Original Research Article

Study of the relationship between degree of handedness and cerebral lateralization for language using the Dichotic Speech Test

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Abstract

Background: Dichotic listening is a procedure in which both ears are stimulated simultaneously with different speech sounds and the listener is required to report what was heard. An Ear Advantage (EA) score is then calculated based on the responses. This test is used as a method of assessment of hemispheric lateralization for language. Language and handedness are closely related. Handedness is quantitatively assessed by Laterality Quotient (LQ) calculated using Edinburgh Handedness Inventory (EHI). **Aim:** The aim of this study was to examine the relationship between LQ and the magnitude of the EA scores for dichotic listening in right handed individuals. **Materials and Methods:** After outliers and anomalous results were removed, the total sample size was 150 right-handed subjects (79 males and 71 females aged between 18 to 35 years). Handedness was confirmed and quantified using the EHI which is a validated questionnaire consisting of 20 questions related to hand preference for certain uni-manual tasks. Handedness Consonant-Vowel (CV) syllables (Ba, Da, Ga, Ka, Pa, Ta), recorded in a uniform male voice and digitally mixed in pairs using the software Audacity®, were delivered in random order. The EA score was calculated. Statistical analysis was done using SPSS 20. **Results:** There was a significant positive correlation between LQ and EA (Pearson's $R=0.568$, $p<0.05$), with males having a stronger correlation. **Conclusion:** Our study revealed a positive correlation between LQ and EA implying that the stronger and more consistent the handedness, greater was the cerebral lateralization for language with this effect being higher in males.

Keywords: dichotic listening, dominance, handedness, lateralisation

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Introduction

Handedness is a unique characteristic of human beings and some higher primates. Similarly, language is also a property that is almost exclusive to human beings. Handedness and lateralization for language are closely related. Around 90% of the population is right handed; over 90% of right-handers and around 70-80% of left-handers have their language functions located at their left hemisphere.[1,2] The relationship between handedness and hemispheric dominance is well documented. But there are relatively few studies exploring the relationship between the degree of handedness and the magnitude of cerebral lateralization for language.

Handedness – Direction and Degree: Handedness is a reflection of lateralization of the nervous system and it does not pertain to just right or left handedness. It is a continuum, with 4% of the population being truly left handed, 30% mixed handed and 66% right handed.[2,3]Direction of handedness refers to left and right-handedness whereas degree of handedness refers to whether they are consistent or inconsistent.[4] The degree of handedness can further be quantified based on an index called Laterality Quotient (LQ) calculated from the Edinburgh Handedness Inventory.[5] The distinction between consistent and inconsistent handedness is based on the scores on the Edinburgh Handedness Inventory.[5] Inconsistent handedness is defined as handedness scores below 80.[4]

Lateralisation of Language and concept of Dominant Hemisphere: In the year 1981, Broca was the first to state that speech function was localized to the left frontal lobe.[6] It is customary to refer to the hemisphere where the language and speech functions are represented (Broca's and Wernicke's areas) as the dominant hemisphere. In most of the population the handedness usually corresponds to the dominant hemisphere ie., left hemisphere dominance in right-handers. So it was speculated that right hemisphere dominance must be present in lef-handers (Broca's rule).[1,6,7]But it soon became apparent that this was not always the case. Most of the left-handers also have left hemispheric dominance for language.[7] In the majority of the population, there is a strong left hemispheric dominance for spoken language, written language, handedness, mathematical skills, scientific skills and reasoning whereas strong right hemispheric dominance for visuo-spatial skills, music awareness, three dimensional awareness, art, insight and imagination. As a result, the convention nowadays is to use the terms 'categorical' for the dominant and *'representational'* for the non-dominant hemispheres.[8]

Dichotic Listening: Dichotic listening is a procedure in which, the two ears are stimulated simultaneously, with different speech sounds and the listener is required to report what was heard.[9]This is known as free recall method. This test is used as a method of assessment of hemispheric lateralization of language.[10]

Concept of 'Ear Advantage': The dichotic listening tests were first employed by Kimura in 1961 and she found that depending on the type of auditory stimulus that is presented, one ear perceives the signals better than the other. This has been termed as "ear advantage". The Ear Advantage (EA) score is calculated as the difference between the correct responses from the right and left ears using the formula $\{(R-L)/(R+L)\} \times 100$.Speech stimuli have generally been shown to have a right ear advantage (REA), i.e., perceived better in right ear, whereas for non-speech stimuli like melodies, a left ear advantage (LEA) has been found.[9–13]

