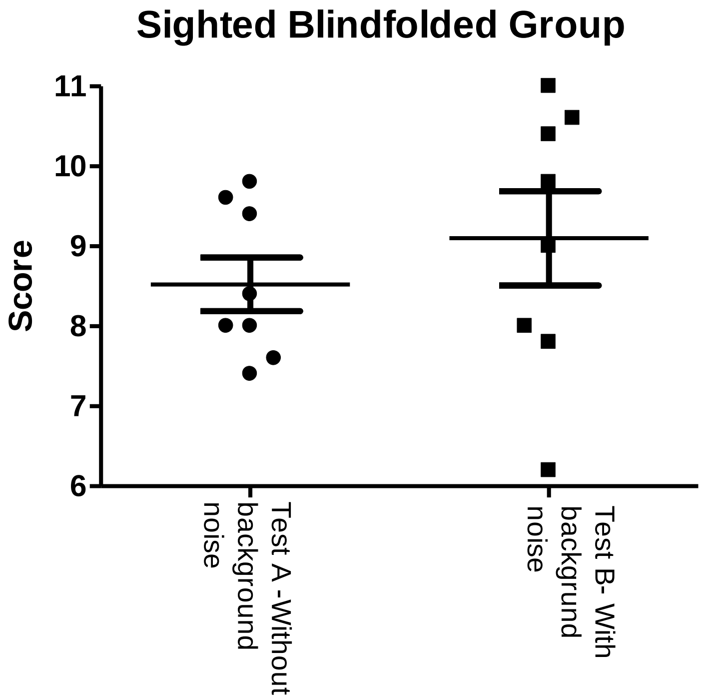


Table 7

	Test A	**Test B**
Number of values	8	8
Median	8.200	9.400
Mean	8.525	9.100
Std. Deviation	0.9438	1.663

Std. Error	0.3337	0.5880
Lower 95% CI of mean	7.736	7.710
Upper 95% CI of mean	9.314	10.49
Wilcoxon Signed Rank Test		
Actual median	8.200	9.400
P value (two tailed)	**0.0078**	**0.0078**
Exact or estimate	Gaussian Approximation	Exact
Significant (alpha=0.05)	**YES**	**YES**
Sum	68.20	72.80

Statistical Analysis-Wilcoxon Signed Rank Test

Sighted Not Blindfolded Group-With/without background noise

Figure 6

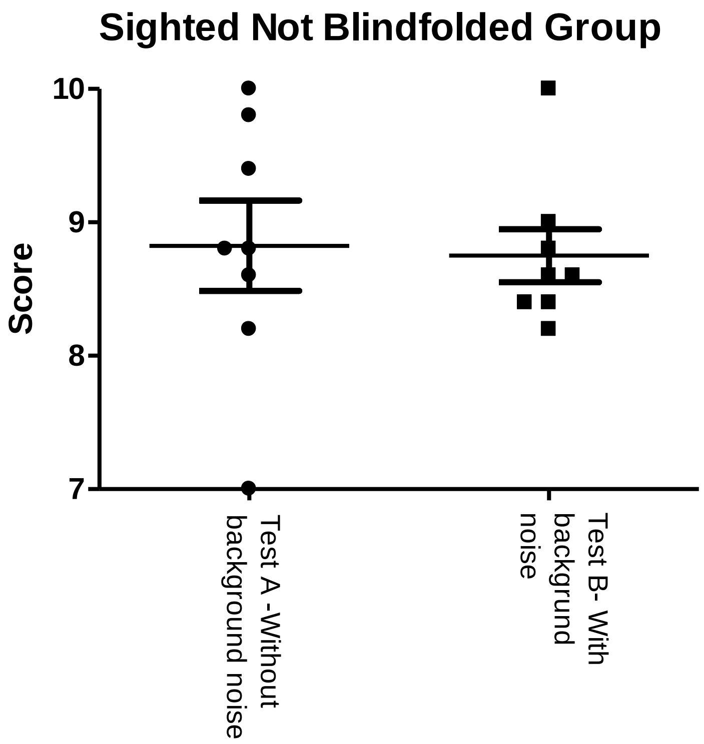


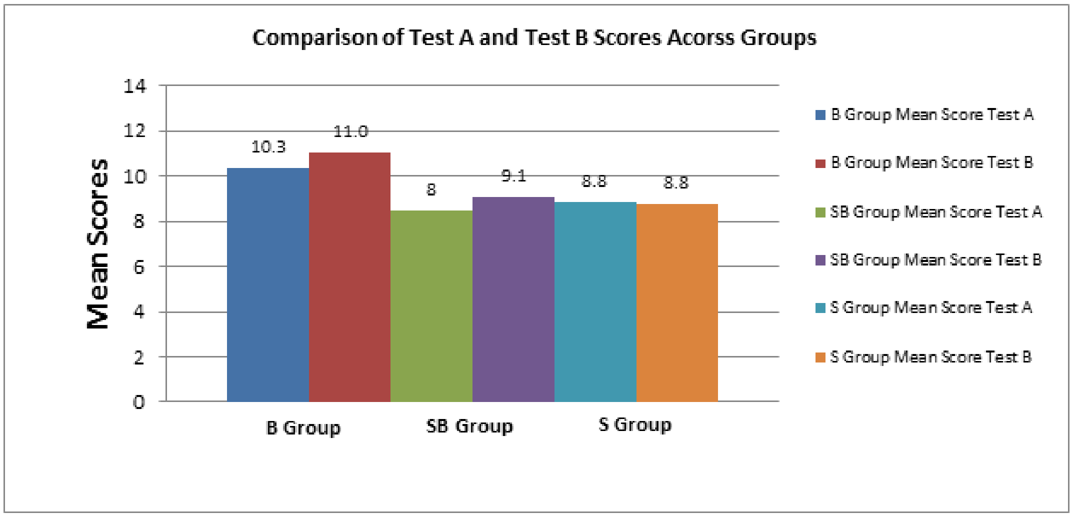
Table 8

	Test A	**Test B**
Number of values	8	8
Median	8.800	8.600
Mean	8.825	8.750
Std. Deviation	0.9588	0.5632
Std. Error	0.3390	0.1991
Lower 95% CI of mean	8.023	8.279
Upper 95% CI of mean	9.627	9.221
Wilcoxon Signed Rank Test		
Actual median	8.800	8.600
P value (two tailed)	**0.0078**	**0.0078**
Exact or estimate	Gaussian Approximation	Gaussian Approximation
Significant (alpha=0.05)	**YES**	**YES**
Sum	70.60	70.00

Subsection 2: Overall performances of the three groups on Tests A and Tests B

The graph that follows shows the simple averaging analysis of the overall performances of each group (B, SB and S) on auditory tests A (without background noise) and B (with background noise). Following this graph, the statistical analysis of the results, through the Kruskal-Wallis Test, is exposed.

Figure 7



*Maximum mean score for Test A and Test B= 14

The analysis above clearly shows that the B Group’s overall performance on both tests was greater than that of the SB and S Groups. The biggest difference can be seen for Test B (with background noise), on which the Blind Group got the best average result of the three groups (B Group M=11 vs. SB Group M=9.1 & S Group M=8.8). No significant difference was found between the two sighted groups, by simply looking at the average scores.

Statistical Analysis : Kruskal-Wallis Test

Performance of the three groups on Test A (without background noise)

Figure 8

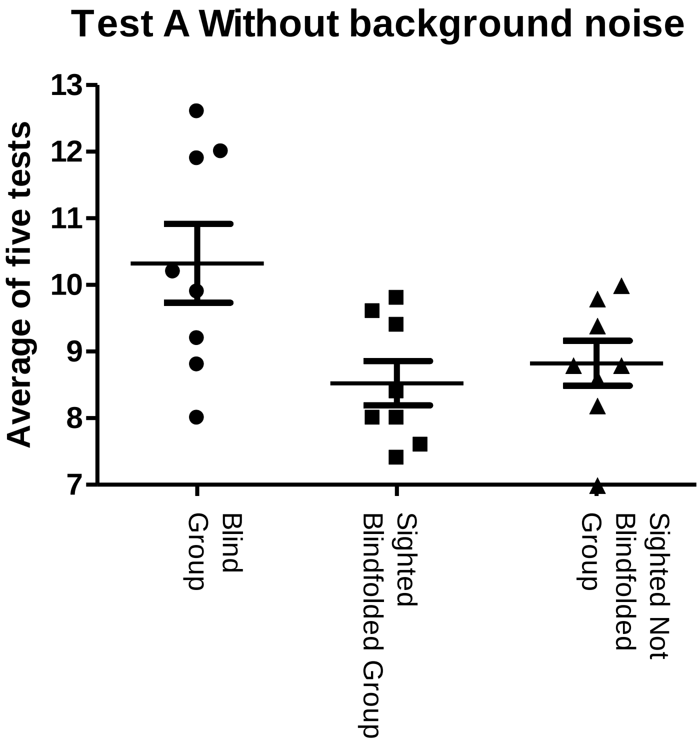


Table 9

Kruskal-Wallis test	
P value	**0.0513**
Exact or approximate P value	Gaussian Approximation
Significant (alpha=0.05)	NO
Number of groups	3
Kruskal-Wallis statistic	5.941

Statistical Analysis : Kruskal-Wallis Test

Performance of the three groups on Test B (with background noise)

Figure 9

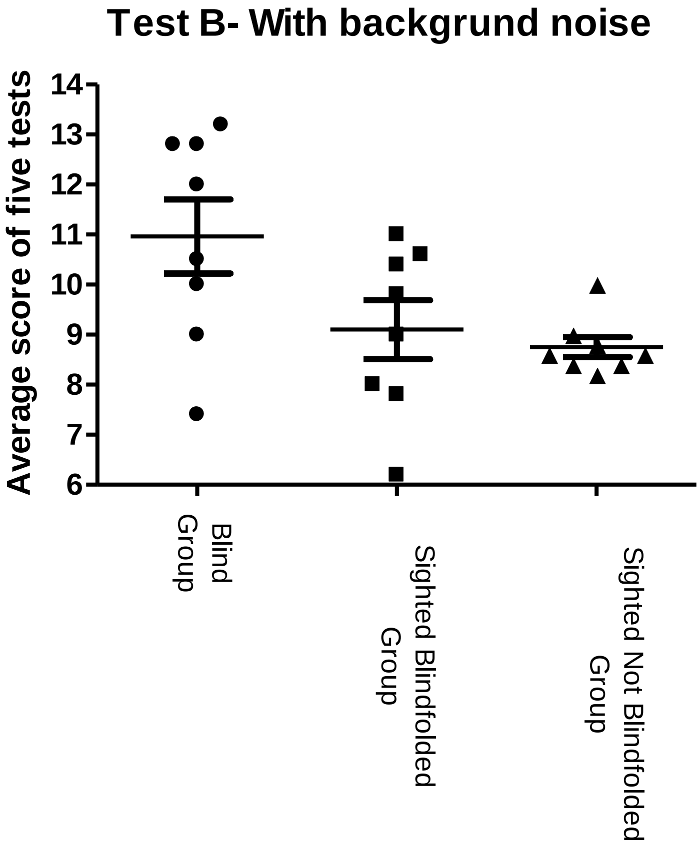


Table 10

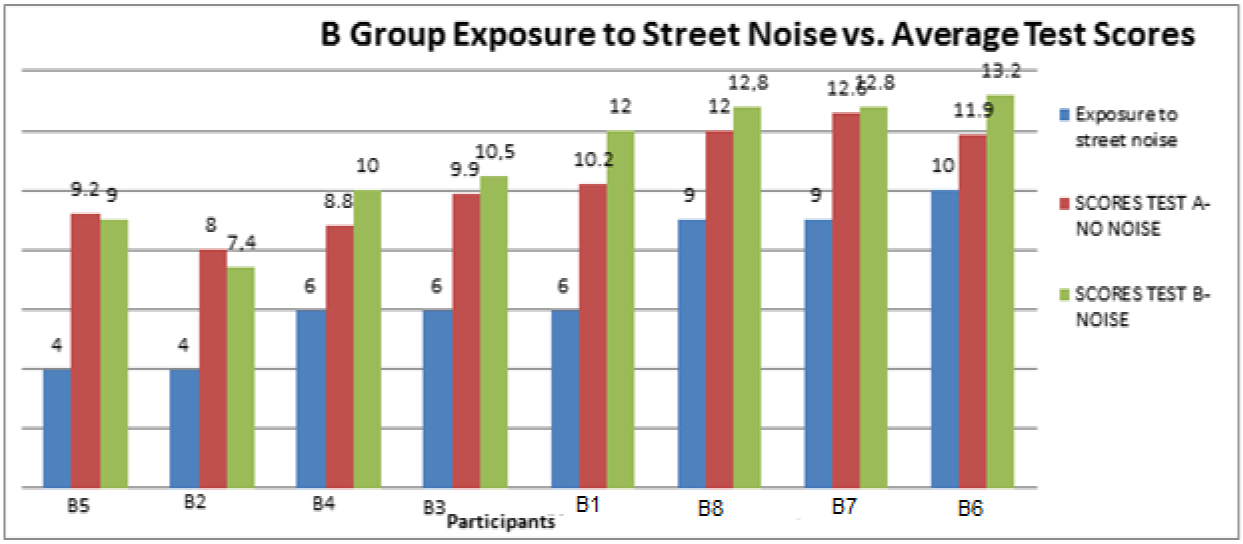
Kruskal-Wallis test	
P value	**0.0585**
Exact or approximate P value	Gaussian Approximation
Significant (alpha=0.05)	**NO**
Number of groups	3
Kruskal-Wallis statistic	5.676

Subsection 3: Participants' levels of exposure to street noise and their scores on Tests A and Tests B throughout the 5 sessions

This subsection exhibits the relationship between the scores that the participants of each group (B Group, SB Group and S Group) obtained on the general of exposure to street noise questionnaire (see Annex 4) and their performance on the auditory discrimination tests designed for this study (Tests A and Tests B) throughout the 5 sessions.

B Group

Figure 10



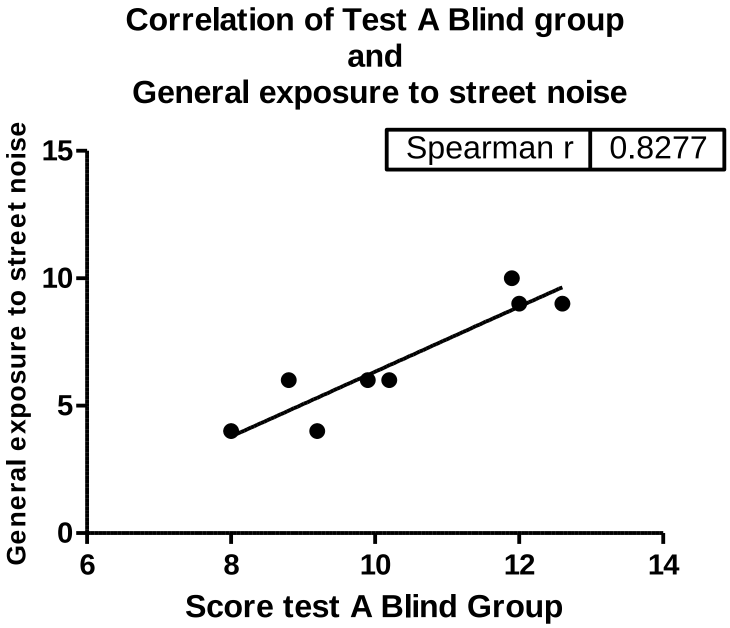
Level of exposure to street noise M=7

In Figure 10 the levels of exposure to street noise are presented in ascending order. According to the data above, there is a tendency for the levels of exposure to street noise to correlate with the blind participants' performances on the two auditory discrimination tests. It is interesting to note that participant B5 scored higher than participant B2, despite having the same level of exposure to street noise. This could be explained by considering the age of blindness onset and the amount of years in which the participants have experienced blindness up until now (please see sections 4 & 5 of these results). Based on the latter, B5 became blind at the age of 15 and has experienced 21 years of blindness to date, which is close to the blindness onset age of B4 (B4 became blind at 18, having experienced 35 years of blindness to date). However, participant B2 became blind at age 33 and had only experienced three years of blindness to date. In this sense, participant B2 may have had less time to undergo brain plasticity, that is, *plasticity de novo*, as well as to reinforce such reorganization and train his auditory perception skills than participants B4 and B5.

Furthermore, B2's age of blindness onset was at the adult stage, whereas B4 and B5 became blind during their teen years. Although there is evidence of brain plasticity in adults, more vast and profound changes have been observed at younger ages. Nevertheless, participant B3 also became blind at an adult age (35), but has experienced more years of blindness (8 years) than B2 and also got a higher level of exposure to street noise, which may explain why B3 got better scores on the auditory discrimination tests than B2. At the higher extreme, participant B2 got the highest level of exposure to street noise and also became blind at the age of 3 (the earliest of the B Group participants), and has experienced 33 years of blindness, which could explain why B2 got the highest scores of the group. A table summarizing the years during which the blind participants have experienced blindness and their ages of blindness onset can be seen in the following subsections of these results (Tables 11 & 12).

It is also interesting to note that the mean scores on auditory discrimination tests B (with background noise) were consistently higher than those in auditory discrimination tests A (without background noise) when the levels of exposure to street noise were 6 or higher. This could imply that more everyday experience of selectively attending to specific acoustic streams within a noisy background (levels of exposure to street noise) fosters better performance in auditorily distinguishing between the sounds of this study while hearing background street noise (Test B condition).

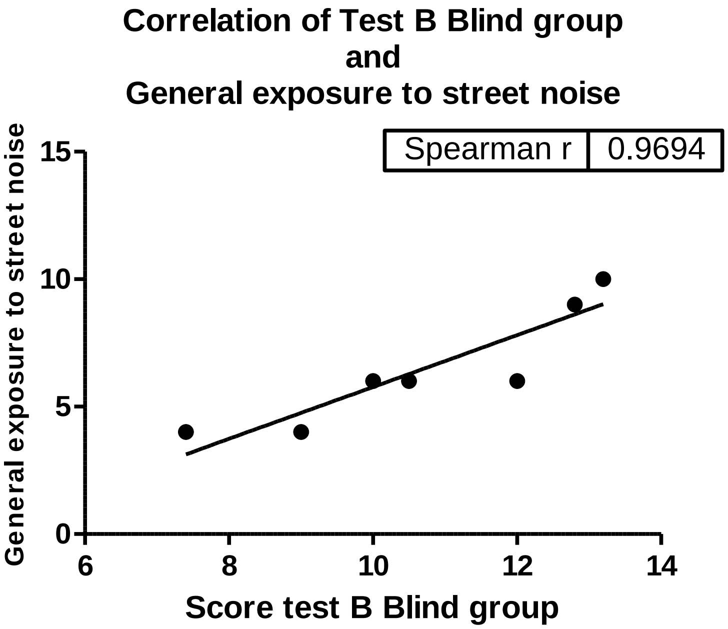
Figure 11



Spearman r	0.8277
P value (two-tailed)	0.0154

The P value shown above is exact, and the correlation between the B Group's levels of exposure to street noise and their scores on the Tests A (condition without background noise) was shown to be significant (alpha=0.05).

