

Hemispheric Dominance and Cell Phone Use

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Importance: A thorough understanding of why we hold a cell phone to a particular ear may be of importance when studying the impact of cell phone safety.

Objective: To determine if there is an obvious association between sidedness of cell phone use and auditory hemispheric dominance (AHD) or language hemispheric dominance (LHD). It is known that 70% to 95% of the population are right-handed, and of these, 96% have left-brain LHD. We have observed that most people use their cell phones in their right ear.

Design: An Internet survey was e-mailed to individuals through surveymonkey.com. The survey used a modified Edinburgh Handedness Inventory protocol. Sample questions surveyed which hand was used to write with, whether the right or left ear was used for phone conversations, as well as whether a brain tumor was present.

Setting: General community.

Participants: An Internet survey was randomly e-mailed to 5000 individuals selected from an otology online group, patients undergoing Wada testing and functional magnetic resonance imaging, as well as persons on the university listserv, of which 717 surveys were completed.

Main Outcome and Measure: Determination of hemispheric dominance based on preferred ear for cell phone use.

Results: A total of 717 surveys were returned. Ninety percent of the respondents were right handed, and 9% were left handed. Sixty-eight percent of the right-handed people used the cell phone in their right ear, 25% in the left ear, and 7% had no preference. Seventy-two of the left-handed respondents used their left ear, 23% used their right ear, and 5% had no preference. Cell phone use averaged 540 minutes per month over the past 9 years.

Conclusions and Relevance: An association exists between hand dominance laterality of cell phone use (73%) and our ability to predict hemispheric dominance. Most right-handed people have left-brain LHD and use their cell phone in their right ear. Similarly, most left-handed people use their cell phone in their left ear. Our study suggests that AHD may differ from LHD owing to the difference in handedness and cell phone ear use. Literature suggests a possible relationship between cell phone use and cancer. The fact that few tumors were identified in this population does not rule out an association.

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HEMISPHERIC DOMINANCE has been a major topic in brain research for over a century. The purpose of this study is to determine if there is an association between sidedness of cell phone use and the auditory hemispheric dominance (AHD) or language hemispheric dominance (LHD). Given the preponderance of left-brain-dominant people and the first author's (M.D.S.) observation that most people use their cell phone on their right ear, we suspect that there may be an association. An important aspect to consider is why people pick a certain hand to use their cell phone: is it related to motor dominance (MD), AHD, LHD, the logic of holding the phone up to the left ear and using their right hand

to write, an asymmetric hearing loss, or some other reason?

Over the years, several tests, including the Wada test,¹ functional magnetic resonance imaging (fMRI),² positron emission tomography,³ and magnetoencephalographic⁴ scans, have been used to assess brain functionality or areas of increased cortical activity. Language dominance refers to the hemisphere of the brain that is primarily responsible for language development, which is the left hemisphere in most people. Most people with left-brain LHD are right-handed. This was shown in 1977, when Rasmussen and Milner⁵ compared handedness and the effects of early brain injury to language dominance. Of the 396 patients with epilepsy in their study, 96% of right-handed

people and 70% of left-handed people showed left hemispheric dominance for simple speech functions. Several studies since then have shown similar results. Some showed that incidence of atypical language dominance depends not only on the direction but also on the degree of handedness.⁶ Pujol et al⁷ used fMRI data to show functional language lateralization to the left hemisphere in right-handed individuals. Left-handed individuals showed left-brain LHD as well but not as consistently. Knecht et al⁸ found that the distribution of LHD varied with the degree of handedness. The more right-handed the individuals, the lower the relative incidence of right-brain LHD and vice versa. Interestingly, Pointer⁹ showed a direct correlation with handedness and eye dominance (ocular or sighting) in right-handed children. In his study, the left-handed individuals were also more likely to display right eye preference. Marzoli and Tommasi¹⁰ performed 3 observational studies to determine ear preference. Their study found that 58% of participants responded positively to a request if the request were made in their right ear, and they also found that 72% of the time a person will present their right ear to hear what someone is saying. This finding is consistent with the right ear preference found in both laboratory studies and questionnaires. Marzoli and Tommasi¹⁰ also demonstrated that the side bias is spontaneously displayed outside the laboratory.

