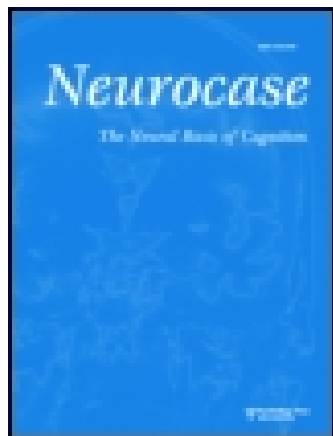


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Sound stimulus qualities and severe auditory neglect

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Sound stimulus qualities and severe auditory neglect

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We report the case of a patient who developed severe left auditory neglect following a cerebral vascular accident with infarction of areas in the frontal, temporal, and parietal lobes of the right hemisphere. The severity of neglect was documented using pure tones, speech, and environmental stimuli, administered binaurally and dichotically. Acuity examination and unilateral presentation of stimuli allowed exclusion of primary hearing deficit. A dichotic word test was used to evaluate the effects of implicit and explicit cuing. Contrary to our expectations, implicit semantic cues did not attenuate the neglect, and explicit manipulation of sound volume, consisting of increasing the volume in the left ear while maintaining right ear volume at a minimum did not increase the perception of neglected stimuli on the left. Explicit commands to selectively attend to the left ear also failed to improve left ear perception. These findings suggest that some manifestations of auditory neglect are not affected by attributes of the sound stimulus. Furthermore, the finding that manipulation of sound volume had no influence on the neglect supports the hypothesis that sound volume is perceived by the brain as encoded information and not as a simple analogue representation of sound magnitude mediated by variance in the firing rate of neurons in the auditory nerve.

Keywords: Auditory neglect; Hearing; Sound volume; Sensory impairment; Dichotic listening; Auditory perception.

INTRODUCTION

A number of studies have demonstrated that explicit and implicit cues can be used to modify the visual neglect associated with lesions of the right hemisphere (Audet, Bub & Lecours, 1991; Kartsounis & Warrington, 1989; Rizzolatti & Berti, 1993; Seron, Coyette & Bruyer, 1989). Explicit cues, such as verbal commands for the patient to attend to the neglected side, can serve to modify behavior so that neglect is decreased. Robertson, Halligan, and Marshall (1993) reported that one patient's spatial neglect was improved by placing a buzzer on his left arm that would cue him to look left every 5–20 s. They also reported results of rehabilitation programs that have effectively ameliorated visual neglect of written material by placing a solid red line in the left margin, and instructing the patient to find the red line before beginning to read each sentence.

Implicit cues are an intrinsic aspect of the neglected stimulus that facilitate awareness of the neglected side. For example, Seron et al. (1989) found that when neglecting subjects were shown an incomplete picture, they were more likely to observe left-sided details on subsequent, more complete presentations of the same picture, if the item was ambiguous and could not be clearly identified by just the right half of the picture. They proposed that the ambiguity of the incomplete picture cued the neglecting individual to scan further left in order to gain information to help identify the picture. Kartsounis and Warrington (1989) found that a variety of implicit cues decreased visual neglect. Overlapping objects, interactive pictures, and grammatically correct sentences were less neglected than similar stimuli without the implicit cue, such as non-interactive pictures and random word strings.

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Recently, we demonstrated that semantic implicit cues attenuate auditory neglect (Coleman & Williams, 2006). Semantically-related words, such as synonyms, and categorically-related words were presented dichotically to subjects with severe auditory neglect caused by a lesion of the right hemisphere. When words in a dichotic pair were semantically-related, the subjects were more likely to hear the word in the neglecting ear.

We report the case of a patient (W.D.), who after a stroke involving the distribution of the right cerebral artery, suffered profound left auditory neglect. The patient was evaluated as a subject for a protocol examining the effect of semantic cues on auditory neglect (Coleman & Williams, 2006). However, since his neglect was very severe, additional studies were conducted to test whether explicit cues, such as volume changes and verbal commands, could attenuate the neglect. The degree of auditory neglect was quantified using a recently developed auditory neglect test battery, and systematic attempts were made to attenuate the neglect by use of both implicit and explicit cues.