Figure 12

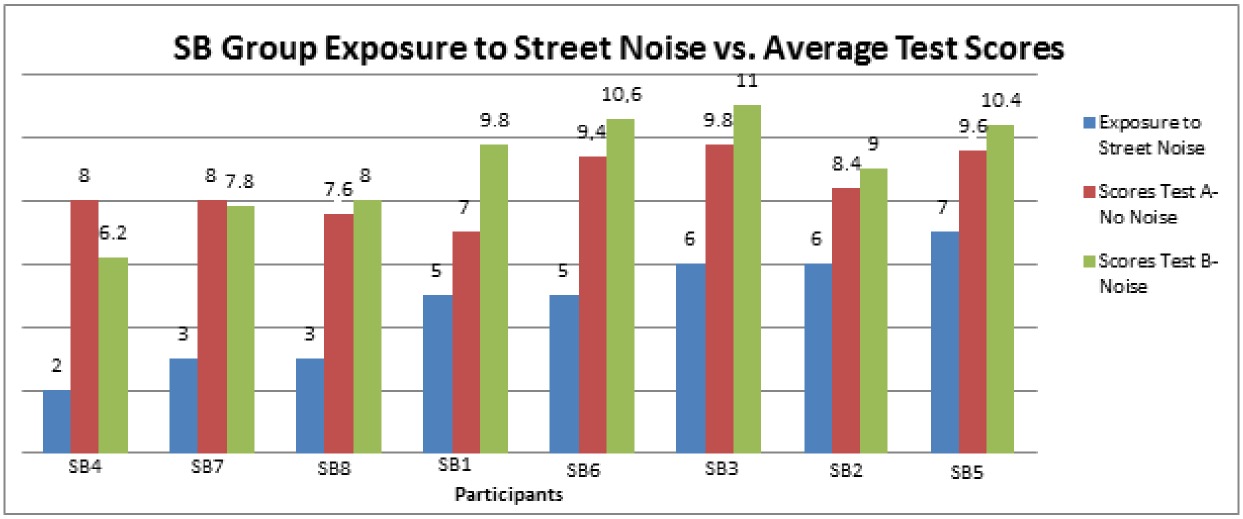


Spearman r	0.9694
P value (two-tailed)	0.0004

There is a greater correlation between the B Group’s levels of exposure to street noise and their scores on Tests B (condition with background noise). The P value is exact and the correlation is significant (alpha=0.05).

SB Group

Figure 13



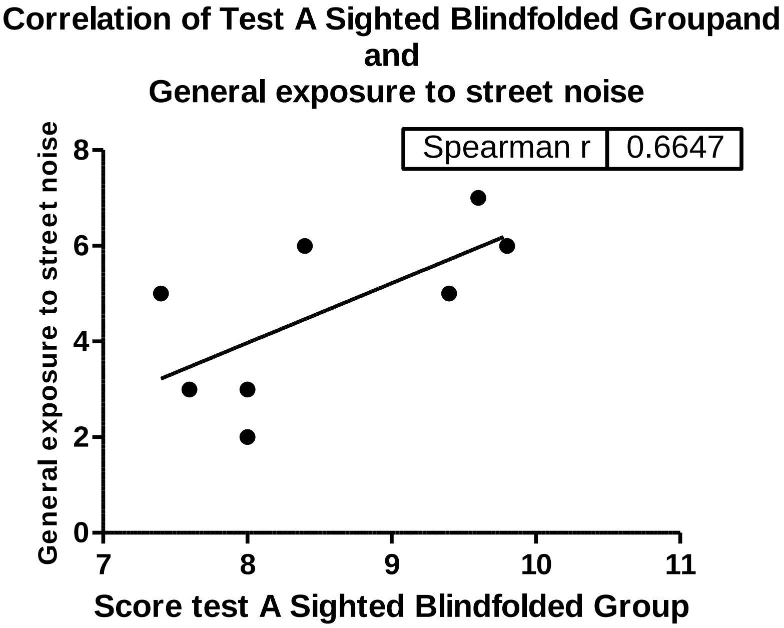
Level of exposure to street noise M=5

Mean Score Test A	**8**
Mean Score Test B	**9.1**

In Figure 13 the SB participants' levels of exposure to street noise are presented in ascending order. Although a slight tendency can be seen in the data above, the correlation between the levels of exposure to street noise and the scores on the auditory discrimination tests for the Sighted Blindfolded participants is not as consistent as the correlation seen for the Blind Group.

It is interesting to note that the scores on auditory discrimination tests B (with background noise) significantly rise when participants' levels of exposure to street noise are 5 or higher. Moreover, greater mean scores on Tests B compared to those on Tests A are maintained when participants' levels of exposure to street noise are 5 or higher. This could imply that the more experience sighted blindfolded participants have with "blocking out" irrelevant noise to attend to relevant acoustic information (levels of exposure to street noise), the more they can focus their attention on distinguishing between the sounds of this study while hearing background street noise (Test B condition).

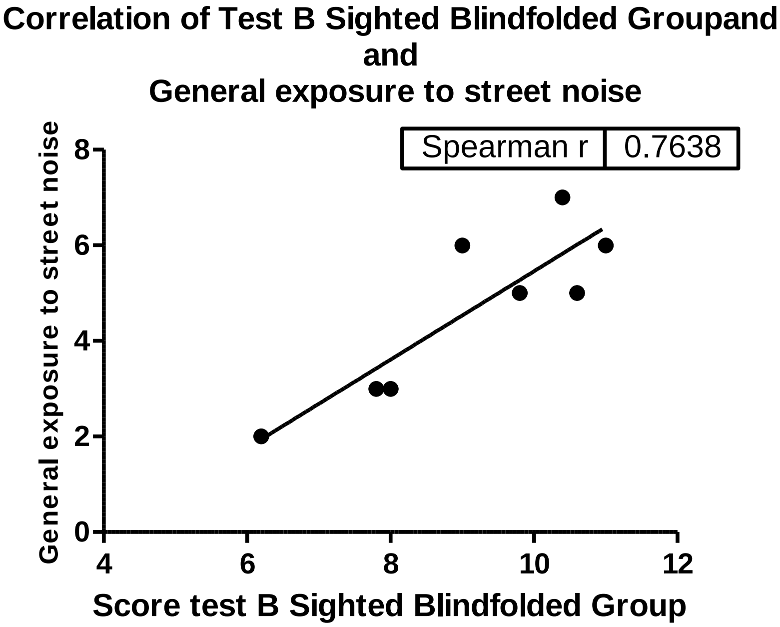
Figure 14



Spearman r	0.6647
P value (two-tailed)	0.0831

The P value is exact, but the correlation between the SB Group's levels of exposure to street noise and their scores on Tests A (condition without background noise) is not significant (alpha = 0.05).

Figure 15

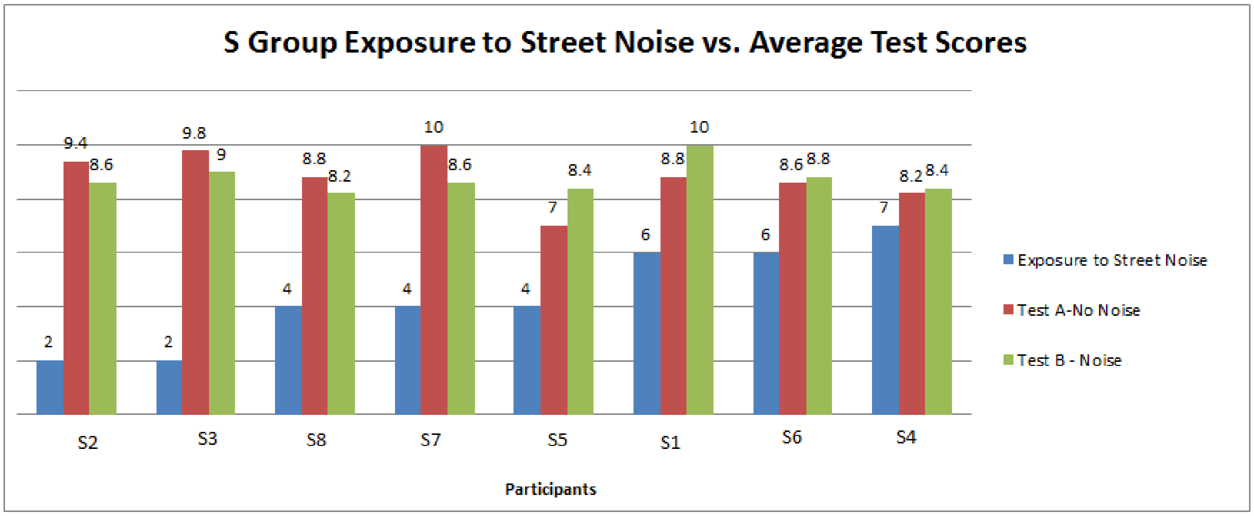


Spearman r	0.7638
P value (two-tailed)	0.0368

The P value is exact, and the correlation between the SB Group’s levels of exposure to street noise and their scores on Tests B (condition with background noise) is significant (alpha = 0.05).

S Group

Figure 16



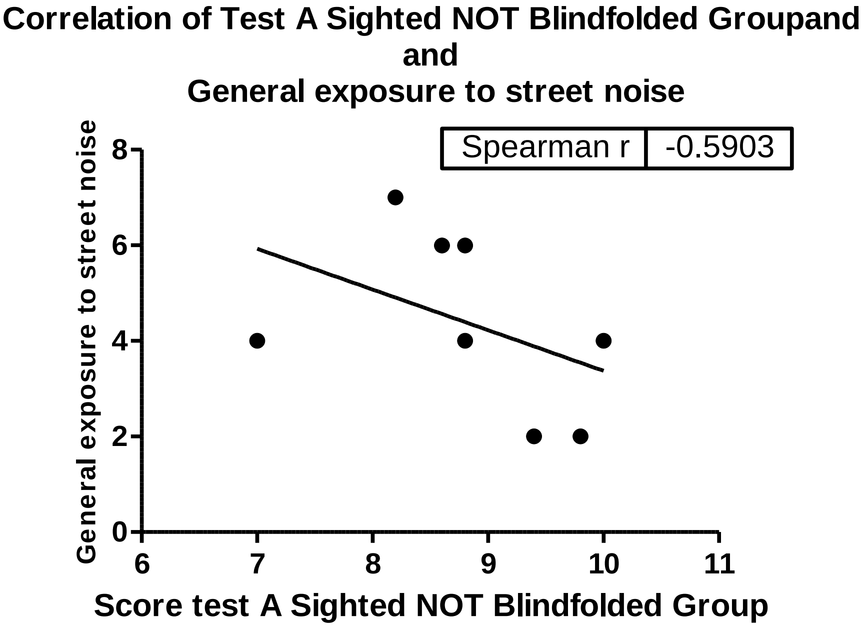
Level of exposure to street noise M=4

Mean Score Test A **8.8**

Mean Score Test B **8.8**

In Figure 16 the participants' levels of exposure to street noise are presented in ascending order. From the data in the graph above, no clear consistency can be seen between the participants' levels of exposure to street noise and the mean scores on auditory discrimination tests A and B. However, the sighted not blindfolded participants tended to get higher mean scores on Tests B (background noise condition) than on Tests A (without background noise) when their levels of exposure to street noise are 6 or higher. This pattern was seen earlier for the Sighted Blindfolded Group (starting levels of exposure of 5 or higher).

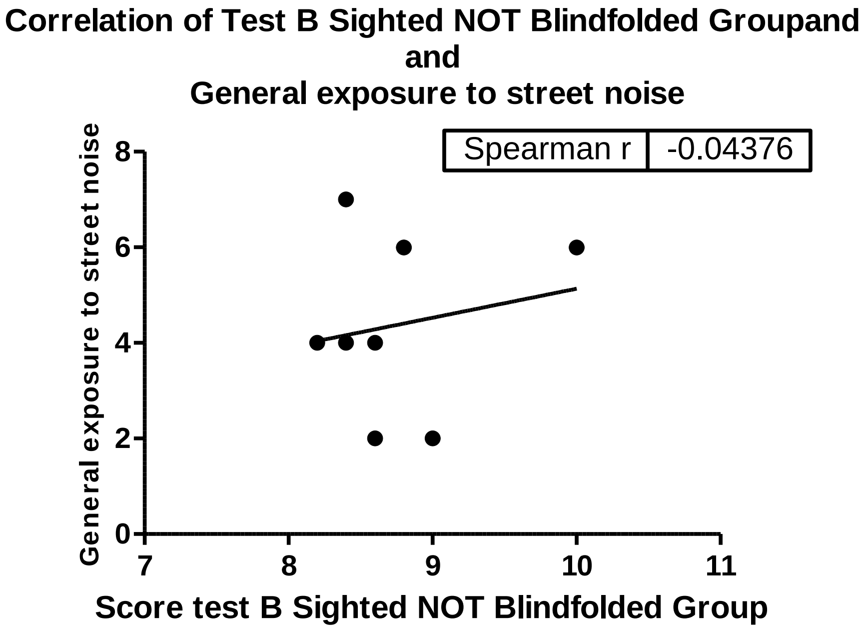
Figure 17



Spearman r	-0.5903
P value (two-tailed)	0.1323

The P value is exact. The correlation between the S Group's levels of exposure to street noise and their scores on Tests A (condition without background noise) is negative and not significant (alpha = 0.05).

Figure 18

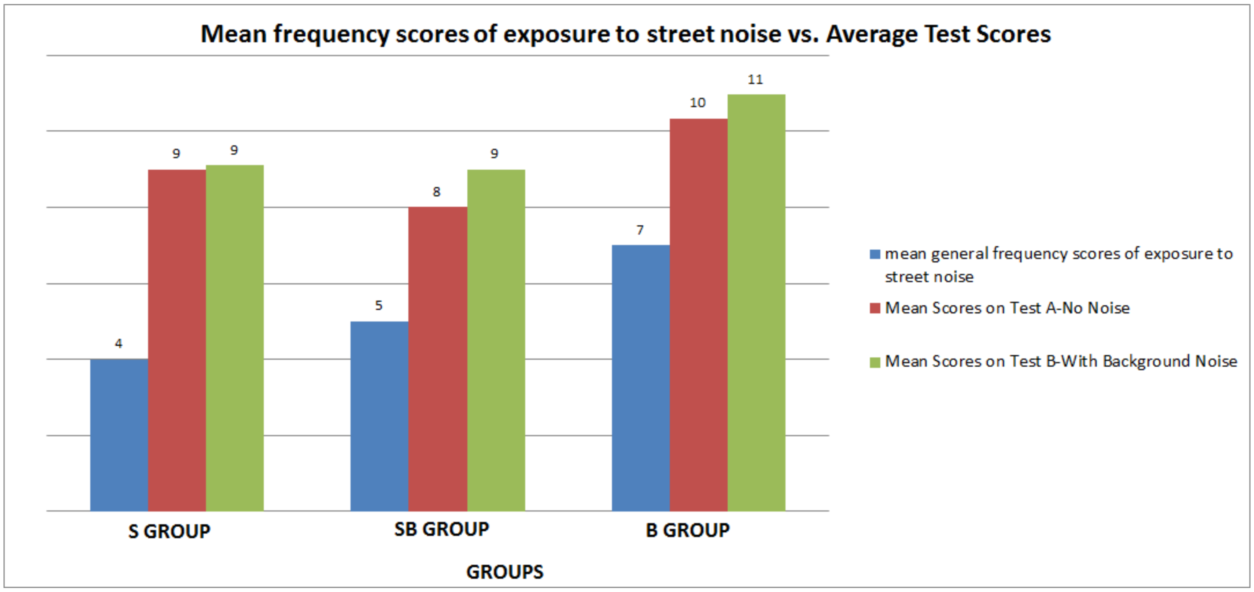


Spearman r	-0.04376
P value (two-tailed)	0.9349

The P value is exact. The correlation between the S Group's levels of exposure to street noise and their scores on Tests B (condition with background noise) is negative and not significant (alpha = 0.05).

The following graph shows the mean levels of exposure to street noise of the three groups in relation to each group's mean scores on auditory discrimination tests A and B.

Figure 19



The mean levels of exposure to street noise for each group were ordered from least to greatest, starting with the lowest level of exposure for the Sighted Not Blindfolded Group (M=4), followed by the Sighted Blindfolded Group (M=5) and finally the Blind Group (M=7). From the data above, the general level at which a person experiences street noise could influence their ability to auditorily distinguish between similar sounds in a foreign language when there is potentially distracting background noise. However, more research is needed with a larger population sample in order to confirm this correlation.

Subsection 4: Number of years in which the blind participants have lacked visual input, and their test scores in Tests A and Tests B throughout the 5 sessions

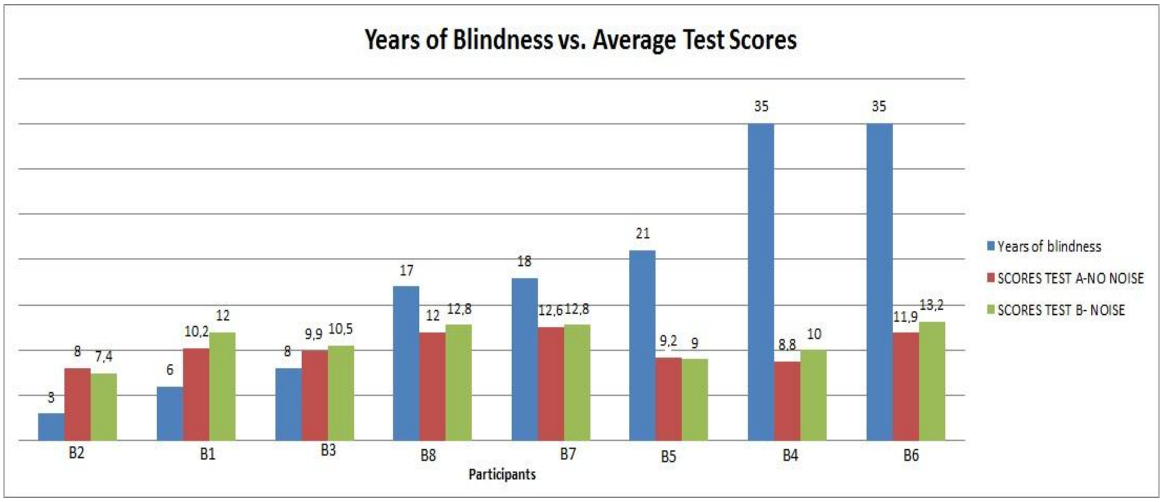
This subsection exhibits the relationship between the blind participants' years of blindness and their test scores on Tests A and Tests B throughout the 5 sessions.

The following table shows the number of years in which each participant had experienced blindness at the time of participating in this pilot study.

Table 11

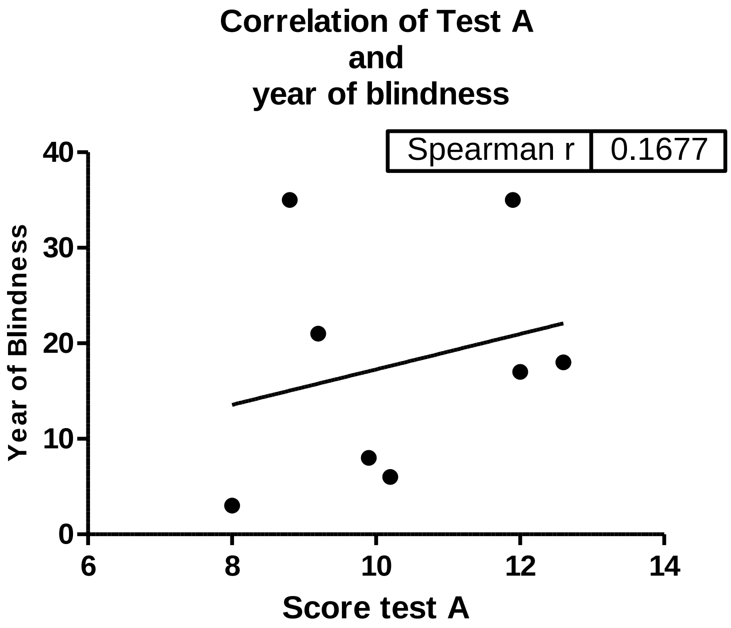
Participant	years of blindness
B1	6
B2	3
B3	8
B4	35
B5	21
B6	35
B7	18
B8	17

Figure 20



Despite the tendency for the test scores to increase with the number of years of blindness from 3 to 18 years of blindness, there is a sharp decrease at 21 (participant B5) and 35 (participant B4) years of blindness, followed by an increase in scores again at 35 years of blindness (participant B6). Clearly, it is important to analyze why these scores suddenly decreased at the individual participant level (see summary at the end of section 5 of these results).