Historically, the percentage of right-handed persons in the general population has been estimated at 70% to 90%.¹¹ The Edinburgh Handedness Inventory (EHI), developed in 1971, is a common tool used to assess handedness.¹² In the EHI handedness protocol, individuals are asked which hand they use for many common tasks, including combing their hair, playing sports, brushing their teeth, and so on. The laterality of the EHI tasks is used to predict the apparent hemisphere dominant for language based on which hand they use the most

Cell phones have become an integral part of daily life, and our general observation has been that most people have a tendency to hold their cell phone preferentially to the right ear. This practice seems illogical given the fact that it is a bit challenging to listen with the right ear and take notes with the right hand. The first author is left-handed and listens with his left ear, which also is seemingly illogical despite symmetric hearing. It was this observation that led to the observation that most people are using cell phones in their right ear and the majority of the population is right-handed. It seems likely that handedness with cell phones will parallel handedness with performance of EHI tasks and may be predictive of overall hemispheric dominance. It is also possible that cell phone sidedness is related to perceived AHD rather than to MD or LHD. Petit et al¹³ showed that the right hemisphere is preferentially engaged in auditory attentiveness. Most likely, it is a combination of these factors that determines the ear individuals prefer to use for their cell phone. Given the relative ease of using handedness as a proxy for language dominance, as opposed to determining auditory dominance, we aimed to establish a correlation between language dominance and sidedness of cell phone

Survey for Cell Phone Study

Name: _____

Date of Birth: ____/____/____ Age: ____ Sex: ____

Month/day/year

Please indicate which hand you would prefer to use for each of the following activities by putting + in the appropriate column. Where the preference is so strong that you would rarely use the other hand or ear put + +. If in any case you are really indifferent, put + in both columns.

Please try to answer all the questions, and only leave a blank if you have no experience at all with the object or task.

	Right	Left
Writing		
Throwing		
Scissors		
Toothbrush		
Knife (without fork)		
Broom (upper hand)		
Which ear do you use to answer the cell phone?		

Do you perceive your hearing to be the same in both ears? Y N
If no, briefly explain -

Do you think that the phone sounds better in your left or right ear, ie, do you have a preference because you think it seems to have more clarity in the right or left ear? Y N

How do you primarily listen to your phone?
☐ Hands-free ☐ Phone directly to ear

How many years have you used a cell phone?

Have you ever had a tumor of the head and neck region? Y N
If yes, what was the location (left or right side) and type if known (meningioma, glioma, etc)?

Have you had an MRI of your head within the past five years? Y N
If yes, what were the results of the MRI?

Figure 1. Internet survey sent to all participants in the study. Adapted from Oldfield¹² with permission from Elsevier. <http://www.sciencedirect.com/science/article/pii/S0028393271900674>.

use. It is plausible that if this association has statistical merit, then the simple question of which ear a person uses for the cell phone (provided their hearing is the same in both ears) may provide information not only on language hemispheric function, but also on auditory hemispheric function.

METHODS

A 1-page Internet survey (**Figure 1**) was e-mailed to 5000 people through surveymonkey.com. The survey asked basic demographic information, including sex and age. A modification of The EHI protocol was used to evaluate handedness. Individuals were asked to indicate which hand they prefer to use in performing the following tasks: writing, throwing, using scissors, brushing teeth, holding a knife, holding a broom, and holding a cell phone. The survey also asked about any hearing loss or perceived hearing loss as well as history of brain tumors. Finally, it inquired about the frequency and extent of cell phone use, both in terms of how many minutes a month the cell phone is used and how many years the individual had had a cell phone. The Henry Ford Hospital (Detroit, Michigan) internal review board approved this study.