Models proposed to explain REA: The structural model proposed by Kimura in 1961 and the attentional model proposed by Kinsbourne in 1970 explain Right Ear Advantage. According to the Structural Model was proposed by Kimura, impulses from the ears travel via both ipsilateral and contralateral pathways and reach the auditory cortex of both sides.[11]The two hemispheres also communicate with each other via the corpus callosum. But electrophysiological evidences suggest that the crossed auditory pathways are stronger than the uncrossed.[14,15] Hence, input to one ear is most strongly represented in the contralateral cerebral hemisphere. Also, Wernicke's area and Broca's area which are the areas for speech processing, are most commonly located in the left hemisphere.[16] The input to the left ear reaches the right hemisphere and has to be transferred via the corpus callosum to the language processing centres in the left hemisphere. Kimura hypothesized that this resulted in a slight delay in speech processing, resulting in REA.[11,12]According to the Attentional Model, the left hemisphere anticipates the incoming auditory signals which is called the priming effect. [17] This anticipation is automatic and results in a bias favouring the left hemisphere and therefore the right ear. This allows acoustic information in the right ear to be processed faster. Directing attention to the right ear increases the magnitude of the REA, whilst directing attention to the left ear can decrease the magnitude of the REA, or cause a shift to a LEA.[18,19]

Past research has shown differences in the ear advantage between right and left-handers. However the concept of consistent and inconsistent handedness, within the right handed group has rarely been explored.[20,21] Moreover, it is important to note that many past studies have used dichotic stimuli consisting of sentences and multiple digits. Such stimuli are dependent on the linguistic knowledge of the subjects. Dichotic listening is a non-invasive technique used to assess brain lateralization and asymmetry when processing auditory signal. We were interested in further investigating changes in dichotic listening performance depending on the degree of handedness by using nonsense Consonant-Vowel stimuli. We intended using single-syllable nonsense words consisting of a consonant and a vowel. These stimuli were chosen because they can evaluate auditory processing without the need for the subject to understand the particular language in which the test is administered. The aim of this study was to examine the relationship between the degree of handedness and the magnitude of the EA in right handed individuals.

Materials and Methods

Participants: Participation was voluntary and informed consent was obtained. The study population consisted of 150 healthy individuals (79 males, 71 females, aged between 18 to 35 years). Volunteers were chosen from the general population. Edinburgh Handedness Inventory was used and Laterality Quotient was calculated to assess the handedness. The EHI is a simple and brief method of assessing handedness on a quantitative scale. [5] It is based on a series of questions regarding the hand preference for various common activities. The inventory includes questions about writing, drawing, throwing, using a toothbrush, using scissors, using a spoon, using a knife, using a broom, striking a matchstick, and opening the lid of a box. [5] Subjects are asked to respond by checking the appropriate hand for each activity. From the responses, an index called the laterality quotient (LQ) is calculated by the formula $LQ = (L – R) / (L + R)$. [5] Accordingly, subjects with $LQ < -50$ are considered left-handers, $LQ > +50$ are classified as right-handers and those for whom the LQ is between -50 to +50 show mixed handedness.[5] The absolute value of the LQ score also determines the degree of handedness.[5] All the participants were screened for hearing loss using tuning fork tests and pure tone audiometry. Montreal Cognitive Assessment[22]was used to establish cognitive function and memory for each participant before completing the dichotic listening task. Participants who scored above the cut-off level of 26 points were only included. Left-handers, those with hearing loss, cognitive disturbances, history of neurological disease or mental illness were excluded from the study.

Stimulus: The syllables used for the test were consonant-vowel (CV) combinations of stop consonants (B, D, G, K, P, T) and the vowel ‘A’. The use of such a stimulus has been validated by previous studies.[9,11–13,18,19,23]An online text-to-speech converter was used to phonate the syllables in a uniform male voice. The sound editing software Audacity® was used to edit and mix the stimuli in dichotic pairs digitally. The onset of the consonants from the two sides was temporally matched so that they started at exactly the same time. The six CV syllables were paired to produce all the 30 possible dichotic combinations. The dichotic stimuli were delivered through noise-cancelling headphones connected to an audiometer. The loudness of delivery was kept constant. The stimuli were presented in random order with an interval of 5 seconds in between.