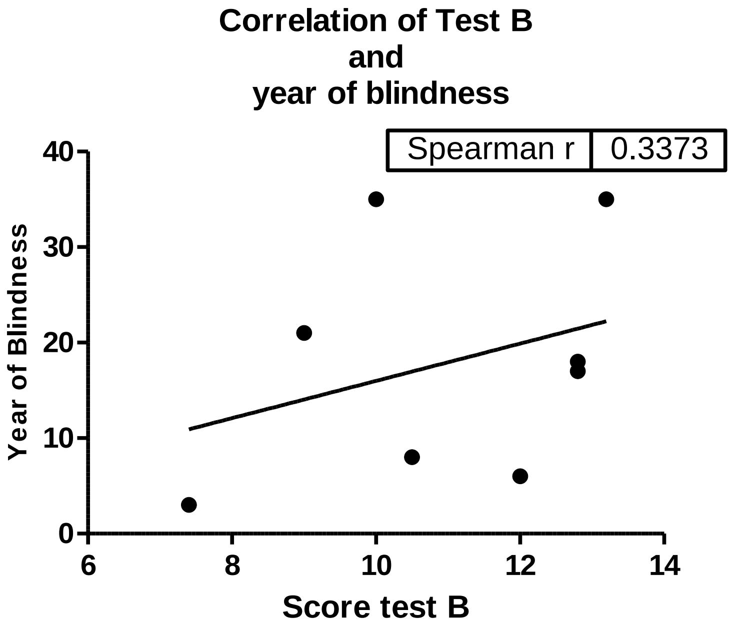
Figure 21



Spearman r	0.1677
P value (two-tailed)	0.7033

The correlation between the number of years in which the blind participants have lacked visual input and their scores on Tests A (condition without background noise) is not significant (alpha=0.05).

Figure 22



Spearman r	0.3373
P value (two-tailed)	0.4279

The correlation between the number of years in which the blind participants have lacked visual input and their scores on Tests B (condition with background noise) is not significant (alpha=0.05).

Subsection 5: Age of blindness onset and test scores in Tests A and Tests B throughout the 5 sessions

This subsection exhibits the relationship between the B Group’s ages of blindness onset and their test scores in Tests A and Tests B throughout the 5 sessions.

The following table shows the ages in which the blind participants became blind.

Table 12

Participant	age blindness onset
B1	26
B2	33
B3	35
B4	18
B5	15
B6	3
B7	14
B8	17

Figure 23

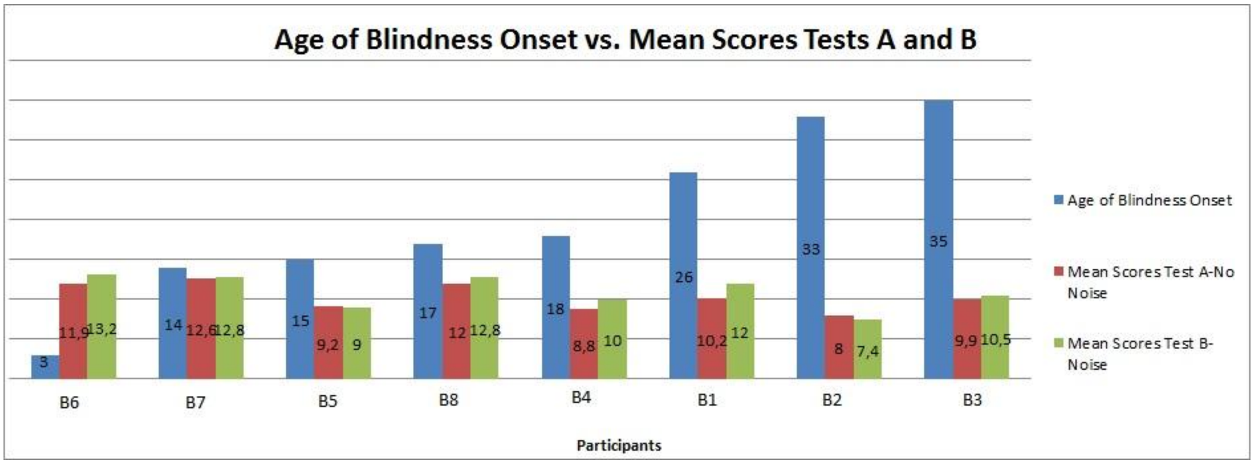
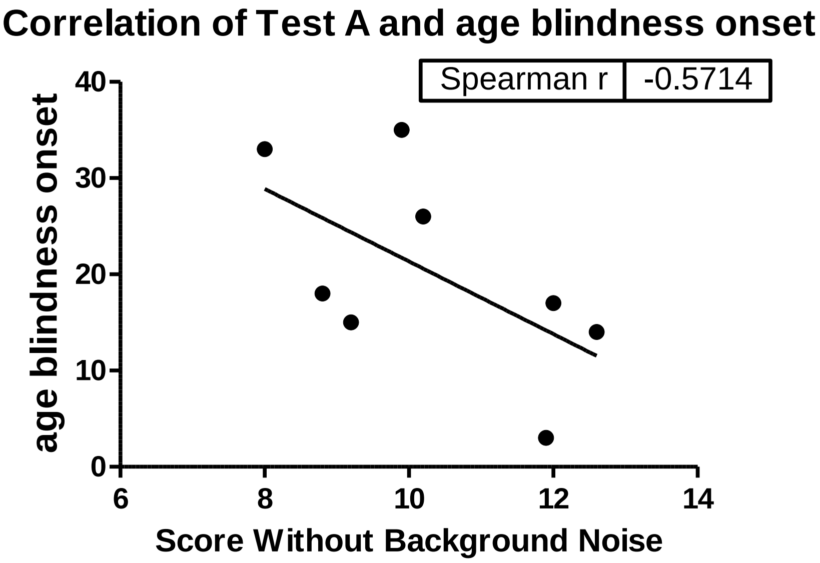


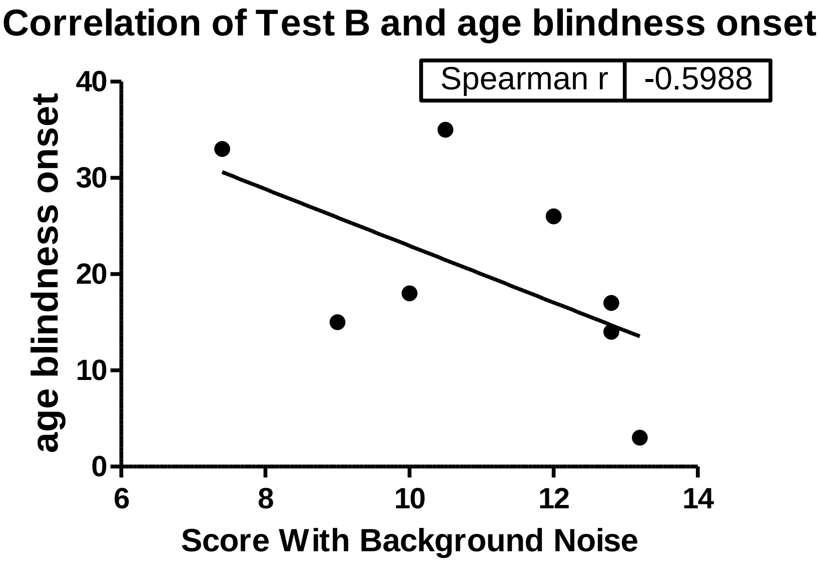
Figure 24



Spearman r	-0.5714
P value (two-tailed)	0.1511

The P value is exact, but the correlation between the participants' ages of blindness onset and their scores on Tests A (condition without background noise) is not statistically significant (alpha=0.05).

Figure 25



Spearman r	-0.5988
P value (two-tailed)	0.1323

The P value is exact, but the correlation between the participants' ages of blindness onset and their scores on Tests B (condition with background noise) is not significant (alpha=0.05).

The analysis above illustrates a tendency for the average scores on both tests A and B to decrease as the age of blindness onset increases.

Individual B Group Participant Analysis Summary

It seems to be clear that participant B6's scores (the highest scores of the group in both Tests A and Tests B) tend to correlate with the number of years of blindness (33 years) and the age of blindness onset (3 years old), which is the lowest age of blindness onset in the group (see Table 12 in section 5 of these results). Participant B6 also scored the highest in level of exposure to street noise in the B Group (B6=10). These three factors seem to correlate with B6's high average scores on both auditory discrimination tests. It is also interesting to note that the other participant who scored the highest on the auditory discrimination tests became blind at the second youngest age, closer to the age of puberty (participant B7: age of blindness onset=14). This participant also scored a high level of exposure to street noise (B7=9).

On the other hand, although participant B5 also became blind right after puberty (15 years of age) as well as B8 (17 years of age), the former scored less than the latter. The level at which B5 is exposed to street noise is much less than that of participant B8 (B5=4 vs. B8=9), which may be influencing B5's lower average score on the auditory discrimination tests compared to B8. Nevertheless, participant B4 scored less than B1, even though B4 became blind at an earlier age and has experienced more years of blindness than B1, and despite the fact that both participants have the same level of exposure to street noise (B1 & B4=6). In other words, individual differences between participants may be exerting a greater influence on their performance than the influence of the variables studied here (years of blindness, age of blindness onset and level of exposure to street noise).

3. Discussion and Conclusions

As mentioned previously, the study reported here is a pilot study, from which only preliminary results can be drawn. Furthermore, much focus was placed on validating the experimental design proposed for this study, so it may be used for future research questioning the relationship between the lack of visual input and the enhanced ability to distinguish between highly similar sounds in a new language, in this case English.

From what is seen in the results section above, there seems to be a close relationship between these two main variables (lack of visual input and the enhanced ability to distinguish between highly similar sounds in a new language, in this case English), which would be worth studying further. Moreover, the relationships between the variables explored in this pilot study would need to be tested in large-scale studies, with higher participant numbers, and could constitute a sequence of independent studies that build onto each other. Additionally, there are several other research questions that stem from this pilot study, which will become evident as present discussion develops.

Firstly, based on the analysis in section 1 of the results above, which expose the simple average results of the three groups, it is interesting to note that all three groups tended to improve their auditory discrimination scores throughout the five sessions of this pilot study (see Figures 1, 2 & 3). Similar to when infants learn their L1, exposure to a specific language may sharpen an adult’s perception of stimuli near phonetic boundaries in an L2. Categorical perception is a building block for language (Kuhl, 2007). The computational strategy approach hypothesizes that infants analyze the frequency distributions of the sounds they hear in their specific language, and these distributional patterns of sound thus provide clues about the phonemic structure of a language. Could this also apply for adults learning a second language? Could this be facilitated if greater attentional resources are assigned to incoming auditory information? A consistent increase in scores was observed for the

Blind and Sighted Blindfolded Groups (Figures 1 & 2) throughout the five sessions. This improved performance, however, was not consistent for the Sighted Not Blindfolded Group (Figure 3). Moreover, the B and SB Groups also maintained their scores higher on Tests B than those on Tests A (B Group Test A M=10.33, B Group Test B M = 10.96; SB Group Test A M=8.525, SB Group Test B M=9.1– see Tables 6 & 7). However, the Sighted Blindfolded Group did not perform better on Tests B compared to Tests A throughout the five sessions (S Group Test A M=8.825, S Group Test B M=8.750- see Table 8). Consequently, these preliminary results could initially indicate that long-term, as well as short-term temporary lack of visual input might influence levels of auditory perception, specifically that of discriminating between highly similar sounds of a new language, in conditions where there is potentially distracting background noise. A possible explanation to this could be related to a reduction in auditory attention in the Sighted Not Blindfolded Groups, due to the visual information that these participants processing while fulfilling the auditory tasks. Thus, visual information could have been distractors during the auditory discrimination tests, and even during the training periods at the beginning of each session. In the case of the Blind Group, this explanation is in line with previous studies showing that improved auditory speech discrimination abilities have been reported in the blind, especially in the context of a noisy background, as early as 1981, by Niemeyer and Starlinger, and have been confirmed by other researchers ever since. For instance, Muchnik (1991), found that blind subjects were better than the sighted subjects in auditory gap detection and speech discrimination in noise (for an overview or this and other related results, please see Section 1.2.1. of this study).

Although the results of this pilot study described above support the initial hypothesis posed in section 2.1, further studies with a larger population sample is necessary to confirm if a significant difference in the perception of novel auditory input occurs in conditions with no visual input, compared to when there is uninterrupted access to visual information from the surroundings, especially in conditions with potentially distracting background noise. For now, a tendency of increased auditory discrimination of the L2 English consonant sounds selected for this study can be appreciated for the groups that were deprived of visual input, compared to the group that had access to all senses, in conditions without background noise (Figure 8) and with background noise (Figure 9).

It is also interesting to note that by session five, group B scored similarly on both tests (A and B), that is, (with and without background noise- see Figure 1). Thus, the difference between their average score on Test A and Test B was 0.4 in session five, while this difference was 0.9 for the SB Group and 0.8 for the S Group. It may be possible that the blind participants could have become so familiar with the sounds by the fifth session of the experiment (and maybe even the voices in the recordings), that they were able to begin performing similarly in both conditions. However, further studies are necessary to see if this similarity in performance under both conditions could be maintained for more sessions.

Based on the above, a distinction should be made between the terms *discrimination* and *recognition*. The latter is an indication that what is sensed has already been encountered, while the former term is used to refer to the ability to note the differences or likeliness within and/or among sounds (or other types of sensory inputs in general). In the book entitled *Visual Handicaps and Learning* (1992), Natalie Barraga and Jane Erin note that when individuals are at the recognition stage, memories and discriminations are being stored and recalled, thus making recognition one of the first indicators that learning is taking place. For the participants who underwent this pilot experiment, discrimination and recognition could have overlapped, since repetitive exposure to the target sounds in the "training stages" throughout the five sessions could have fostered a process of *learning* these sounds. Therefore, it could be said that the blind participants were only trying to *discriminate* between the sounds during the early stages of the experiment, but may have reached the border of *recognizing* these sounds at the latest stage. In any case, the border between discrimination and recognition is fuzzy, and while people are storing and recalling memories and discriminations, they may be amidst the very process of learning.

In relation to the analyses exposed in subsections 1, 2 and 3 of the Results, especially those from the condition with background noise (Tests B), selective auditory attention may be playing a curial role in the increased auditory discrimination performance seen in the Blind and Sighted Blindfolded Groups. Selective attention is the key to highlighting foreground over background and switching attentional focus to different features, objects, or streams of interest within the acoustic scene. Several studies have supported the notion of a more efficient top-down attention modulation of non-visual sensory events in participants who are blind. Furthermore, based on studies carried out recently in relation to blind children, there is enough evidence to suggest that blind children have advantages in what is called *phonological memory*, which refers to the capacity to recognize and remember phonological elements and their order of occurrence (O'brien et. al., 2007), and *phonological fluency* which is the capacity to generate words given a letter or sound (for example, words starting with 'F'). In this sense, blind adults could also qualify to have better *phonological memory*, although further studies with greater population samples are necessary to confirm such claim.

Moreover, based on the results presented in subsection 3, a relationship appears to be seen between the levels of exposure to street noise that the participants reported to have (see questionnaire in Annex 4) and their performance in distinguishing between the L2 English sounds selected for this study (Figure 19). The use of the *exposure to street noise questionnaire* raises the hypothesis that a certain level of experience and exposure to noisy environments, such as the city street surroundings, like those in Santiago, Chile, may be needed to acquire a trained ear, which can selectively extract auditory streams of interest from the overall noise. Thus, the decision to prepare the questionnaire was made after observing the blind group's leading performance in the condition with background noise (Tests B) compared to the two sighted groups.

As expected, the correlation between the above variables (levels of exposure to street noise and auditory discrimination of the novel sounds selected for this study) is strong for the B Group with regards to Tests A (r=0.8277 - see Figure 11) and especially regarding Tests B (r=0.9694 - see Figure 12). It is interesting to see that the correlation between these two variables was not significant for the Sighted Blindfolded Group in the condition without background noise (Test A, r=0.6647 – see Figure14), but it was significant in the condition with background noise (Test A, r=0.7638 – see Figure 15). However, the correlations between the levels of street noise exposure and performance on Tests A and B were not significant for the S Group (see Figures 17 & 18). Once again, lack of visual input seemed to have played a role in heightening the blind and sighted blindfolded participants' auditory selective attention to acoustic streams of interest from non-target background noise.

Focusing on individual participant analysis, the participant who got the highest exposure to street noise score (10) in the Blind Group also got the highest average score on the two auditory discrimination tests (M=12.6). On the other end, the participant with the lowest exposure value (4) also got the lowest auditory discrimination average score (M=9.1). In the case of the sighted-blindfolded group, this tendency was still present, but not as strong or consistent as in the case of the Blind Group. In the Sighted Blindfolded Group, the participant with the lowest exposure value (2) also got the lowest auditory discrimination average score (M=7.1), but the participant with the highest exposure value did not score the highest in the auditory tests (exposure value=7; Test A and B M=10), but was close to the participant with the second highest exposure score who scored the highest on the auditory tests (value=6, Test A and B M=10.3). In the Sighted Not Blindfolded Group, the exposure values did not seem to affect the auditory discrimination scores, since the participant with the lowest exposure value actually scored higher on the auditory discrimination tests (exposure value=2; Test A and B M=9) than the participant with the highest street noise exposure value (exposure value=7; Test A and B M=8.3). Therefore, since the street noise exposure values did not relate to an increase in auditory discrimination scores in the Sighted Not Blindfolded Group, but did relate the auditory scores of the groups that lacked visual input while receiving the acoustic information of this pilot experiment, then it is not clear whether the variable that is causing differences between the three groups is not the participants' exposure to street noise. Despite the results, this relationship should be further validated, since the sole variable of lack of vision could be influencing the participants' auditory discrimination performance scores more than the levels of exposure to street noise. Nevertheless, and as mentioned previously, street noise exposure levels mostly influenced auditory discrimination performance in conditions where there is potentially distracting background noise (Tests B). Thus, the practice of selecting auditory streams of interest and "blocking out" non-target background noise may have greatly influenced auditory the discrimination performances of the participants who scored high on Tests B (condition with background noise) and got high street noise exposure values.

It is also important to mention that the blind participants of this study spend much more time outdoors than the sighted ones (as reflected by their scores on the questionnaire on exposure to street noise in Annex 4). This is basically due to the nature of their everyday activities. Many blind adults in Santiago, Chile, find their only source of income by selling merchandise on the streets or on busses around the city. On the other hand, sighted participants usually work in offices, at home or study at educational institutions and only experience street noise during their commutes to and from their work and study locations.

Language learners' ability to selectively attend to phonetic patterns to develop language-specific speech categories becomes critical when they listen to speech in the presence of noise or competing talkers. Perception may be difficult in noise because competing signals block access to relevant sensory information and/or pull attention away from speech information of interest. The participants who became blind more recently than others (at a higher age of blindness onset and, thus, with less years of experience with blindness) may still be in the process of controlling the amount of auditory information they attend to. These participants informally reported to receive so much auditory information in general, that they feel overwhelmed with the amount of auditory streams they need to process. However, the blind participants who have experienced blindness for a more extensive amount of time commented to have been able to learn how to select the streams that they are interested in, and block the unneeded information. In this sense, the greater the number of years in which a person has been blind, the higher the ability to selectively attend to auditory streams of interest should be, and therefore, the probabilities that they will be distracted by unwanted auditory stimuli should be lower.