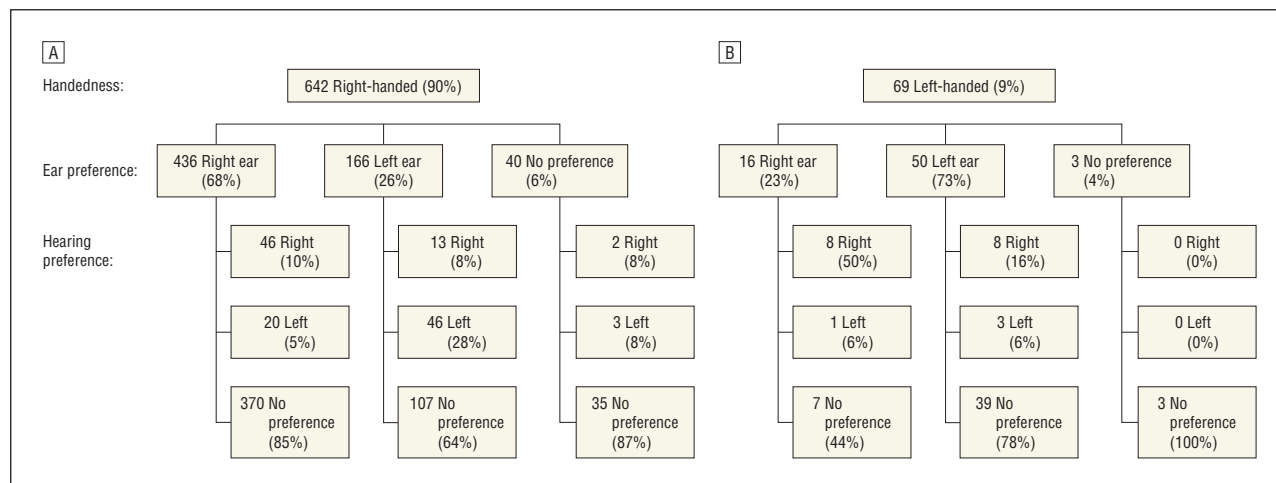


Figure 2. Distribution of participants based on phone-to-ear preference and perceived relative hearing acuity. A, Right-handed participants; B, left-handed participants.

Respondents were recruited from an otology online group, patients undergoing Wada testing and fMRI for noninvasive localization purposes, persons on the Wayne State School of Medicine (Detroit) listserv, and persons who could be contacted by any of the authors. Five thousand potential participants were contacted via e-mail, and their survey information was collected on the Internet using surveymonkey.com.

The study addresses using cell phone handedness as a relatively simple determinant for LHD. The primary hypothesis is that people will use their dominant hand to place their cell phone next to their LHD ear. In the other words, a person will use a cell phone with his or her right ear if he or she is right-handed. A binomial exact test was applied for testing this hypothesis.

RESULTS

The first e-mailing of surveys was sent to approximately 3000 people, and we received a few responses. A second e-mailing was sent to more than 2000 people as well as repeated e-mailing to the nonresponders to encourage further response, resulting in a cumulative total of 5000 people being surveyed from both the mailings. We received responses from 14% of the individuals pooled, totaling 717 surveys. Of the population that returned the surveys, 5 respondents (7%) did not enter their sex, 42% were male, and 57% were female. Before performing the statistical analyses, the distribution of age and sex were verified to confirm sample population. The mean (SD) age was 41 (16) years for people returning the survey. Respondents were more likely to be female (58%) than male ($P < .001$).

The data demonstrated that 90% of the respondents (642 of 717) were right-handed, 9% (69) were left-handed, and 1% (6) were ambidextrous. On average, people used their cell phones for 540 minutes per month. Surveys reported that the average length of time a respondent had had a cell phone was 9.07 years, with responses ranging from 1.5 to 20.0 years.