Procedure: Informed consent was obtained from all participants. Institutional ethical committee approval was obtained. A detailed socio-demographic history was taken and a thorough general examination was done. The Edinburgh Handedness Inventory and the Montreal Cognitive Assessment were administered. Ear examination was done to rule out wax and to ensure the normalcy of auditory canal and tympanic membrane. Hearing loss was screened using tuning fork tests and pure tone audiometry performed in a sound treated room. Instructions were provided on the dichotic listening task. The participants were made to sit comfortably in a sound treated room and the stimuli were delivered through a noise cancelling stereo headset connected to an audiometer. The loudness of sound delivery was kept constant. The subjects were not informed that two different stimuli were presented to both the ears. The syllables were presented in a random order and the subjects were asked to repeat loudly what they heard.

Statistical Analysis: All the information gathered regarding the selected subjects was documented in a spreadsheet by the observer. Statistical Package for the Social Sciences (SPSS), version 20 was used for analysis of data. Using this software ranges, frequencies, percentages, means and standard deviations were calculated. Student’s t-test was used for comparison of means between the gender groups and for comparison between consistent and inconsistent handedness groups. Pearson’s correlation coefficient was used to analyze the relationship between laterality quotient (LQ) and ear advantage (EA).

Results

This study was conducted to examine the relationship between LQ and the magnitude of the EA scores for dichotic listening in right handed individuals. Table 1 shows the he descriptive statistics of the participants.

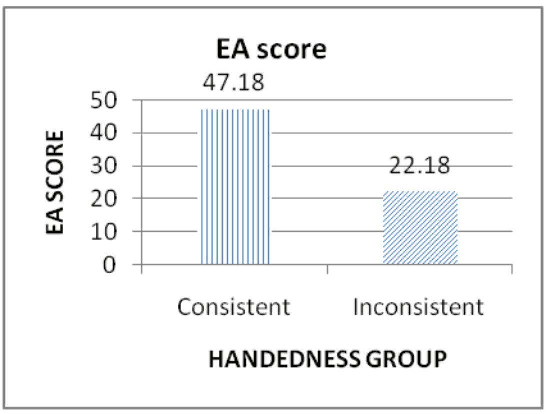
Table 1: Means and Standard deviations of Age, LQ and EA scores

Variable	Total (n=150)	Males (n=79)	Females (n=71)
Age (years)	26.45 ± 5.15	27.44 ± 5.24	25.172 ± 5.33
Laterality quotient	80.70 ± 15.49	86.69 ± 12.44	74.04 ± 15.91
Ea scores	37.68 ± 22.72	36.95 ± 23.13	38.49 ± 22.39

LQ = Laterality Quotient; EA = Ear Advantage

Differences between consistent and inconsistent handedness groups: As shown in Figure 1, the consistent right-handers showed a higher right ear advantage when compared to inconsistent-handers ($p<0.05$).

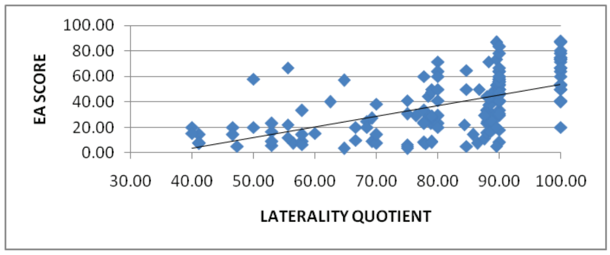
Figure 1: Comparison of EA between consistent and inconsistent handedness groups



Student's t test showed that consistent right-handers show stronger right ear advantage. p<0.05 was taken as significant. EA = Ear Advantage

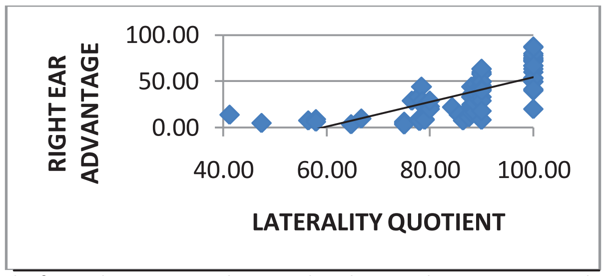
Correlation between Laterality Quotient and Right Ear Advantage: There was significant positive correlation between LQ and EA (Figure 2). The overall Pearson coefficient was 0.568 ($p<0.05$). Both males and females showed a positive correlation with the Pearson's coefficient being 0.714 ($p<0.05$) for males and 0.581 ($p<0.01$) for females as shown in Figure 3 and Figure 4 respectively. The correlation was stronger in males compared to females.