CASE REPORT

W.D. was a 63-year-old, right-handed, African-American man with 7 years of education. His previous medical history was significant for hypertension, diabetes mellitus, and heart disease that was treated with coronary artery bypass. On March 4, 1994 he presented to the emergency room, accompanied by his daughter, 24 h after new onset of left side weakness, facial droop, and slurred speech. He had apparently fallen earlier in the week but,

according to his daughter, he had refused to seek medical care and was then able to walk. She reported that he refused medications. The physical exam at admission found a pulse of 100 and blood pressure of 116/89. He was alert and oriented to person and place, slightly agitated, and exhibiting upper and lower left extremity weakness, left ptosis, and dysarthria. A CT scan performed at the time of admission showed acute infarct in the right posterior frontal, parietal, and temporal lobes (Figure 1). The cerebral cortex and white matter were involved, and some mass effect on the right lateral ventricle was apparent, but without midline shift. There was one small area of old infarction in the right Globus Pallidus. Real-time Duplex Ultrasound of the carotid arteries showed 99% occlusion of the right internal carotid artery and 40–59% stenosis of the left internal carotid artery.

During his hospital stay W.D. had dysphagia and was generally lethargic. The echocardiogram showed enlarged left ventricle and sclerosis of the mitral and aortic valves. Following 10 days in the acute care hospital, he was transferred to a rehabilitation hospital where he was examined for the present study.

Evaluation with the Mini Mental Status Exam at the time of the present study found W.D. to be oriented to person, place, and time. He was severely impaired in copying simple designs. Overall, he was noted to have flat affect and poor spontaneous speech. He demonstrated anosodiaphoria regarding his left arm, saying that he had ‘no problem’ with it, and at an initial evaluation denied that it belonged to him. On tests of executive function he demonstrated severe verbal and motor perseverations. He produced only three words on a word list generation task, the Controlled Oral Word Association Test (COWA;

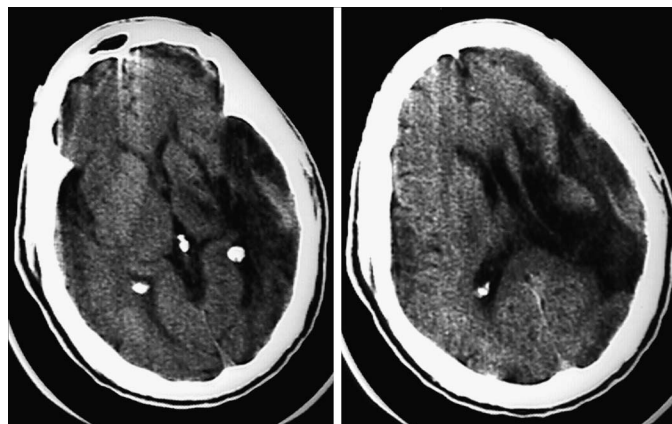


Figure 1. CT scan depicting a large infarction in the right cerebral hemisphere.

Spreen, 1991), and was impaired when requested to generate a story about a picture. Although visual-constructional abilities were deficient, a visual memory task from the Memory Assessment Scales (MAS; Williams, 1991), requiring recognition of a series of designs after a delay, was above average. Also, basic language skills, such as sentence repetition and following simple commands were within normal limits.

Difficulty dressing the left side of his body, failing to shave the left cheek, and not pointing to the left when commanded to do so, were consistent with severe left hemispatial neglect. Only the extreme right targets were canceled on an object cancellation task. Evaluation of auditory extinction with standard clinical methods, using bilateral finger rubbing, found significant left side auditory extinction; W.D. had 100% Left ear errors and 25% errors in the Right ear.