Of the surveyed respondents (**Figure 2**) who were right-handed (90%) based on the EHI protocol, 68% held the cell phone to their right ear, 26% to the left, and 6% used either ear. Of the surveyed respondents who were

left-handed (9%) based on the EHI protocol, 73% used the cell phone to their left ear, 23% to the right, and 4% used either ear.

Statistical analysis was performed using a binomial exact test. To simplify the analysis, we excluded respondents who had no preference for ear or hand use, so the total survey responses included in the final analysis were 668. Most respondents were right-handed (90%). The percentage of respondents who used their dominant hand-side ear with their cell phone is significantly larger than 50% (73% [486 of 668]; 95% CI, 69%-76%; $P < .001$).

One question that we addressed in the survey was if individuals believed they had better hearing in a specific ear. It is interesting to note that of the respondents who held their cell phone to their right ear, only 11% felt that their hearing was better in their right ear. In fact, 5% of them actually believed that their hearing was better in their left ear, and the remaining 85% did not think there was a difference in their hearing in either ear. Of the respondents who were right-handed and used their left ear to talk on the cell phone, 28% believed that their hearing was better in the left ear, 8% of them believed their hearing was better in the right ear, and most (64%) did not think there was a difference. Of the left-handed, left-ear-using respondents, 16% felt that their hearing was actually better in their right ear, 6% believed their hearing was better in their left ear, and most (78%) did not think there was a difference in their hearing.

Based on our analysis, we found that if a person does not have a hearing difference the probability of using the same side ear as the dominant hand (85% for left-handed and 79% for right-handed) is not significantly different regardless of handedness ($P = .34$). The overall probability of using the dominant hand-side ear is 80% (76% and 83% for left-handedness and right-handedness, respectively).

If a person has a hearing difference, the probabilities of using dominant hand-side ear are not different regardless of handedness (53% and 50% for left- and right-handedness, respectively; $P = .81$). The overall probability of using the dominant hand-side ear is 50% (42% and 58% for left- and right-handedness, respectively).

For patients who reported better hearing on the left, the proportions of using the dominant hand-side ear with their cell phone are 67% and 30% for left-handed and right-handed respondents, respectively. The overall proportion is 31%.

For those patients who reported better hearing on the right, the proportions of using the dominant hand-side ear with a cell phone are 50% and 75% for left-handed and right-handed people, respectively. The overall proportion is 70%.

Of the surveyed respondents who were ambidextrous based on the EHI protocol (1%), 50% used the cell phone in their left ear, 50% in the right, and none documented using either ear preferentially.

Fifty respondents of the total 717 had had neuroimaging studies done at some point in the past. Sixteen of them had an identified tumor in the head and neck region. These included benign tumors like thyroid nodules, hemangiomas, and lipomas. Of these 16 people with a tumor history, 8 people did not specify laterality, and 2 people had pituitary tumors (which cannot be lateralized). Of the remaining 6 people, 3 (2 of whom used their cell phones on the left side) had left-sided tumors, and the remaining 3 (all of whom used their cell phones on their right side) had right-sided tumors.

DISCUSSION

Our questionnaire focused on inferring handedness via a modified EHI handedness protocol and obtaining information regarding cell phone use. Based on the responses, we set out to determine if there was a correlation between hand preference, laterality of cell phone use, and LHD determined by a modified EHI. Since prior research shows that handedness has a definite correlation to LHD, we believe that by demonstrating an association between handedness and laterality of cell phone use, logically there is a correlation between LHD and cell phone use laterality.

Our data indicated that most people perform their activities of daily living using their right hand. Of the right-handed people, most held their cell phones to their right ear, either owing to motor preference of using their right hand or because of an aspect of auditory dominance, a finding that is consistent with those of observational studies that most people prefer to listen with their right ear.¹⁰ Demographics had little bearing on these results. We saw similar trends with people who were left-handed and used their left ear to speak on their cell phones.