Stemming from the above, and regarding the question of whether the amount of time in which the participants lacked visual input influenced auditory discrimination test scores, the short-term blindfolding during the sessions of this pilot experiment did not allow the participants in the SB Group to reach the auditory discrimination performance seen in the B Group (see Figure 7). However, the amount of time in which the blind participants lacked visual input, i.e., the amount of years in which they had been blind, was shown to be an important variable (see section 4 of the results above). There seems to be a tendency for the number of years of blindness to correlate with the blind participants’ performance on the auditory discrimination tasks. Nevertheless, this relationship isn’t very consistent across the participants of the B Group and, thus, the correlation coefficient was not significant with regards to Tests A (r=0.1677, see Figure 21) and Tests B (r=0.3373, see Figure 22). Individual participant analysis, based on age of blindness onset and level of exposure to street noise (subsections 5 and 3, respectively), was necessary in order to understand some inconsistencies. There may even be other individual differences between participants that were not accounted for in this pilot study, which may be exerting a greater influence on their performance than the variables considered for the analysis of the results. In this pilot study, it could be sufficient to say that there seems to be a tendency for auditory discrimination abilities to increase with the number of years of blindness. However, despite this tendency, further studies are needed with larger population samples in order to see if a strong correlation may exist.

A relationship was also seen between the ages of blindness onset and auditory discrimination performance scores across the blind participants (see section 5 of the results above). Although there was a tendency for the age of blindness onset to negatively correlate with the B Group's scores on Tests A (r= -0.5714, see Figure 24) and Tests B (r= -0.5988, see Figure 25), the correlation values were not statistically significant. This negative correlation can be slightly appreciated in Figure 23, where the average scores on both auditory discrimination tests (A and B averaged together) tend to decrease as the age of blindness onset increases. An underlying factor for this, which has been proposed in recent studies, could be that age of blindness onset has an impact on crossmodal plasticity. Some results suggest that crossmodal plasticity is age-dependent (Cohen et al., 1999; Sadato et al., 2002), indicating that there are different neuronal mechanisms involved in neuronal reorganization during development up to puberty, compared to those involved in adulthood. However, other studies show similar results in late blind participants (Büchel et al., 1998; Rösler et al., 1993) and even sighted humans who have been blindfolded for some days, in which short-term plasticity has been found to be induced in occipital areas (Merabet et al., 2008; Pascual-Leone & Hamilton, 2001), or the *unmasking* of existing pathways that become available when visual input is removed, as mentioned previously in this study (see section 1.1.1. of this study). Furthermore, more years of reinforcement of the newly recruited occipital networks that process auditory information could also lead to more acute attentional selectivity and perception of the acoustic streams of interests. Nevertheless, the results drawn from this pilot study were not conclusive in correlating the ages of blindness onset or years of blindness with the B Group's scores on the auditory discrimination tests. In some cases, linking these factors to the levels at which the participants are exposed to street noise helped clarify why certain participants scored higher than others. For example, although participants B4 and B5 had spent more than 20 years without visual input (B4=35 years of blindness, B5=21 years of blindness) and became blind at a similar age (B4=18 years old, B5=15 years old), their auditory discrimination scores were at the lower end of the B Group averages (B4 average test score=9.4, B5 average test score=9.1). However, their low auditory discrimination scores could be justified, if their low levels of exposure to street noise are considered (B5 & B4=4, within a range of 4-10). Furthermore, since no conclusions could be drawn regarding auditory discrimination performance differences between the early blind and late blind participants, further studies with larger population sample sizes should be conducted to try to visualize such differences.

It is important to highlight the fact that the reliability of the instrument used to measure the participants' levels exposure to street noise (Annex 4) has not been determined. Also, the rate at which the participants have contact with the English language on a daily basis is also difficult to control for, and may be a confounding variable (see questionnaire in Annex 3). Furthermore, other extraneous variables, such as motivation, memory and other cognitive skills may cause the participants' test scores to vary. With specific regards to motivation, by simple observation, the blind participants seemed to be more motivated towards participating in the study. They constantly expressed their interest in learning English as a tool to survive in society, considering that their range of job opportunities is so limited. Furthermore, all of the participants had the opportunity to choose the days in which they would attend the five study sessions, as long as these days were within a time frame of two weeks (see Annex 5). Most of the blind participants (75%) chose to attend the five sessions consecutively, that is, they participated in the study for five consecutive days, whereas all of the sighted participants scheduled their sessions with one or more days between sessions. For future studies, it may be recommendable to focus more control on the frequency at which the participants are exposed to the experimental auditory input.

With regards to the nature of the auditory input used for this study, although stress patterns were controlled for, participants might have relied on other acoustic features of the speech sounds, other than the target consonant sounds, to decide whether the pairs of words presented to them were the same or different. Two of such features are prosodic cues and idiosyncratic production of vowels in the input recorded for this experiment. Since natural speech was preferred as auditory input for this experiment, these phonetic features were more difficult to account for. Thus, participants may have perceived differences in prosodic cues or idiosyncratic vowel production between two words that were supposed to be the same. Furthermore, these phonetic aspects may have contributed to shifting the participants' attention from the target sounds, for which they received training at the beginning of each session. Although a possible solution could be to use computer-generated synthetic speech, several studies have reported that synthetic speech is significantly harder to perceive than natural speech (eg: Duggy & Pisoni, 1992). Moreover, these studies suggest that prosodic cues are actually necessary for facilitating speech perception, guiding the parsing of speech, and when they are absent there may be additional burden placed on working memory that exceeds its capacity, especially in time-limited, demanding tasks (Paris et al., 2000). Therefore, it might be better to place more care on the instructions given to the participants when asking them to decide whether two words are the same or different, inviting them to ultimately focus on the target consonant sounds that they have been frequently hearing in the training stages.

Continuing with comments related to the design of this pilot experiment, it would be interesting to include novel English words in the auditory discrimination tests, that is, words that the participants didn't hear in the "training stages". This could be useful in assessing if the participants are able to distinguish between the target sounds in words that they have never heard before, apart from those with which they become familiarized in the "training stages". It would also be interesting to analyze gender and age based auditory discrimination differences, with a greater population sample.

Furthermore, although the target sounds were presented in initial, mid and final word positions, in several phonetic environments permitted in the English language, it would be interesting to include *all* of the environments in which the consonant sounds selected for this study can occur. This could shed light on which word positions and phonetic environments linked to these consonant sounds cause greater perceptual difficulty for Spanish native speakers learning English as a second or foreign language. Additionally, this could provide insight into the idea that there are certain phonetic occurrences (certain positions and environments in which the target consonant sounds occur) that are more salient to these learners and, thus, attract their attention so as to ease perception. Consequently, the phonetic environments that may be less salient to these learners might be those that cause greater perceptual difficulty.

As mentioned previously, attention is a key factor in learning, especially when learning a new language. Having access to environmental information through all of our five senses creates several points of attention that can distract us. Since the blind and sighted blindfolded participants lacked one of these senses that could cause distraction, they may have been able to focus and dedicate more attentional resources to what they received auditorily compared to the sighted participants. In this sense, and based on the results of this pilot study, blind participants could learn to distinguish between highly similar sounds in a new language better than sighted individuals, due to their heightened auditory attentional power. Moreover, blindfolding may be an effective strategy to learn to categorize new sounds from incoming L2 speech. However, the latter could spark a new independent study, which may have pedagogical implications. Additionally, further studies that compare the effects of accessing highly similar sounds in a new language through sight *and* sound, compared to only accessing them through sound should be carried out. Thus, we would be able to see if blind participants can still outperform individuals who hear and see representations of highly similar sounds in a new language, either through mouth movements of the sounds or symbolic representations of them.

Finally, based on the results and discussion above, further studies that test blind individuals’ abilities to learn to distinguish and categorize sounds from a new language could foster the idea that this population is apt to learning a new language by means of materials and instruction that suits their auditory capacities. Moreover, and as noted by Rokem & Ahissar (2008), blind individuals may form strategies of encoding acoustic information better than sighted people, which, following *phonological memory*, could further promote learning by enabling blind individuals to distinguish word boundaries toward vocabulary learning. There is still much to be discovered, but mounting evidence in favor of greater auditory perceptual skills in the blind has gradually become available. Additionally, more attention has been recently placed on the effects of blindfolding on assigning greater attentional resources to auditory input. Ultimately, such results may have positive and important pedagogical implications, and could be applied to language instruction, especially for second and foreign language learning and acquisition.

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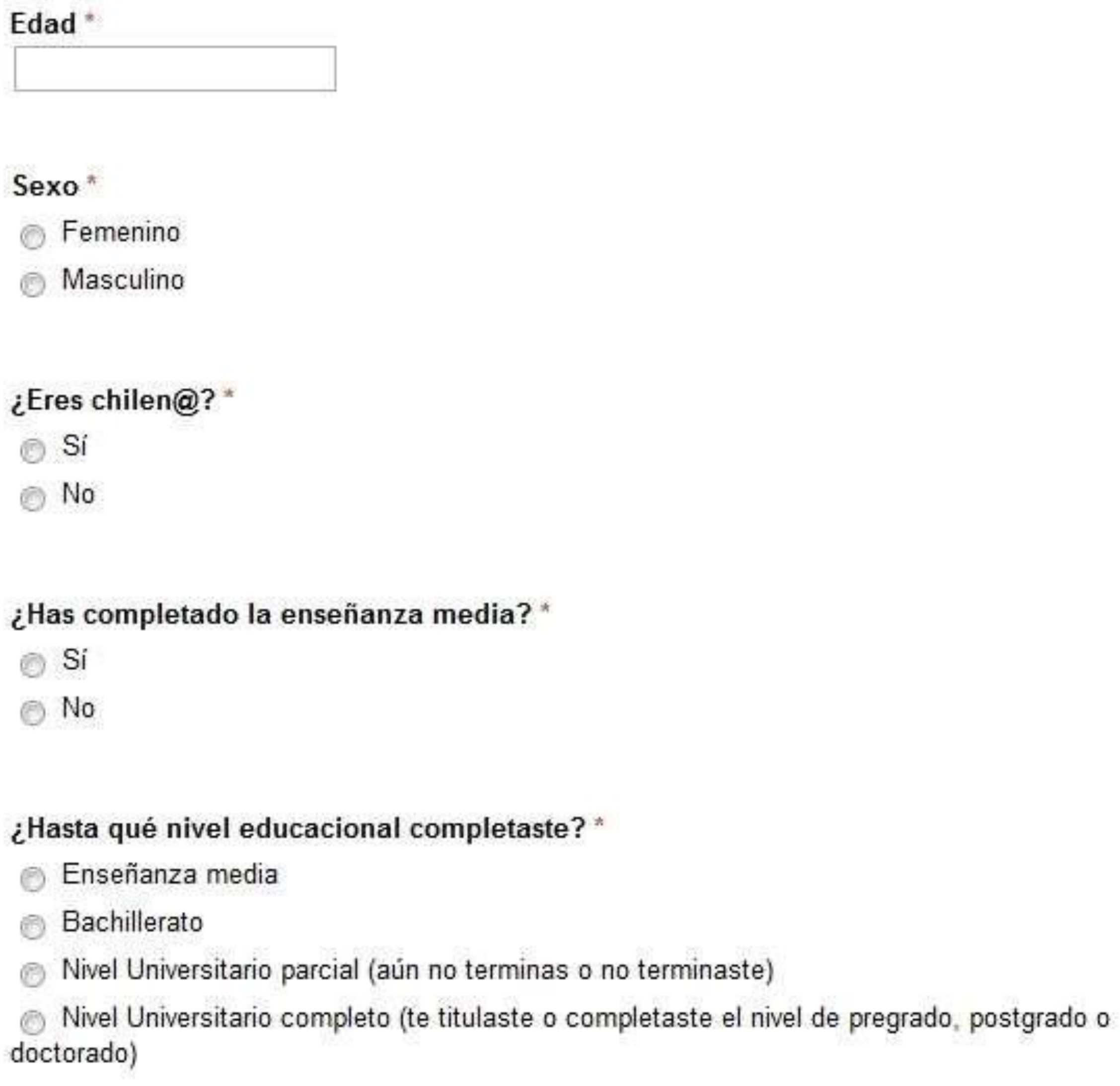
5. ANNEX 1: Questionnaire applied for sighted participant screening



Edad *

Sexo *

○ Femenino

○ Masculino

¿Eres chilen@? *

○ Sí

○ No

¿Has completado la enseñanza media? *

○ Sí

○ No

¿Hasta qué nivel educacional completaste? *

○ Enseñanza media

○ Bachillerato

○ Nivel Universitario parcial (aún no terminas o no terminaste)

○ Nivel Universitario completo (te titulaste o completaste el nivel de pregrado, postgrado o doctorado)

¿Tomas medicamentos? *

○ Sí

○ No

Si tu respuesta a la pregunta anterior fie SÍ, ¿para qué tomas medicamentos?

¿Qué medicamentos tomas y en qué dosis?

¿Por cuánto tiempo has tomado esos medicamentos?

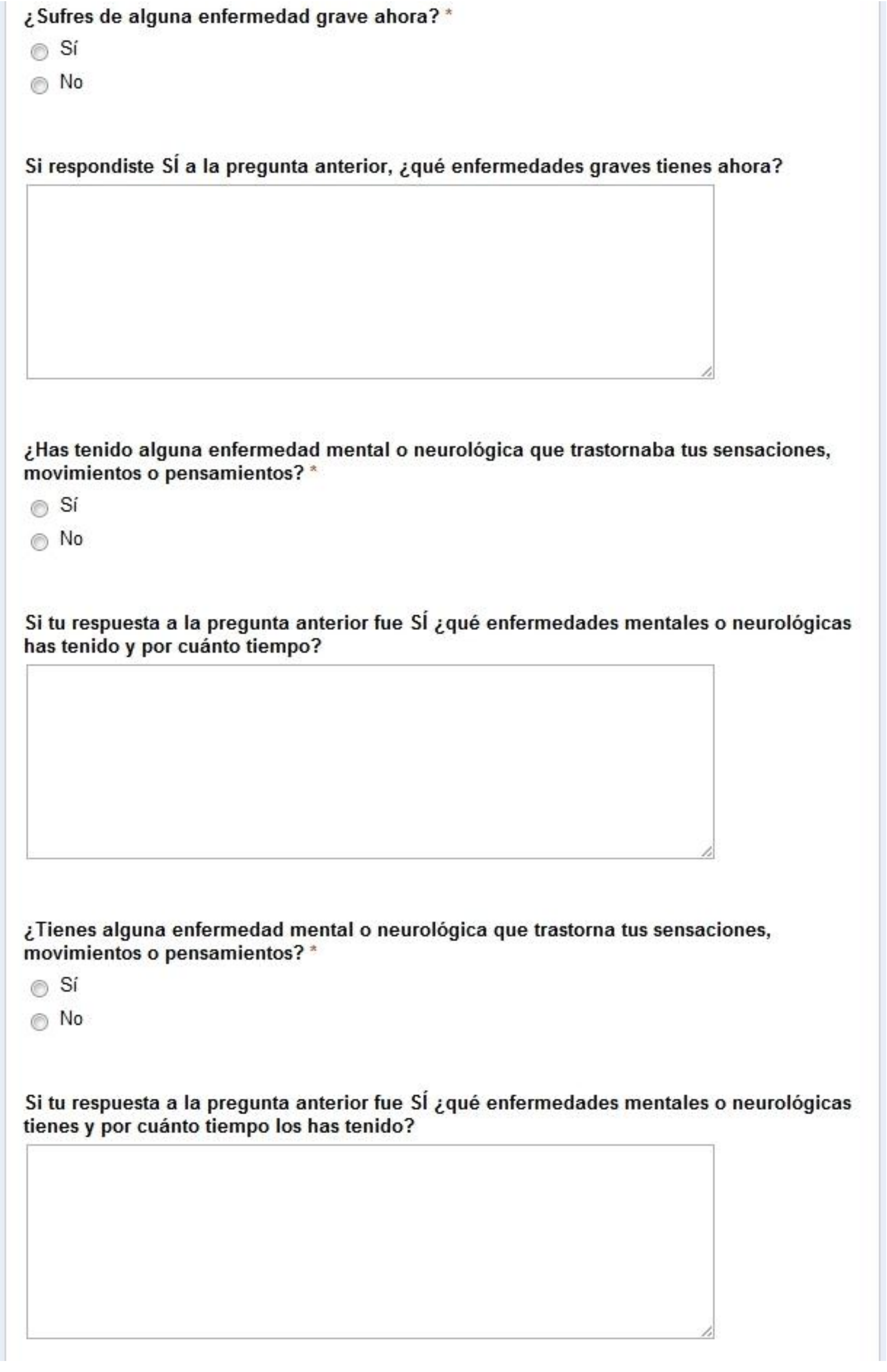
Si tomas medicamentoe ¿qué efectos te producen cuando los tomas?

¿Tienes historia de enfermedades graves? *

○ Sí

○ No

Si respondiste SÍ a la pregunta anterior, ¿qué enfermedades graves has sufrido?



¿Sufres de alguna enfermedad grave ahora? *

○ Sí

○ No

Si respondiste SÍ a la pregunta anterior, ¿qué enfermedades graves tienes ahora?

¿Has tenido alguna enfermedad mental o neurológica que trastornaba tus sensaciones, movimientos o pensamientos? *

○ Sí

○ No

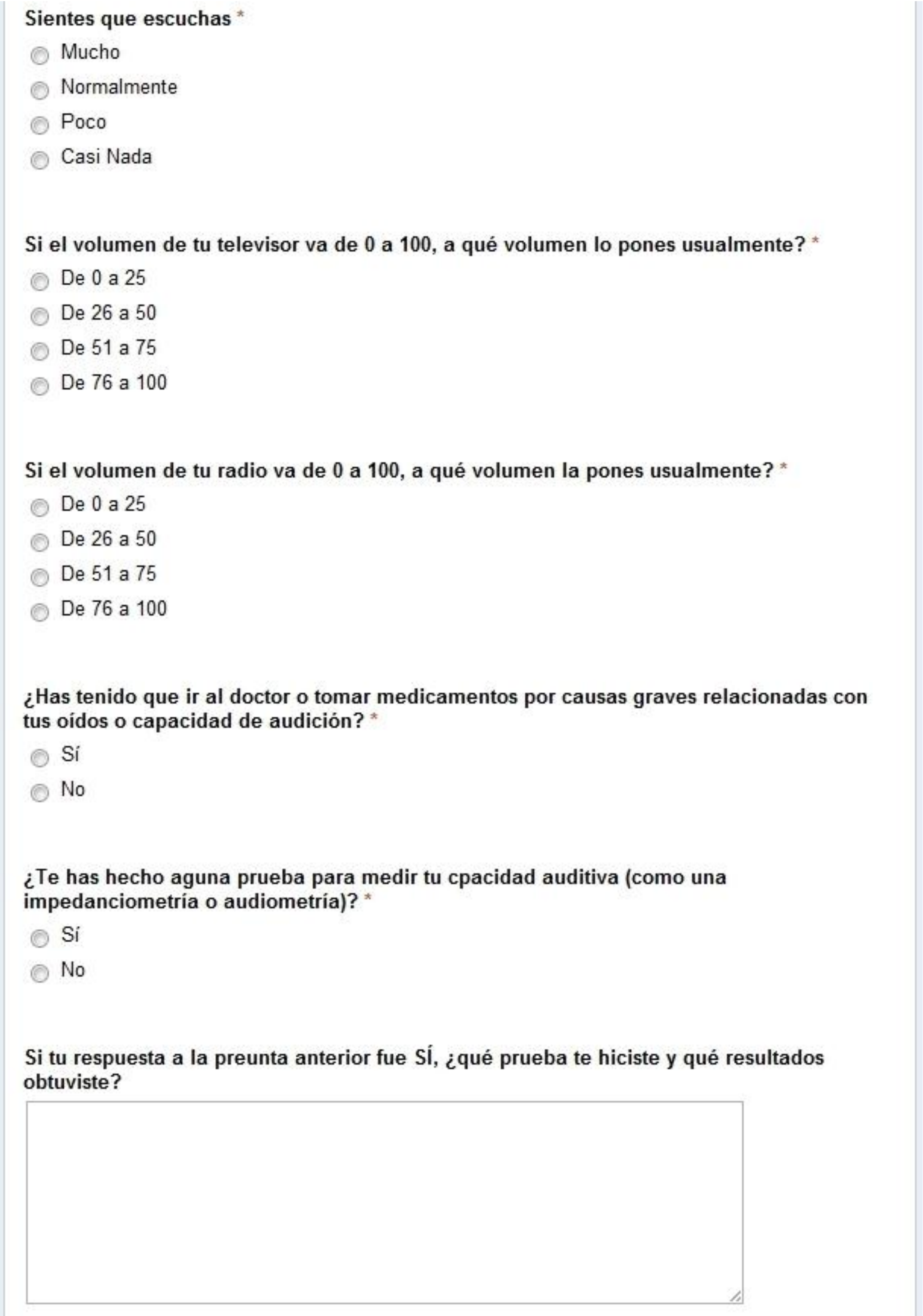
Si tu respuesta a la pregunta anterior fue SÍ ¿qué enfermedades mentales o neurológicas has tenido y por cuánto tiempo?