AUDITORY TESTS

The Test of Auditory Perception (TAP; Williams, 1990) was used to assess acuity and neglect. The TAP is a computer program that allows the user to administer a wide array of monaural, binaural and dichotic sounds. The acuity screening consists of six levels of pure tones (200–5000 Hz) presented at increasingly higher decibel levels. The neglect section of the TAP includes bilateral pure tones and words, environmental sounds, and dichotic words. The acuity and neglect subtests of the TAP are listed below.

Acuity testing. The primary purpose of the acuity section was to establish a comfortable decibel level for listening, insure that subjects will be able to perceive the stimuli, and confirm that hearing acuity is approximately equivalent between the ears. The acuity testing for this study consisted of four sets of randomly presented right/left, 1000 Hz tones, with six presentations (three right, three left) per set. Tones at 1000 Hz were chosen since this is within the frequency range of the human voice and 1000 Hz tones were used for the Tonal Neglect subtest. The tones were played at approximately 40 Db for the first set and increased by 20 Db for each consecutive set played. The spoken word 'Baseball' was also played unilaterally to the left and right ear during each set to insure that words were accurately perceived at the incremental volume settings.

Pure tone neglect. This subtest consists of 26 trials of 1000 Hz tones. Sixteen trials are unilateral

presentations of the tone (eight left, eight right) and 10 are bilateral simultaneous presentations. The first eight trials are unilateral stimuli only, presented left or right randomly, and the last 16 trials contain both unilateral and bilateral stimuli, again randomly ordered. The unilateral stimuli establish the capacity for monaural perception of the stimuli and ability to reliably report left/right orientation. The bilateral simultaneous stimuli are used to measure the presence and severity of extinction and neglect. A bilateral stimulus is scored as neglected when it is reported as occurring only in one ear. If the subject reports hearing nothing in either ear, it is scored as a failed item but not as neglected. Reasons for hearing no sound may include poor acuity, inconsistent concentration, confusion, or interference from outside sounds. The degree of neglect was calculated as a percentage of the 10 bilateral items perceived as occurring unilaterally. For example, if three stimuli were perceived as bilateral and seven stimuli were perceived as occurring only in the right ear, then the subject would have 70% neglect of the left ear.

Verbal neglect. This subtest is exactly the same as the Pure Tone subtest, except that the tonal stimuli are replaced by a single word spoken by a male voice. In this test, the word 'Cat', was played either unilaterally or bilaterally.

Environmental sound neglect. Ten environmental stimuli, such as a baby crying, a running lawn mower and water running, are played unilaterally and dichotically. The first 10 presentations are unilateral, each different stimulus is played once, and the other 16 are a random presentation of unilateral and dichotic stimuli. The 10 stimuli are played in random order during the initial unilateral section. For the dichotic presentations, the sounds are randomly paired with each other, with no combination occurring more than once, and each stimulus is played twice over the 10 trials. The participant was requested to report the ear in which they hear the stimuli. Degree of neglect was calculated in the same manner as with the first two subtests.

Bilateral environmental sounds. The bilateral environmental test consisted of 16 stimuli (10 bilateral, six unilateral). The same 10 sounds were used as stimuli, eliminating the need for the 10 preliminary unilateral trials, but instead of sounds being played dichotically (i.e., different sounds being paired for dichotic presentation), each sound was played bilaterally one time. In other words, the sounds were a manner similar to the Tonal and Verbal Neglect Tests.

Displaced spondaic words. Spondaic words have two syllables, with equal stress on each syllable. Twenty trials were presented. Each trial contains four words. Two words were played to the right ear and two to the left ear. The two words played to the right ear form a compound spondaic word (e.g., base-ball), as do the two words in the left channel (e.g., high-chair). The words were offset so that two of the simple words are dichotic and two are unilateral. For example, the word 'base' was played unilaterally in the right ear, after which 'ball' and 'high' were played simultaneously ('ball' in the right ear, 'high' in the left ear); 'chair' was then played unilaterally in the left ear. The subject was requested to only report the words heard. Left and right indications are not necessary since the examiner knows into which ear the words were played. The monaural words provided an indication of attention to the task, while perception of the dichotic words were an indicator of auditory neglect. A percentage of neglect was calculated based on the number of dichotic trials missed out of 20.