It is interesting to note, however, that there was a subset of people who used their left ear for their cell phone although they were right-handed and still thought their hearing was better in their right ear. There are similar numbers with people who are left-handed, used their right ear to talk on their cell phones, and had better hearing with their left ear. A few respondents commented that the reason for using their nondominant hand was related to the fact that they frequently use their cell phone while driving or performing other tasks, which require their dominant hand to be free. In today's busy multitasking society, these types of factors may skew the re-

lationship between laterality of cell phone use and handedness because for various reasons people are forcing themselves to perform tasks in ways that are not necessarily the most natural.

Although our results are interesting and thought provoking, there were some limitations in this study. First, AHD is a contributory factor to the laterality of cell phone use that we could not take into account based on the survey data. Second, we did not have an even representation of age, sex, and other demographic aspects in our surveyed population. With new advents in technology, there are several Bluetooth devices and headphones that have not been accounted for in these numbers. Finally, none of these people had undergone any audiometric testing to support perceived hearing discrepancies between the left and right ears.

Despite these limitations, we had an overwhelming set of people with a positive association between handedness and laterality of cell phone use. Most right-handed, left hemispheric-dominant people chose to talk with their cell phone to their right ear. Similarly, most left-handed, right hemispheric-dominant people chose to talk with their cell phone to their left ear. There were a few exceptions: a few ambidextrous users and a few people who were aware of some hearing difficulty that could have changed their natural use. Controlling for ambidextrous users, bilateral cell phone users, and users with hearing disorders, most right-handed people preferred to use their cell phone on their right ear, and most left-handed people preferred to use their cell phone on their left ear.

Although cell phone use is now nearly ubiquitous, several questions about its implications remain unanswered. Controversy regarding the adverse effects of cell phone use is becoming more prevalent. The first step to gain a deeper understanding of this issue is to study why people choose to use their cell phone on one ear vs another. The logic of which hand to hold the cell phone with may just be related to convenience. You may hold the cell phone with your left hand if you need to write something down with your right hand or vice versa if you are left-handed. Although these details might seem intuitive and superfluous, a thorough understanding of why we hold a cell phone to a particular ear may be of importance when studying the impact of cell phone safety. With further studies along these lines we can examine the adverse effects that may have an impact on cell phone users. Owing to the very short history of mobile telephony, knowledge of the long-term effects of cell phones is still in its infancy. It is crucial to document and conduct more clinical trials to evaluate the implications of hemispheric dominance and auditory dominance as well as evaluate the long-term safety of cell phone use.

These results are relevant to a recent controversial topic in popular literature: the constant debate over whether cell phone use is causatively related to the development of brain and head and neck tumors. There is currently no strong evidence to support any such association, although it seems that most cell phone users and scientists suspect such a relationship on some level. Although certainly preliminary and limited, our findings would suggest that, if cell phone use was directly associated with tumorigenesis, most of these tumors in the

population as a whole would occur on the right side, since most cell phone users use their right ear primarily. In our survey, 50 of our respondents had undergone neuroimaging studies; of these studies, tumors were identified in only 6 (3 in the right hemisphere and 3 in the left hemisphere). These results were too small for any statistical analysis. It would be interesting to determine if the incidence of any particular type of tumor has shown an increasing predilection to the right side over the past 20 years (since cell phones have been popularized), as this would suggest a possible association.

In conclusion, through the work conducted in this study we were able to demonstrate that there is a correlation between hemispheric brain dominance, determined by modified EHI, and laterality of cell phone use. The probability of the dominant hand-side ear for cell phone use (73%) is significantly larger than average (50%) ($P < .001$). Having a hearing difference does have an impact on ear preference. First, persons who hear better in their left ear are more likely to use the left ear regardless of handedness. Second, persons who hear equally well in both ears are more likely to use their dominant hand-side ear and the same-side ear. Third, for those who hear better in the right ear, the probability of using the dominant hand side with a cell phone is more than 50%.

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script for important intellectual content: Seidman and Bowyer. *Statistical analysis:* Seidman and Shah. *Administrative, technical, and material support:* Seidman and Bowyer. *Study supervision:* Seidman.

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