¿Tienes alguna enfermedad mental o neurológica que trastorna tus sensaciones, movimientos o pensamientos? *

○ Sí

○ No

Si tu respuesta a la pregunta anterior fue SÍ ¿qué enfermedades mentales o neurológicas tienes y por cuánto tiempo los has tenido?



Sientes que escuchas *

○ Mucho

○ Normalmente

○ Poco

○ Casi Nada

Si el volumen de tu televisor va de 0 a 100, a qué volumen lo pones usualmente? *

○ De 0 a 25

○ De 26 a 50

○ De 51 a 75

○ De 76 a 100

Si el volumen de tu radio va de 0 a 100, a qué volumen la pones usualmente? *

○ De 0 a 25

○ De 26 a 50

○ De 51 a 75

○ De 76 a 100

¿Has tenido que ir al doctor o tomar medicamentos por causas graves relacionadas con tus oídos o capacidad de audición? *

○ Sí

○ No

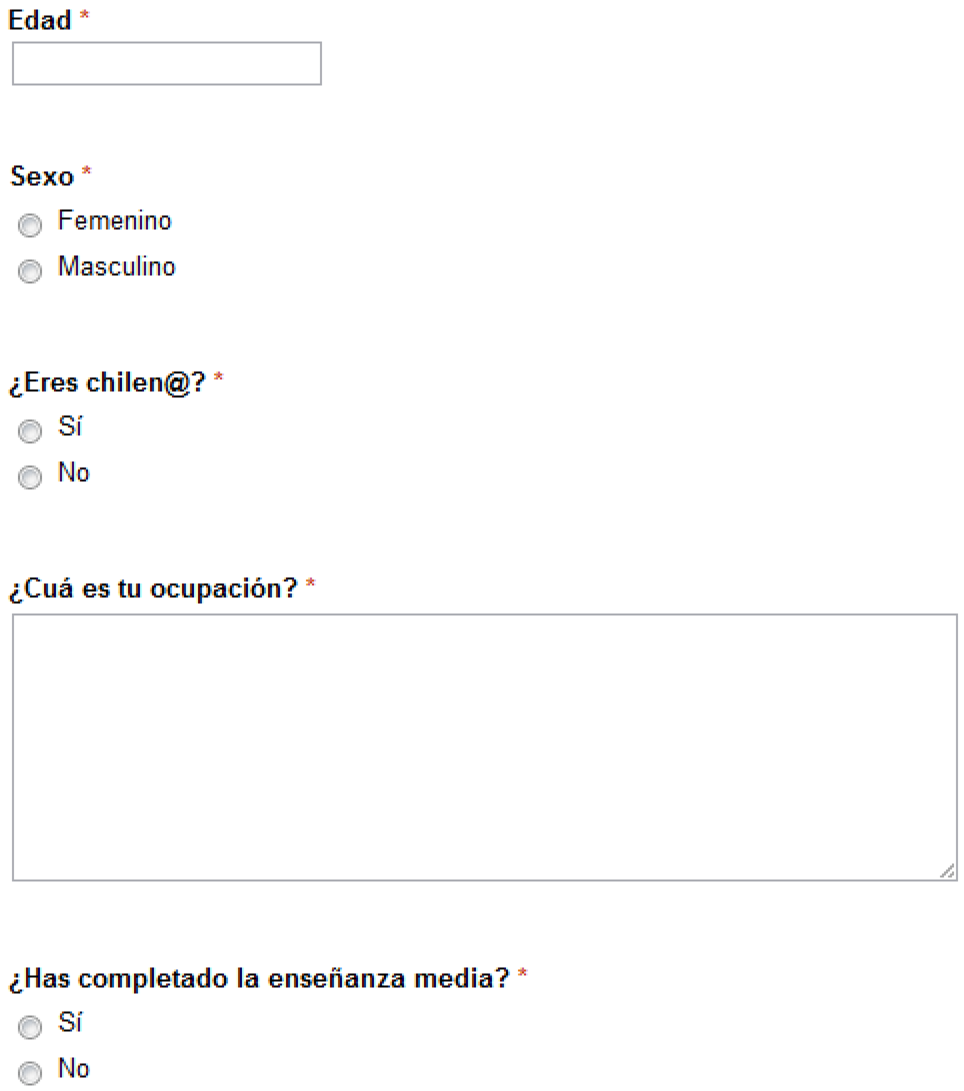
¿Te has hecho aguna prueba para medir tu cpacidad auditiva (como una impedanciometría o audiometría)? *

○ Sí

○ No

Si tu respuesta a la preunta anterior fue SÍ, ¿qué prueba te hiciste y qué resultados obtuviste?

6. ANNEX 2: Questionnaire applied for blind participant screening



Edad *

Sexo *

○ Femenino

○ Masculino

¿Eres chilen@? *

○ Sí

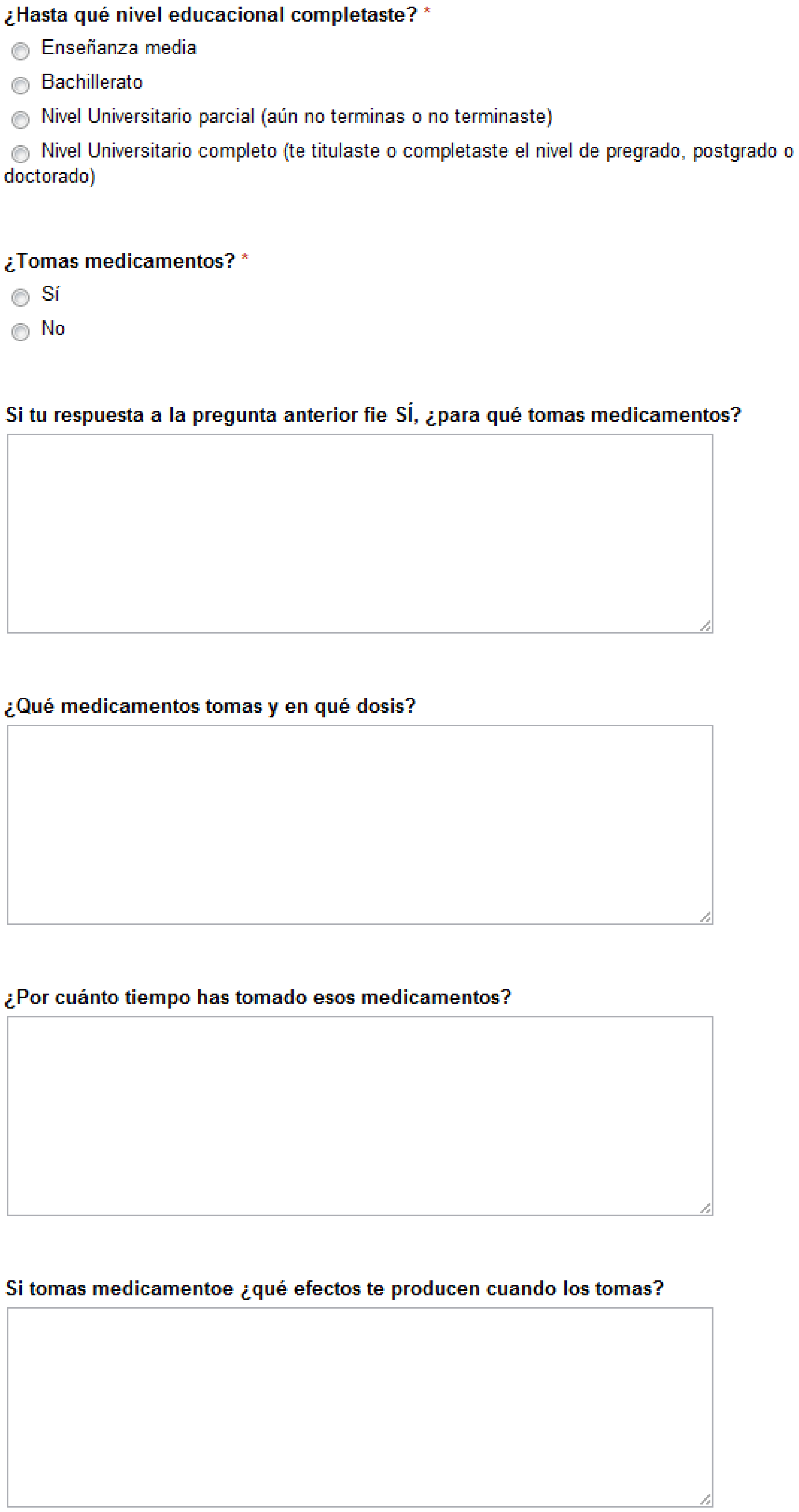
○ No

¿Cuá es tu ocupación? *

¿Has completado la enseñanza media? *

○ Sí

○ No



¿Hasta qué nivel educacional completaste? *

○ Enseñanza media

○ Bachillerato

○ Nivel Universitario parcial (aún no terminas o no terminaste)

○ Nivel Universitario completo (te titulaste o completaste el nivel de pregrado, postgrado o doctorado)

¿Tomas medicamentos? *

○ Sí

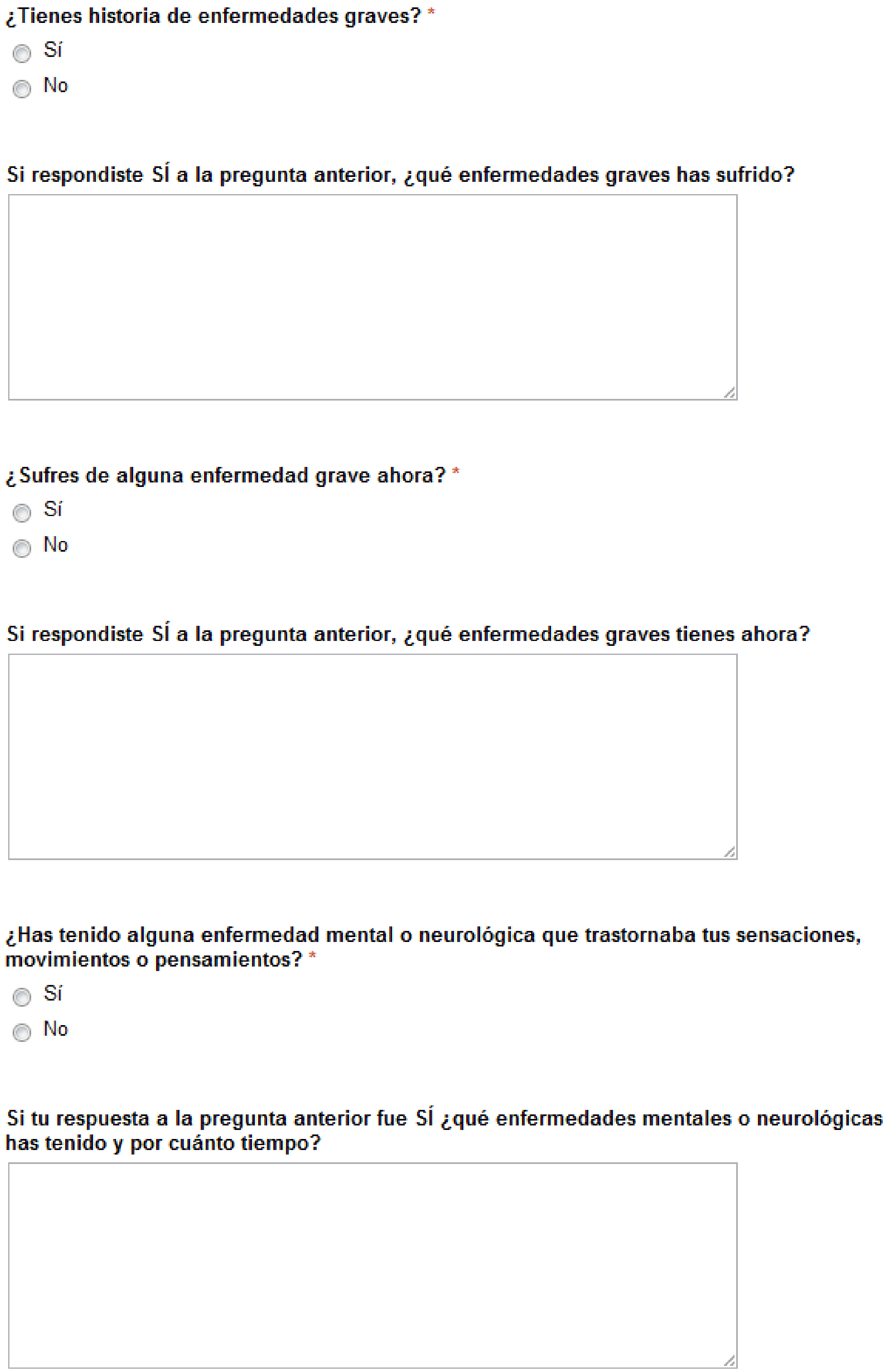
○ No

Si tu respuesta a la pregunta anterior fie SÍ, ¿para qué tomas medicamentos?

¿Qué medicamentos tomas y en qué dosis?

¿Por cuánto tiempo has tomado esos medicamentos?

Si tomas medicamentoe ¿qué efectos te producen cuando los tomas?



¿Tienes historia de enfermedades graves? *

○ Sí

○ No

Si respondiste SÍ a la pregunta anterior, ¿qué enfermedades graves has sufrido?

¿Sufres de alguna enfermedad grave ahora? *

○ Sí

○ No

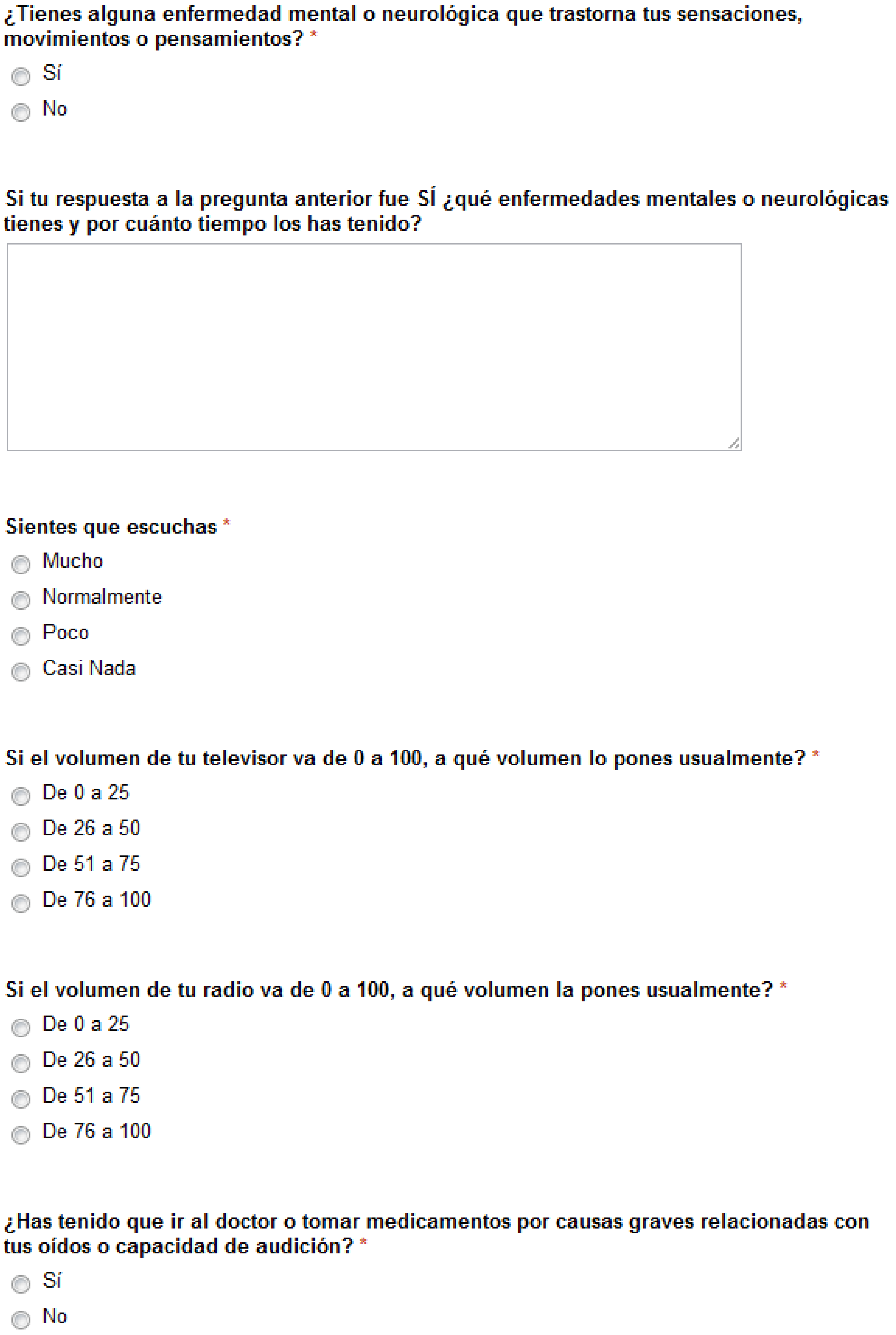
Si respondiste SÍ a la pregunta anterior, ¿qué enfermedades graves tienes ahora?

¿Has tenido alguna enfermedad mental o neurológica que trastornaba tus sensaciones, movimientos o pensamientos? *

○ Sí

○ No

Si tu respuesta a la pregunta anterior fue SÍ ¿qué enfermedades mentales o neurológicas has tenido y por cuánto tiempo?



¿Tienes alguna enfermedad mental o neurológica que trastorna tus sensaciones, movimientos o pensamientos? *

○ Sí

○ No

Si tu respuesta a la pregunta anterior fue SÍ ¿qué enfermedades mentales o neurológicas tienes y por cuánto tiempo los has tenido?