Figure 2: Overall correlation between LQ and EA



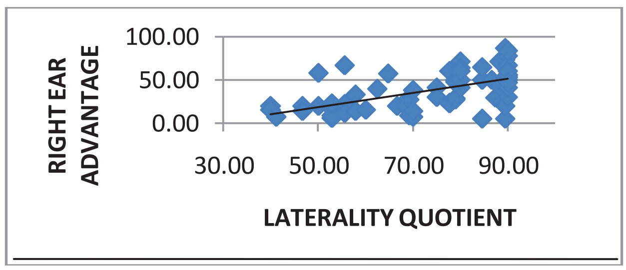
The figure shows a significant and linear increase in the EA score as the degree of handedness increases. Pearsons coefficient (R) = 0.568, p<0.05 was taken as significant.

Figure 3: Correlation between LQ and EA for males



The figure demonstrates that in males, there is a linear increase in the EA score as the degree of handedness increases. Pearson's coefficient (R) = 0.714, p<0.05.

Figure 4: Correlation between LQ and EA for females



In the female group, there is a linear increase in the EA score as the degree of handedness increases. Pearson's coefficient (R) = 0.581, p<0.05.

Discussion

In the present study, all the subjects showed right ear advantage. Since all subjects were right handed, this finding was not unexpected. This can be explained by the structural and attentional models mentioned earlier.

Also, there was a significant positive correlation between handedness (assessed by LQ) and language lateralization. This is similar to the findings of Bourne, who showed a linear positive relationship between degree of handedness and degree of cerebral lateralization.[24] Groen *et al.* measured handedness dichotomously and found significant correlations between cerebral lateralization for language and handedness in children.[25] However, functional MRI studies by Van der Haegen *et al.* [26] showed that at the group level the direction of the ear advantage in dichotic listening was predicted by language dominance but not by hand preference.

This study also demonstrated a gender difference, with males showing a stronger correlation than females indicating that men are more strongly lateralized than women. This has been previously demonstrated by Iwabuchi and Kirk.[27]

Another parameter studied was the difference between consistent and inconsistent handedness groups. The consistent right-handers showed a stronger lateralization compared to inconsistent right-handers. These results are in accordance with the findings of Prichard *et al.* [4] that inconsistent handedness is associated with increased inter-hemispheric interaction.

In summary, it is evident from the above discussion that the stronger and more consistent right-handers show a stronger right ear advantage and this effect is demonstrated more clearly in males when compared to females. The plausible explanation for this phenomenon is that inconsistent-handers and females have a more functionally symmetrical brain and greater inter-hemispheric interactions. Hence lateralization is less strongly demonstrated.

Limitations of the study and future scope: All Participants in this study were right-handed and there was no attempt to recruit left-handed adults. Thus only the characteristics of right ear advantage could be studied. Future studies can recruit consistent and inconsistent-handers in the left handed population too. Even though all the participants were screened for hearing loss, since the overall intensity delivered through the headphones was the same for every participant, individual variations in hearing were not accounted for. The study used only Consonant Vowel syllables as stimuli. This does not make room for exploring the hemispheric lateralization taking place for other auditory signals like speech sounds, music, tones etc.

The clinical implication of the current study is the use of dichotic listening as a means of diagnosing auditory processing difficulties. Another clinical implication is the use of dichotic listening to explore laterality and cognitive impairments in clinical populations with diseases like schizophrenia and other mental illnesses. To use it as a diagnostic test, the factors that may cause normal variations have to be first studied, one of which is handedness, which has been explored in the present study.

Conclusion

Our study revealed that the degree of handedness was directly proportional to the cerebral lateralization. There have been many studies regarding the relationship between direction of handedness and lateralization of language. This study further explores the effect of the degree of handedness within one group. This study can be further expanded by including left handed subjects, using various types of dichotic stimuli other than CV sounds, and studying other functions that are lateralized to the right hemisphere like music, emotions, facial recognition and many more.

Acknowledgment: Nil

Conflicts of interests: Nil

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