Sientes que escuchas *

○ Mucho

○ Normalmente

○ Poco

○ Casi Nada

Si el volumen de tu televisor va de 0 a 100, a qué volumen lo pones usualmente? *

○ De 0 a 25

○ De 26 a 50

○ De 51 a 75

○ De 76 a 100

Si el volumen de tu radio va de 0 a 100, a qué volumen la pones usualmente? *

○ De 0 a 25

○ De 26 a 50

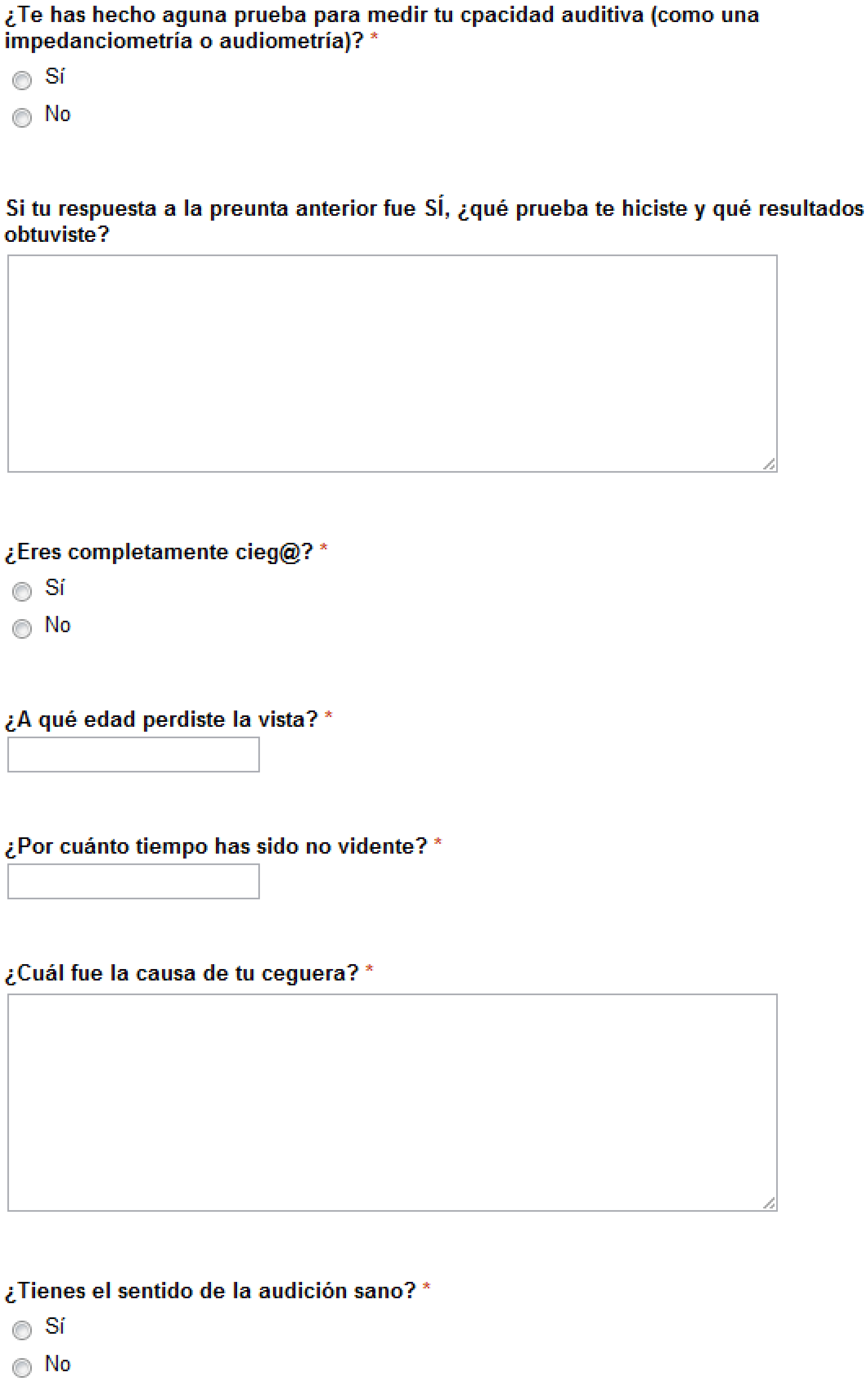
○ De 51 a 75

○ De 76 a 100

¿Has tenido que ir al doctor o tomar medicamentos por causas graves relacionadas con tus oídos o capacidad de audición? *

○ Sí

○ No



¿Te has hecho aguna prueba para medir tu cpacidad auditiva (como una impedanciometría o audiometría)? *

○ Sí

○ No

Si tu respuesta a la preunta anterior fue SÍ, ¿qué prueba te hiciste y qué resultados obtuviste?

¿Eres completamente cieg@? *

○ Sí

○ No

¿A qué edad perdiste la vista? *

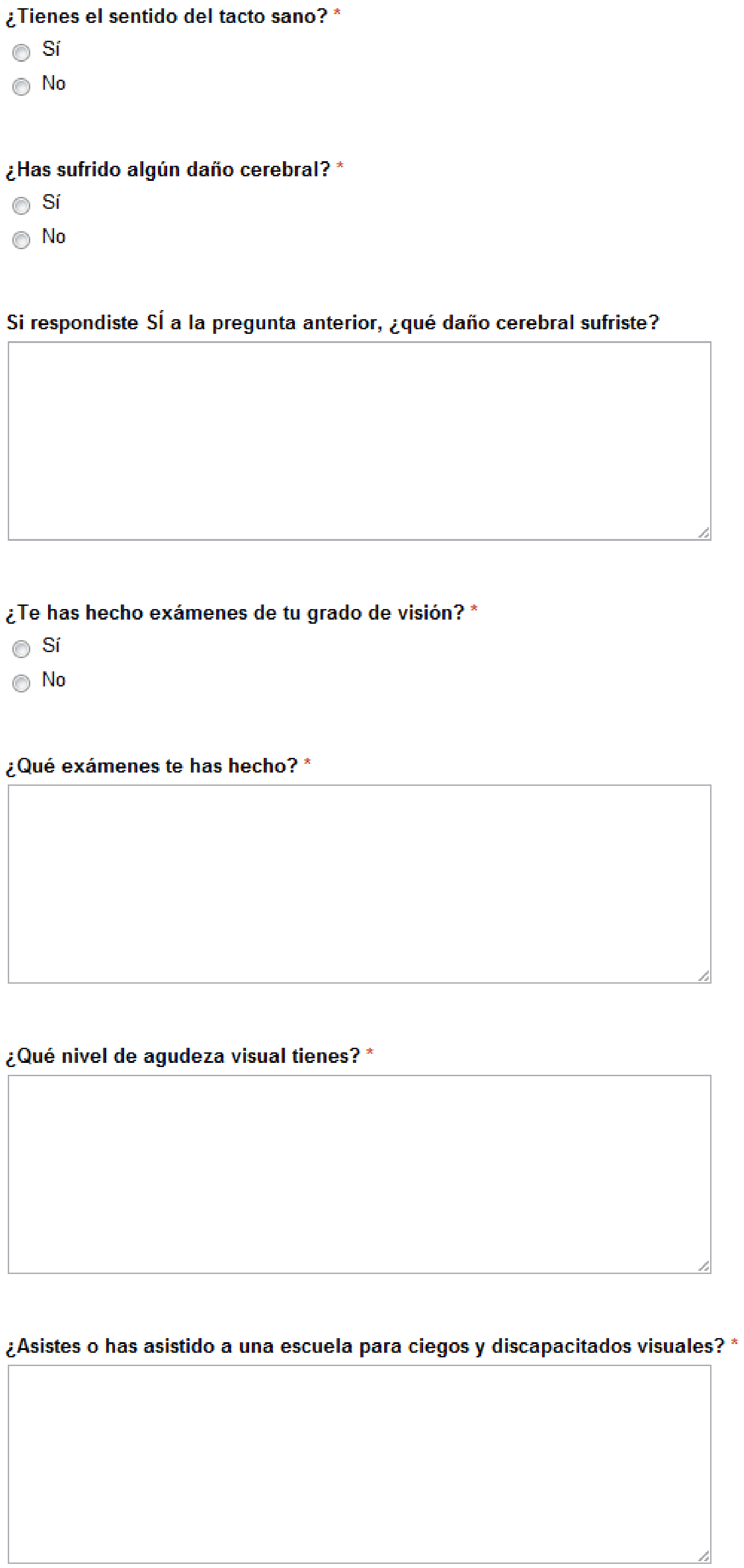
¿Por cuánto tiempo has sido no vidente? *

¿Cuál fue la causa de tu ceguera? *

¿Tienes el sentido de la audición sano? *

○ Sí

○ No



¿Tienes el sentido del tacto sano? *

○ Sí

○ No

¿Has sufrido algún daño cerebral? *

○ Sí

○ No

Si respondiste SÍ a la pregunta anterior, ¿qué daño cerebral sufriste?

¿Te has hecho exámenes de tu grado de visión? *

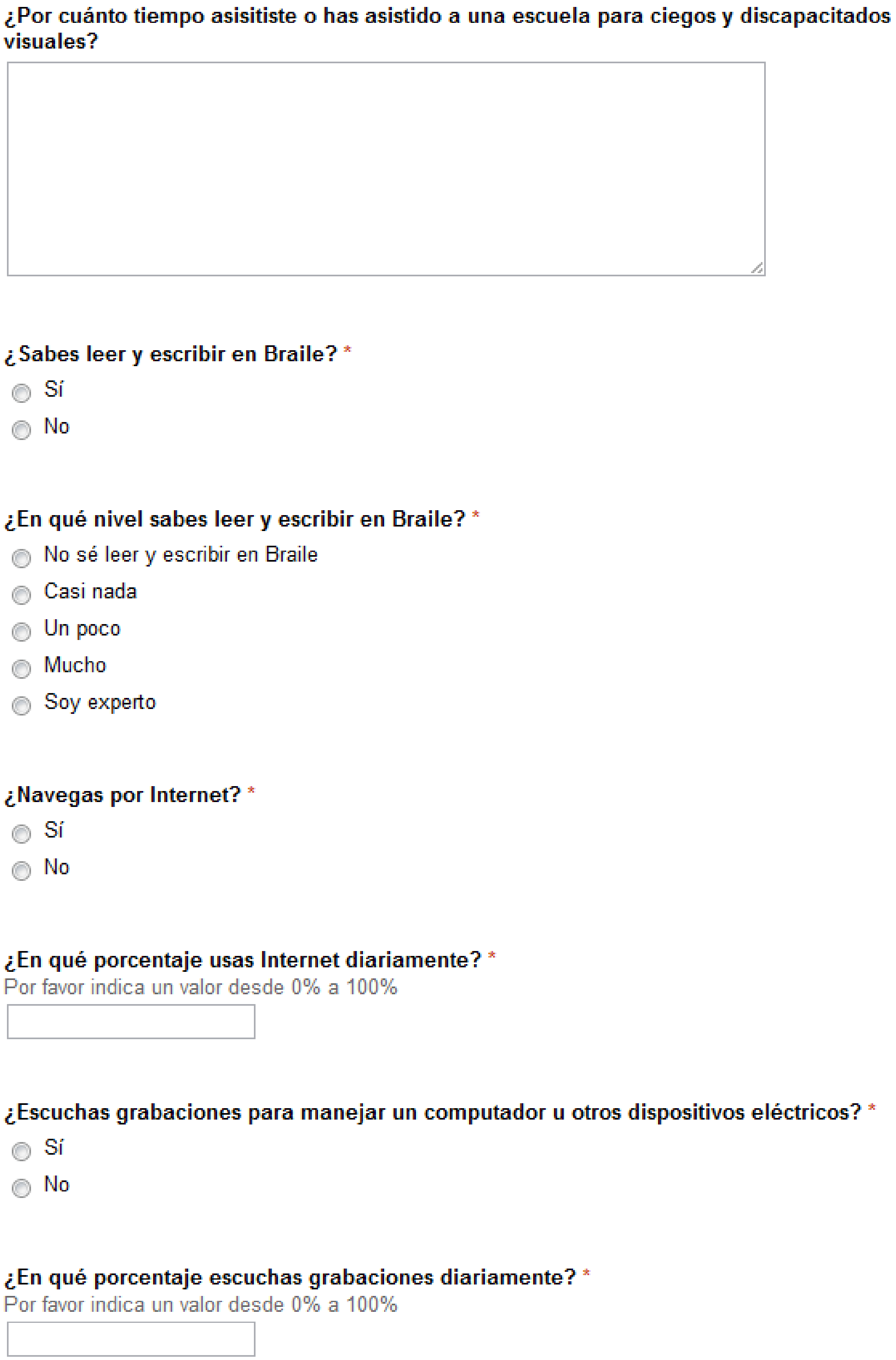
○ Sí

○ No

¿Qué exámenes te has hecho? *

¿Qué nivel de agudeza visual tienes? *

¿Asistes o has asistido a una escuela para ciegos y discapacitados visuales? *



¿Por cuánto tiempo asisitiste o has asistido a una escuela para ciegos y discapacitados visuales?

¿Sabes leer y escribir en Braile? *

○ Sí

○ No

¿En qué nivel sabes leer y escribir en Braile? *

○ No sé leer y escribir en Braile

○ Casi nada

○ Un poco

○ Mucho

○ Soy experto

¿Navegas por Internet? *

○ Sí

○ No

¿En qué porcentaje usas Internet diariamente? *

Por favor indica un valor desde 0% a 100%

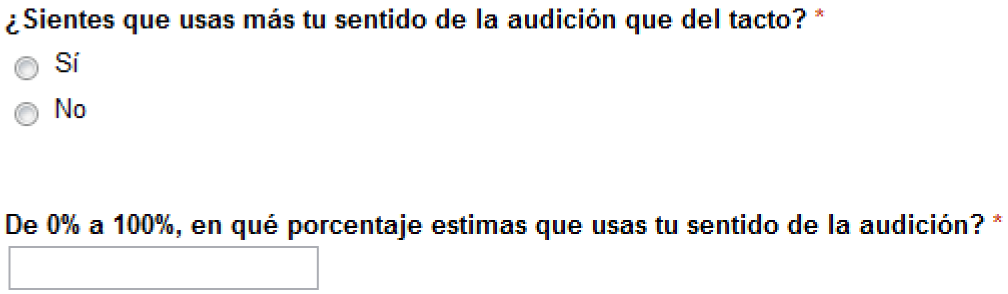
¿Escuchas grabaciones para manejar un computador u otros dispositivos eléctricos? *

○ Sí

○ No

¿En qué porcentaje escuchas grabaciones diariamente? *

Por favor indica un valor desde 0% a 100%



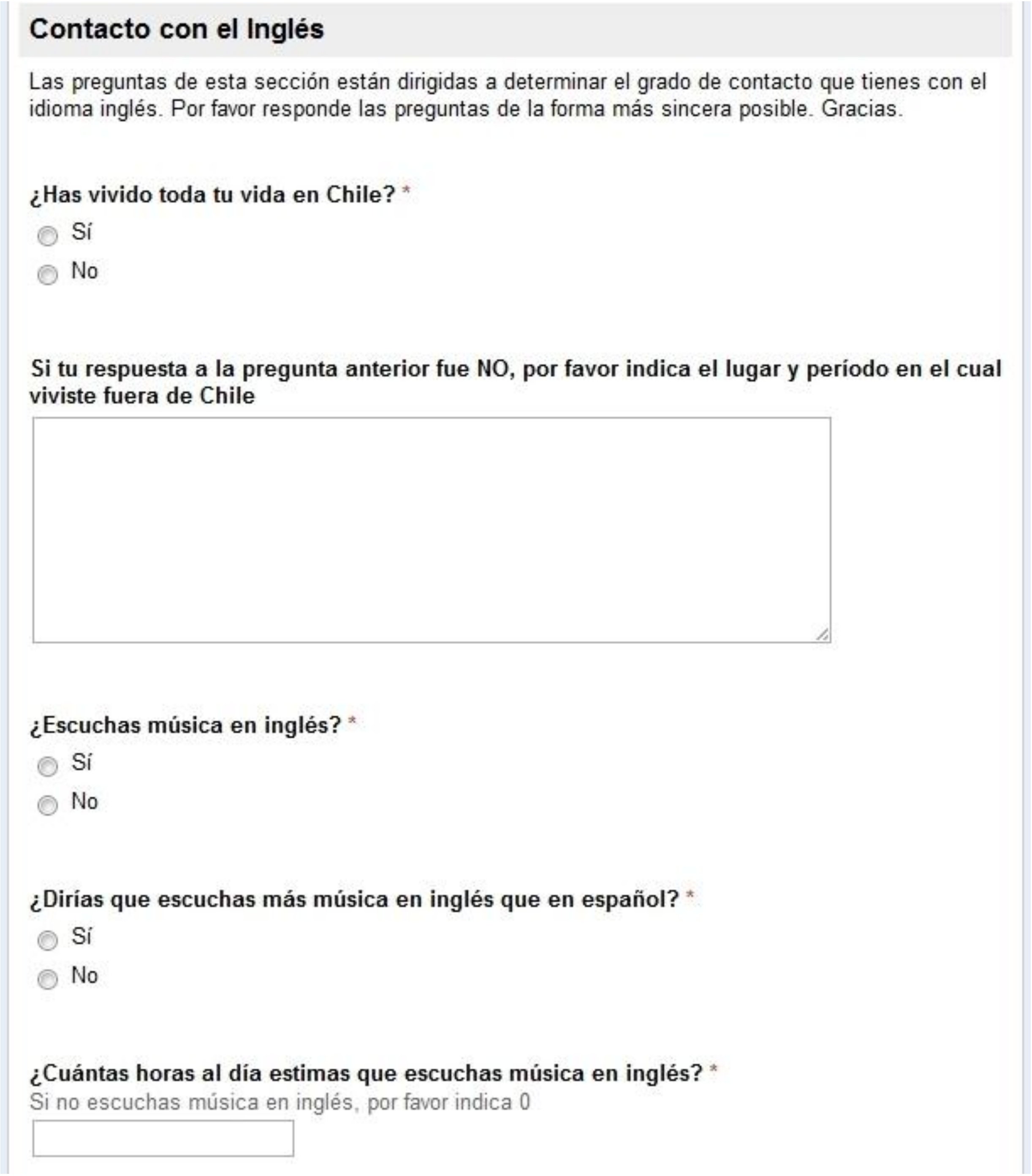
¿Sientes que usas más tu sentido de la audición que del tacto? *

○ Sí

○ No

De 0% a 100%, en qué porcentaje estimas que usas tu sentido de la audición? *

7. ANNEX 3: Questionnaire to measure participants' frequency of contact with the English language



Contacto con el Inglés

Las preguntas de esta sección están dirigidas a determinar el grado de contacto que tienes con el idioma inglés. Por favor responde las preguntas de la forma más sincera posible. Gracias.

¿Has vivido toda tu vida en Chile? *

○ Sí

○ No

Si tu respuesta a la pregunta anterior fue NO, por favor indica el lugar y período en el cual viviste fuera de Chile

¿Escuchas música en inglés? *

○ Sí

○ No

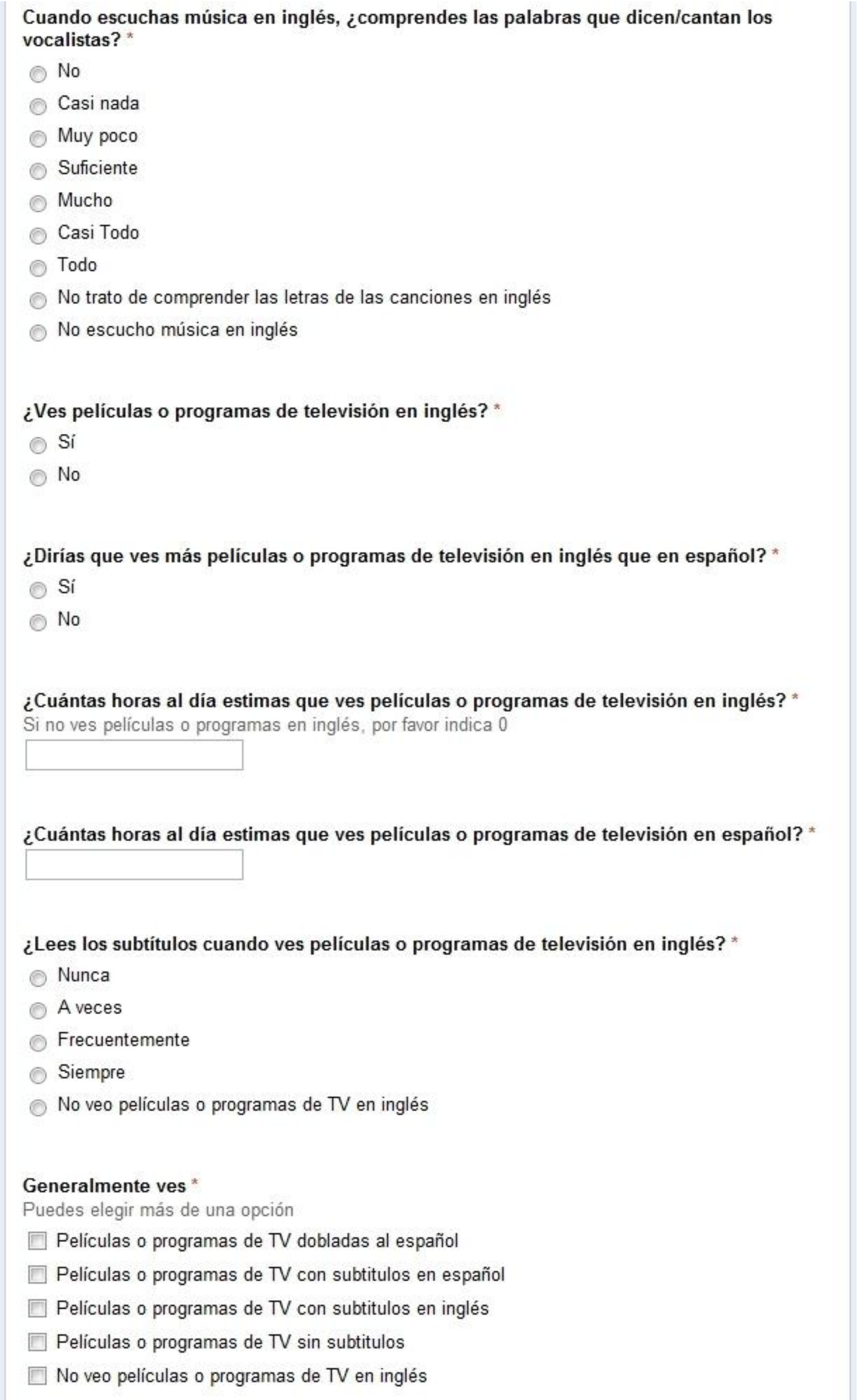
¿Dirías que escuchas más música en inglés que en español? *

○ Sí

○ No

¿Cuántas horas al día estimas que escuchas música en inglés? *

Si no escuchas música en inglés, por favor indica 0



Cuando escuchas música en inglés, ¿comprendes las palabras que dicen/cantan los vocalistas? *

○ No
○ Casi nada
○ Muy poco
○ Suficiente
○ Mucho
○ Casi Todo
○ Todo
○ No trato de comprender las letras de las canciones en inglés
○ No escucho música en inglés

¿Ves películas o programas de televisión en inglés? *

○ Sí
○ No

¿Dirías que ves más películas o programas de televisión en inglés que en español? *

○ Sí
○ No

¿Cuántas horas al día estimas que ves películas o programas de televisión en inglés? *

Si no ves películas o programas en inglés, por favor indica 0

¿Cuántas horas al día estimas que ves películas o programas de televisión en español? *

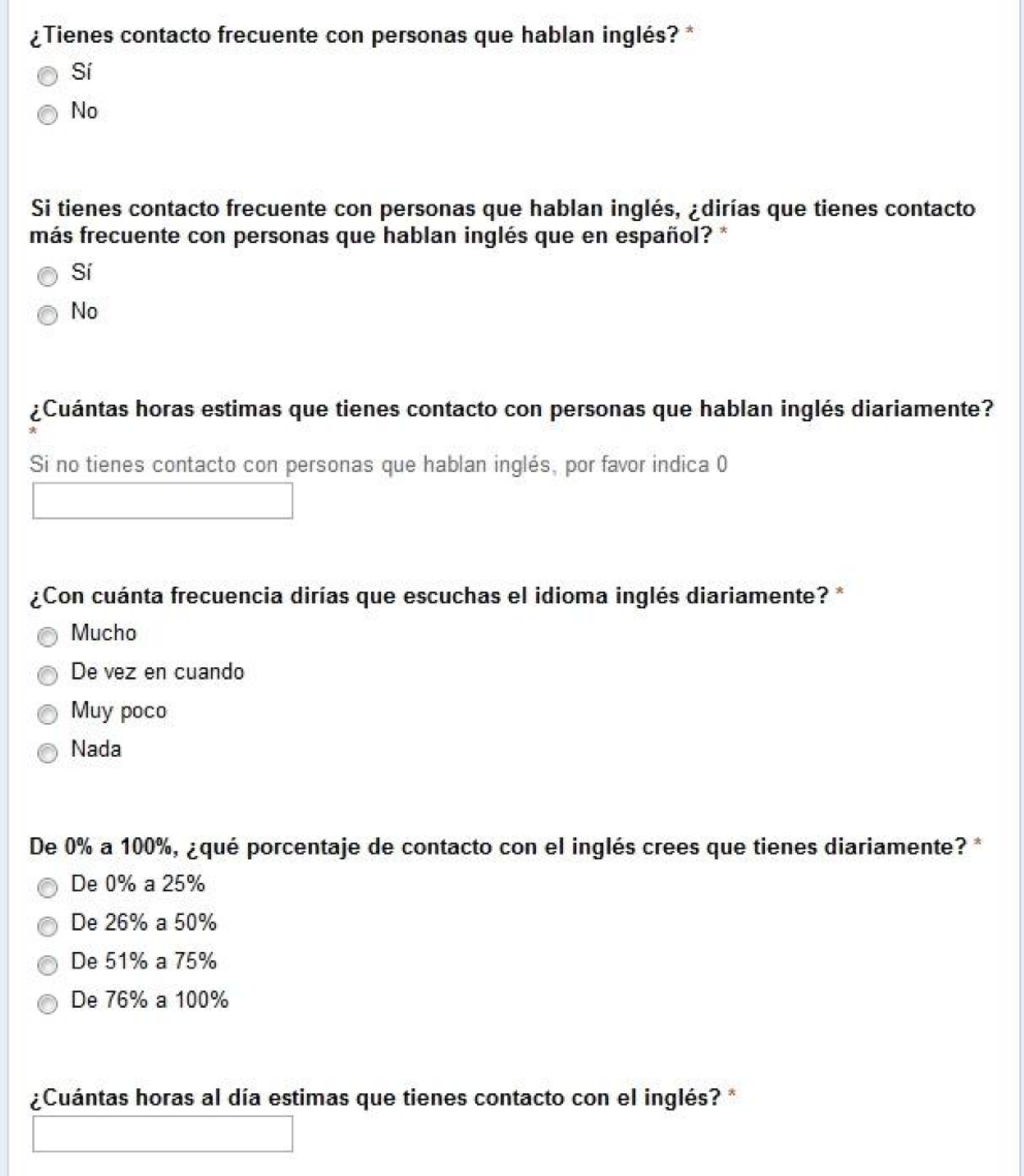
¿Lees los subtítulos cuando ves películas o programas de televisión en inglés? *

○ Nunca
○ A veces
○ Frecuentemente
○ Siempre
○ No veo películas o programas de TV en inglés

Generalmente ves *

Puedes elegir más de una opción

☐ Películas o programas de TV dobladas al español
☐ Películas o programas de TV con subtitulos en español
☐ Películas o programas de TV con subtitulos en inglés
☐ Películas o programas de TV sin subtitulos
☐ No veo películas o programas de TV en inglés



¿Tienes contacto frecuente con personas que hablan inglés? *

○ Sí

○ No

Si tienes contacto frecuente con personas que hablan inglés, ¿dirías que tienes contacto más frecuente con personas que hablan inglés que en español? *

○ Sí

○ No

¿Cuántas horas estimas que tienes contacto con personas que hablan inglés diariamente? *

Si no tienes contacto con personas que hablan inglés, por favor indica 0

¿Con cuánta frecuencia dirías que escuchas el idioma inglés diariamente? *

○ Mucho

○ De vez en cuando

○ Muy poco

○ Nada

De 0% a 100%, ¿qué porcentaje de contacto con el inglés crees que tienes diariamente? *

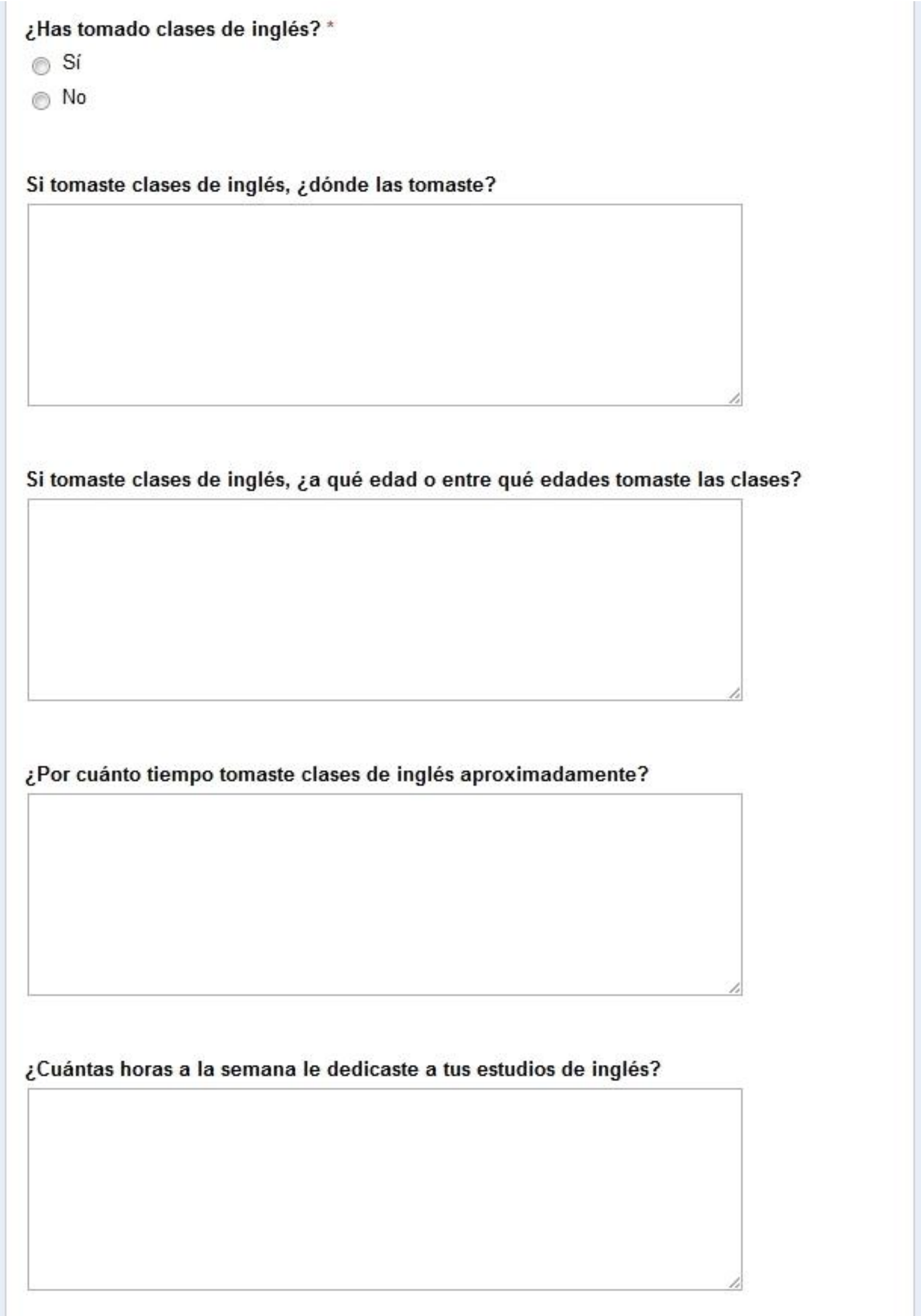
○ De 0% a 25%

○ De 26% a 50%

○ De 51% a 75%

○ De 76% a 100%

¿Cuántas horas al día estimas que tienes contacto con el inglés? *



¿Has tomado clases de inglés? *

○ Sí

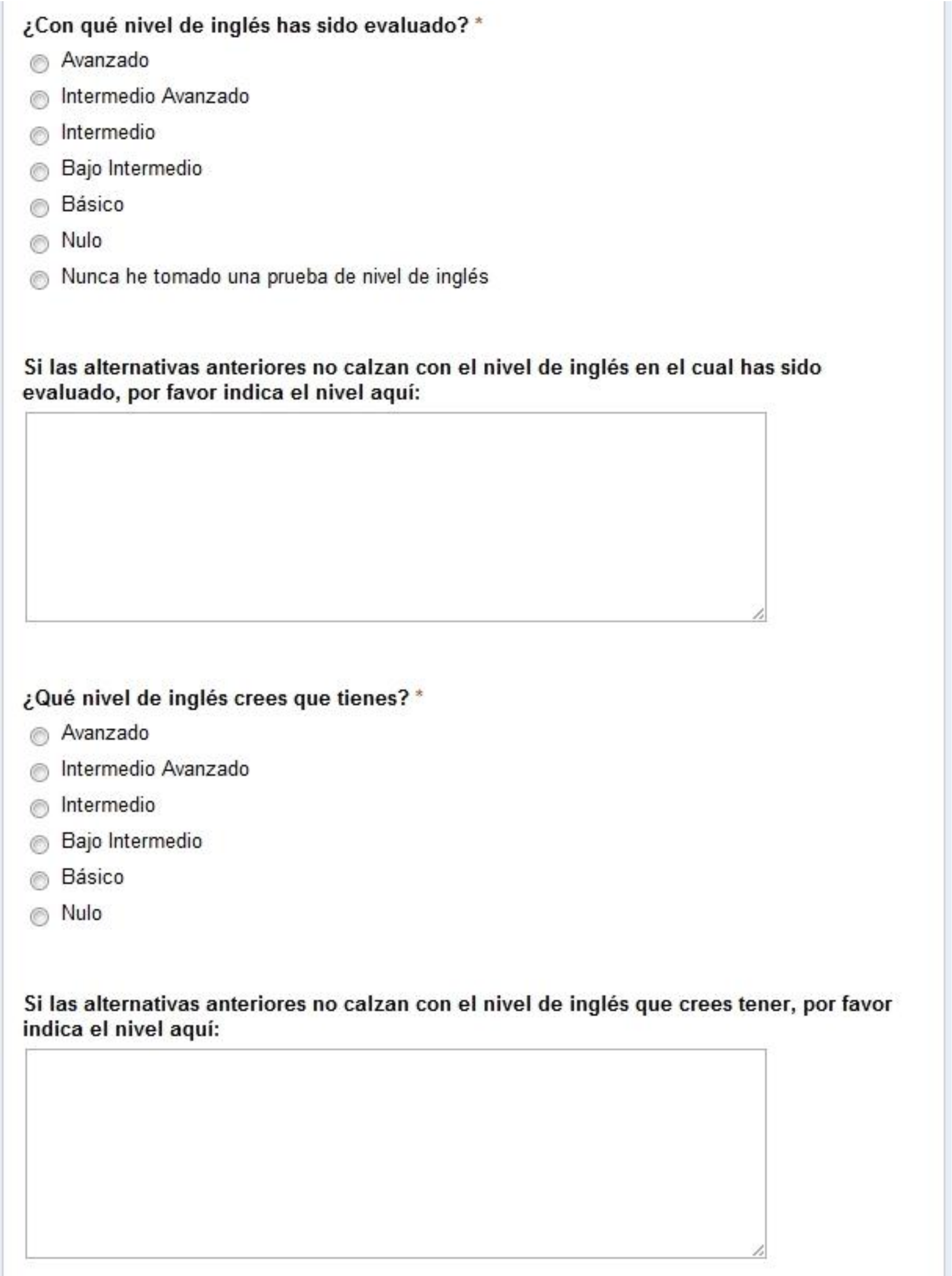
○ No

Si tomaste clases de inglés, ¿dónde las tomaste?

Si tomaste clases de inglés, ¿a qué edad o entre qué edades tomaste las clases?

¿Por cuánto tiempo tomaste clases de inglés aproximadamente?

¿Cuántas horas a la semana le dedicaste a tus estudios de inglés?



¿Con qué nivel de inglés has sido evaluado? *

○ Avanzado
○ Intermedio Avanzado
○ Intermedio
○ Bajo Intermedio
○ Básico
○ Nulo
○ Nunca he tomado una prueba de nivel de inglés

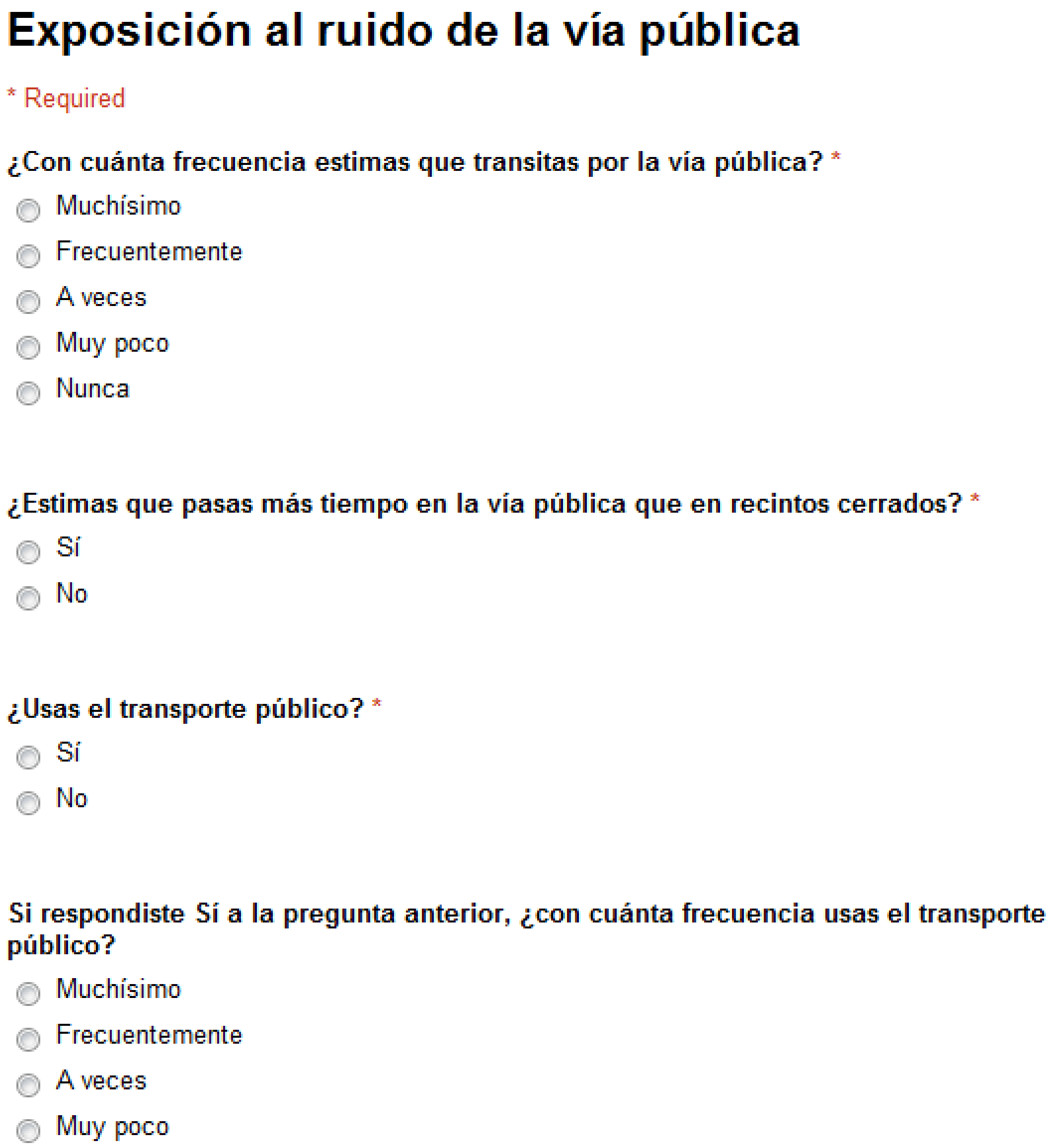
Si las alternativas anteriores no calzan con el nivel de inglés en el cual has sido evaluado, por favor indica el nivel aquí:

¿Qué nivel de inglés crees que tienes? *

○ Avanzado
○ Intermedio Avanzado
○ Intermedio
○ Bajo Intermedio
○ Básico
○ Nulo

Si las alternativas anteriores no calzan con el nivel de inglés que crees tener, por favor indica el nivel aquí:

8. ANNEX 4: Questionnaire to measure participants’ general exposure to street noise



Exposición al ruido de la vía pública

* Required

¿Con cuánta frecuencia estimas que transitas por la vía pública? *

○ Muchísimo
○ Frecuentemente
○ A veces
○ Muy poco
○ Nunca

¿Estimas que pasas más tiempo en la vía pública que en recintos cerrados? *

○ Sí
○ No

¿Usas el transporte público? *

○ Sí
○ No

Si respondiste Sí a la pregunta anterior, ¿con cuánta frecuencia usas el transporte público?

○ Muchísimo
○ Frecuentemente
○ A veces
○ Muy poco

9 Annex 5: Written consent in Spanish for the participants of the pilot experiment, certified by the Ethics Board of the Universidad de Chile

Universidad de Chile
Facultad de Filosofía y Humanidades

COMITÉ DE ÉTICA DE LA INVESTIGACIÓN
EN CIENCIAS SOCIALES Y HUMANIDADES
Facultad de Filosofía y Humanidades
UNIVERSIDAD DE CHILE

Consentimiento Informado Proyecto

Percepción y discriminación auditiva de fonemas altamente similares del inglés como lengua extranjera en personas no videntes comparadas con personas videntes

Tú has sido invitado(a) a participar en un estudio relacionado con el aprendizaje de los sonidos de un idioma extranjero. Este estudio forma parte de la tesis de Magíster en estudios cognitivos de la investigadora principal, Natalia Sáez, realizada a través del Centro de Estudios Cognitivos de la Universidad de Chile.

Este documento contiene toda la información que debes saber acerca de este estudio y que te ayudará a decidir si quieres participar o no en él. En el caso de que tú seas no vidente, este documento te deberá ser leído íntegramente por una persona de toda tu confianza, antes de que expreses tu aceptación respecto de su contenido. Si tienes cualquier consulta, duda o comentario, por favor contáctate con Natalia Sáez a nataez@gmail.com o al nº de celular 08-7769482. Puedes hacer todas las consultas que quieras antes de firmar y aceptar lo señalado en el formulario de consentimiento, como también en cualquier momento, durante o después del estudio, las que serán respondidas por la investigadora.

Propósito del estudio: Determinar si la privación de la visión juega un rol en mejorar la percepción e identificación de los sonidos del inglés como nueva lengua.

Selección de los participantes: Si quieres participar como voluntario(a), puedes formar parte de uno de los tres grupos ideados para este estudio, es decir, el grupo de personas no videntes que perdieron la vista durante su adolescencia o adultez, el grupo de videntes que tendrán los ojos vendados durante el estudio o el grupo de videntes que no tendrán sus ojos vendados durante el estudio.

Es importante que sepas que si eres vidente y decides participar en este estudio, serás seleccionado(a) al azar para constituir el grupo de participantes que tendrán sus ojos vendados o de los participantes que no tendrán sus ojos vendados durante el estudio. Si has sido seleccionado para participar en un grupo, pero prefieres participar en el otro, puedes solicitar que se te cambie de grupo a Natalia Sáez a nataez@gmail.com o al nº de celular 08-7769482.

Para participar, debes ser chileno(a), hablante nativo del español chileno, haber completado al menos la educación media, haber vivido toda tu vida en Chile, tener entre 18 y 55 años de edad, no tener patologías psicomotoras o desórdenes psiquiátricos, no tener historia de desórdenes o patologías relacionadas con el oído o la audición, tener poco contacto con el idioma inglés y tener un nivel de inglés básico.

Descripción de la participación: Si decides participar en este estudio, se te invitará a asistir a 5 sesiones de media hora cada una aproximadamente. No podrás asistir a más de una sesión al día. Puedes elegir los días y horas en que más te convenga asistir a tales sesiones, siempre y cuando lo hagas dentro del período de dos semanas (14 días).

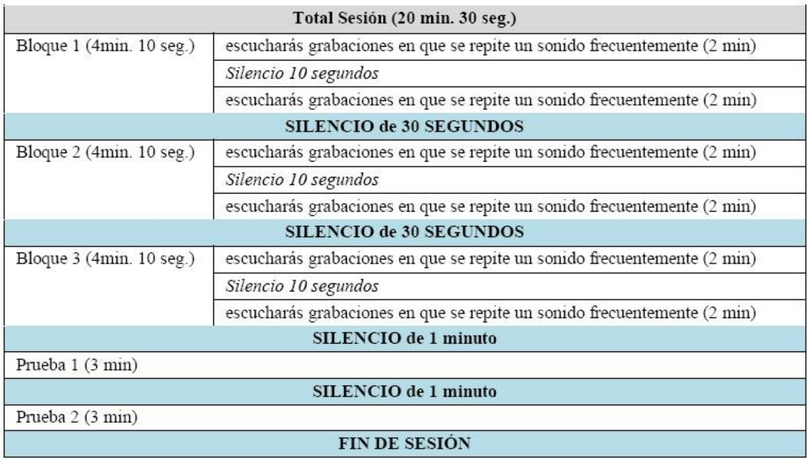
Para cada sesión solicitaremos que acudas a General Salvo 674, oficina H, Providencia (cerca del Metro Salvador). En cada visita te pediremos que te sientes en un escritorio en una sala y que te pongas unos audífonos sin retirarlos por 22 minutos aproximadamente. La investigadora principal estará presente en la sala durante el tiempo en que estés con los audífonos puestos, por si necesitas detener tu sesión o hacer consultas. Esta persona también estará disponible para que le hagas preguntas en cualquier momento, ya sea en el lugar del estudio, vía email (nataez@gmail.com) o por teléfono (08-7769482).

A través de los audífonos escucharás grabaciones de un estadounidense pronunciando palabras en inglés y palabras inventadas en que se repiten 6 sonidos del inglés frecuentemente. Te pediremos que le pongas el mayor grado de atención que puedas a estas grabaciones. Si decides participar en el grupo de voluntarios videntes que no tendrán sus ojos vendados durante el estudio, te pediremos que por favor no cierres los ojos mientras tengas los audífonos puestos (sólo para pestañar). Durante los primeros 2 minutos escucharás palabras en inglés y palabras inventadas en que se repite el primer sonido del inglés frecuentemente. Luego, habrá un silencio de 10 segundos, y después escucharás palabras en inglés y palabras inventadas en que se repetirá el segundo sonido frecuentemente por 2 minutos. Luego, habrá 30 segundos de silencio. Después escucharás palabras en inglés y palabras inventadas en que el tercer sonido se repetirá frecuentemente por 2 minutos, luego habrá un silencio de 10 segundos, y después escucharás palabras en inglés y palabras inventadas en que se repetirá el cuarto sonido frecuentemente por 2 minutos. Luego, habrá 30 segundos de silencio. Finalmente, durante los 2 minutos que siguen, escucharás palabras en inglés y palabras inventadas en que el quinto sonido se repetirá frecuentemente, luego habrá un silencio de 10 segundos, y después escucharás palabras en inglés y palabras inventadas en que se repetirá el sexto sonido frecuentemente por 2 minutos. Luego, habrá un minuto de silencio. Durante todo este tiempo, y también por los 7 minutos que siguen, te pediremos que no te saques los audífonos.

Inmediatamente después del minuto de silencio, escucharás un tono que te indicará el comienzo de la primera prueba. En esta prueba, escucharás pares de palabras en inglés o palabras inventadas con sonidos en inglés. Después de cada par, habrá un silencio de 10 segundos durante el cual podrás indicar si las palabras que escuchaste son iguales o diferentes. Para indicar esto, podrás contestar oralmente diciendo “iguales” o “diferentes” (en español). La persona presente en la sala anotará tus respuestas. Después de que escuches el último par de palabras y decidas si son iguales o distintas, habrá un silencio de 1 minuto. Luego escucharás un tono y comenzará la segunda prueba. En esta prueba, también escucharás palabras en inglés o palabras inventadas con sonidos en inglés. La diferencia es que en esta prueba también habrá ruido de fondo en las grabaciones que escucharás. Este ruido de fondo puede ser de gente tosiendo y sonidos que típicamente se escuchan en la calle. Después de cada par, habrá un silencio de 10 segundos durante el cual podrás indicar si las palabras que escuchaste son iguales o diferentes. Para indicar esto, podrás contestar oralmente diciendo “iguales” o “diferentes” (en español). La persona presente en la sala anotará tus respuestas.

Si decides participar en este estudio, te pediremos que hagas lo que se describe arriba cada vez que acudas a una sesión. Son cinco sesiones en total. La siguiente tabla es un ejemplo de las actividades que te pediremos que hagas en cada sesión y sus tiempos respectivos. Puedes pensar con calma en toda esta información y consultar todas las dudas que tengas antes de decidir si participarás en este estudio. Puedes escribir tus consultas a nataez@gmail.com o llamar al 08-7769482.

Tabla 1. Actividades de cada sesión y sus respectivos tiempos de duración.



Total Sesión (20 min. 30 seg.)	
Bloque 1 (4min. 10 seg.)	escucharás grabaciones en que se repite un sonido frecuentemente (2 min)
	Silencio 10 segundos
	escucharás grabaciones en que se repite un sonido frecuentemente (2 min)
SILENCIO de 30 SEGUNDOS	
Bloque 2 (4min. 10 seg.)	escucharás grabaciones en que se repite un sonido frecuentemente (2 min)
	Silencio 10 segundos
	escucharás grabaciones en que se repite un sonido frecuentemente (2 min)
SILENCIO de 30 SEGUNDOS	
Bloque 3 (4min. 10 seg.)	escucharás grabaciones en que se repite un sonido frecuentemente (2 min)
	Silencio 10 segundos
	escucharás grabaciones en que se repite un sonido frecuentemente (2 min)
SILENCIO de 1 minuto	
Prueba 1 (3 min)	
SILENCIO de 1 minuto	
Prueba 2 (3 min)	
FIN DE SESIÓN	

Riesgos: Este estudio no presenta ningún riesgo para ti. El volumen de lo que escuches estará a un nivel en que no pueda causar daño de ningún tipo a tus oídos.

Beneficios: En este estudio podrás estar expuesto a material auditivo en que se repiten 6 sonidos del inglés frecuentemente, lo que podría ayudarte a reconocer estos sonidos en el futuro y así ayudarte a percibir y aprender palabras nuevas que contengan estos sonidos. También, es posible que algunas de las palabras que escuches a lo largo del estudio se queden en tu memoria, lo que te ayudará a ampliar tu vocabulario en inglés si luego aprendes los significados de las palabras que recuerdas. Esta preparación para el futuro aprendizaje de palabras en inglés que contienen los sonidos de este estudio se llama *priming* en psicología.

Costos: No hay costos asociados a este estudio.

Compensaciones: Recibirás dinero para cubrir el transporte al lugar de las sesiones y te ofreceremos refrigerios en el lugar del estudio. Agradecemos la cooperación de los participantes en este estudio, por medio de la cual colaboran con el progreso de la docencia y la investigación.

Confidencialidad: Tu nombre no será conocido a través de este estudio, por lo que todas tus respuestas y resultados serán completamente anónimos. En lugar de usar tu nombre, te asignaremos una letra y un nº de identificación (por ejemplo, B2), por lo que tu nombre nunca será incluido en el informe final de este estudio y tampoco será mencionado en las conversaciones o discusiones en torno a este estudio.

Resultados: Si quieres conocer tus resultados al final del estudio, puedes contactar a Natalia Sáez a nataez@gmail.cl y solicitar tus resultados indicándole la letra y número que se te fue asignado para el estudio (por ejemplo, SB4). Ella te enviará tus resultados en formato PDF por email.

Derecho a negarse o retirarse: Si quieres retirarte del estudio, lo podrás hacer en cualquier momento sin necesidad de entregar explicaciones y sin que esto tenga consecuencias negativas para ti. También, si quieres detener las grabaciones o quitarte los audífonos en cualquier momento de una sesión, lo podrás hacer libremente. No estás obligado(a) a completar las 5 sesiones descritas arriba si no lo quieres hacer.

Contactos:

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Natalia Sáez Sáez
José Manuel Infante 14 dpto. 41, Providencia, Santiago, Chile
Celular: 08-7769482 ó 08-2410484
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Universidad de Chile
Facultad de Filosofía y Humanidades

COMITÉ DE ÉTICA DE LA INVESTIGACIÓN
EN CIENCIAS SOCIALES Y HUMANIDADES
Facultad de Filosofía y Humanidades
UNIVERSIDAD DE CHILE

FORMULARIO DE CONSENTIMIENTO

He sido invitada(o) a participar en el estudio llamado "Percepción y discriminación auditiva de fonemas altamente similares del inglés como lengua extranjera en personas no videntes comparadas con personas videntes". Entiendo que mi participación consistirá en asistir a 5 (cinco) sesiones de media hora cada una aproximadamente. En cada sesión escucharé algunos sonidos del inglés, palabras en inglés y palabras inventadas con algunos sonidos del inglés a través de audífonos, después de lo cual responderé a dos pruebas auditivas. He leído (o se me ha leído) la información del documento de consentimiento. He tenido tiempo para hacer preguntas y se me ha contestado claramente. No tengo ninguna duda sobre mi participación. Acepto voluntariamente participar y sé que tengo el derecho a terminar mi participación en cualquier momento.

Este documento de consentimiento informado se firma en dos copias, de las cuales una quedará en posesión del participante y la otra de la investigadora principal, quienes firman abajo.

________________________	________________________
Firma del Participante	Firma de la Investigadora Principal

Fecha:________________________________

10. Annex 6: Evaluation report and certificate of approval for the pilot experiment of this study, issued by the Ethics Board of the Universidad de Chile

Universidad de Chile
Facultad de Filosofía y Humanidades
Centro de Estudios de Ética Aplicada
Comité de Ética de la Investigación en Cs. Sociales y Humanidades
Decreto Exento Rectoría Nº 32492 - 28.11.05

032/2011

INFORME DE EVALUACIÓN

IDENTIFICACIÓN DEL PROYECTO

Proyecto: Percepción y discriminación auditiva de fonemas altamente similares del inglés como lengua extranjera en personas no videntes comparadas con personas videntes.

Investigador responsable: Natalia Sáez.

Otra información relevante: Tesis para optar al grado de Magíster en Estudios Cognitivos en la Facultad de Filosofía y Humanidades de la Universidad de Chile.

DESCRIPCIÓN GENERAL DEL PROYECTO

Este estudio forma parte de la tesis de Natalia Sáez para optar al grado de Magíster en estudios cognitivos de la Universidad de Chile. Plantea la hipótesis general de que las personas que han sido privados del sentido de la visión tienen una capacidad superior de percibir y procesar información auditiva en comparación con las personas videntes. Específicamente, propone correlacionar la evidencia reportada sobre plasticidad neuronal, compensación intermodal, percepción, memoria y atención auditiva en no videntes con un experimento diseñado para este estudio. A través de tal experimento se espera obtener resultados iniciales que indiquen si las personas no videntes tienden a aprender a identificar algunos fonemas del inglés como lengua extranjera mejor que las personas que ven. Se espera que las personas ciegas tengan mayor facilidad para aprender a identificar los fonemas de dicho idioma por el modo sensorial auditivo comparadas con los videntes. Adicionalmente, se espera obtener resultados preliminares que indiquen si las personas videntes pueden aprender a identificar los sonidos del inglés como nueva lengua con mayor facilidad si no reciben información visual mientras reciben la información auditiva, para así concentrar mayores recursos de atención y memoria auditiva. Ocho participantes ciegos y dieciséis videntes (ocho vendados y ocho no vendados durante los experimentos) serán seleccionados. Todos los participantes escucharán grabaciones en que se repiten frecuentemente 6 fonemas de consonantes en inglés. Luego, responderán a dos pruebas de discriminación auditiva: una en que escucharán pares de palabras y decidirán si son iguales o distintas, y otra en que harán lo mismo pero las grabaciones de las palabras que escucharán también tendrán ruido de fondo. Este estudio puede tener un impacto positivo en la manera de enseñar dicha lengua extranjera a personas con discapacidad visual, basándose en técnicas y actividades que se enfocan en sus capacidades superiores de audición.

EVALUACIÓN DE ASPECTOS ÉTICOS

El Comité ha evaluado los antecedentes presentados por la Investigadora Responsable. Se han revisado los objetivos de la investigación, su marco teórico y su metodología, estimándose que el proyecto está bien concebido y fundamentado en todos estos aspectos. Se considera, al mismo tiempo, que el proyecto tiene valor teórico porque permite aumentar el conocimiento de factores importantes que determinan el aprendizaje y la adquisición de patrones de conocimiento del idioma inglés mediante el recurso a un diseño experimental que contrasta la experiencia de personas videntes y no videntes. Esto podría contribuir al diseño y eventual implementación posterior de estrategias metodológicas para el desarrollo de nuevas modalidades curriculares de enseñanza y aprendizaje de la lengua inglesa, lo que tiene por sí mismo un alto valor en el contexto de los futuros desafíos que deberá enfrentar nuestro país en el proceso de creciente globalización y de incorporación a los nuevos patrones de desarrollo social, material y cultural.

Los riesgos de este proyecto están suficientemente atendidos en cada una de las intervenciones propuestas, sin que se pueda presumir una eventual lesión o menoscabo ni de la intimidad o privacidad de los sujetos, ni tampoco de sus derechos personales y profesionales. Se enfatiza que el proyecto comprende la participación de población vulnerable, que aparece suficientemente protegida por el diseño planteado y que se asegura en todo momento la confidencialidad de la información provista por los sujetos participantes. Ello queda manifiesto en forma debida en los documentos presentados por la investigadora para estos fines.

Por lo anteriormente expuesto, el Comité declara no tener reparos éticos con el proyecto, calificándolo como aprobado.

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Presidente
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Facultad de Filosofía y Humanidades
Universidad de Chile

Santiago de Chile, 24 de agosto de 2011.