Displaced numbers. This subtest is exactly the same as the Dichotic Words, except that all of the words are replaced by a male voice speaking single-digit numbers. Four different random numbers occurred in each trial with the first and last number presented unilaterally to the right and left ear, respectively, and the middle two numbers presented dichotically.

Fourteen normal volunteers were tested by Coleman and Williams (2006) using the neglect tests described above. Normal volunteers essentially made no errors on these tests. The mean errors for each test ranged from one to two errors. The worst performance was demonstrated by one subject who made six errors on the Displaced Numbers test. This subject made no errors on the other tests.

Experimental manipulation of semantics and rhyming. Six lists of word-pairs were developed to evaluate semantic implicit cues. The lists were as follows: synonyms, antonyms, categorically related, rhyming, compound, and unrelated words. Each list contained 40 word-pairs listed in random order. Forty sets of six word-pairs were developed, each set including one word-pair from each category. The presentation order of the word-pairs in each set was randomized. The 240 word-pairs were played at 4-s intervals. The words used in developing the experimental test were rated for comprehension difficulty based on The Teacher's Book of 30,000 Words (Thorndike & Lorge, 1959). All words were

rated at a sixth-grade level or lower. When choosing rhyming word-pairs three elements of the words were considered. The words were required to have a matching vowel/consonant combination, that must have the same relative placement in the word (e.g., at the beginning of both words, end of both words), and the words had to be of equivalent duration when spoken aloud.

Stimuli were initially recorded on a Digital Audio Tape (DAT) in a professional studio where recording quality could be controlled and bilateral simultaneous stimuli exactly synchronized. Pure tones were produced with a synthesizer, environmental sounds were dubbed from a compact disc of special effects sounds, and verbal stimuli were spoken by a male voice. All stimuli were recorded from the DAT to a TDK audiotape cassette (LECI Type II, high position, SA-X90) and played to subjects through Pro-60 Realistic headphones from a SCR-51 Realistic recorder (model 14-1068B). The diaphragm of the Pro-60 headphones is made from titanium alloy and porcelain for high resolution, and the earpiece has foam cups that completely cover the ear, containing sound to the ear and substantially reducing extraneous external noise. While the subjects were being tested, the examiner also listened to the stimuli using stereo headphones. Responses were recorded by the examiner on a standard record form developed for the test.

Experimental manipulation of volume. The word lists used to examine semantic and rhyming implicit cues were administered twice. The first administration was conducted at the 40 Db level suggested by the acuity testing. In order to examine whether differences of sound volume influenced this patient's severe neglect, the following manipulations were conducted during the second administration of the dichotic word list in the order listed: (1) no manipulation and volume at 40 Db binaurally; (2) verbal cuing to listen in the left ear; (3) increase of binaural volume to 80 Db; (4) increase binaural volume to 100 Db; (5) decrease binaural volume to 40 Db; (6) maintain right ear at 40 Db and increase left ear to 60 Db; (7) maintain right ear at 40 Db and increase left ear to 80 Db; (8) maintain right ear at 40 Db and increase left ear to 100 Db; (9) turn off right channel while maintaining left ear at 100 Db; (10) decreasing left ear volume to 40 Db; (11) placing both left and right volume back at baseline of 40 Db; and (12) maintaining right ear again at 40 Db while increasing left ear to 100 Db.

RESULTS

W.D. had normal bilateral acuity. He consistently heard 1000 Hz tones at the 40-Db level in each ear. Stimuli used in all the tests except the volume manipulations were played at this volume level. Each neglect subtest was analyzed separately (Table 1). On the tonal subtest right errors were greater than left, and on the second environmental subtest, using bilateral sounds, equal numbers of errors were made on both sides. However, on all other subtests, W.D. made significantly more left side errors, resulting in 66% neglect of left sided stimuli and 17% neglect of the right side. On the Verbal Neglect Test that consisted of bilateral presentations of the word 'Cat', he demonstrated 90% left neglect, and on the Displaced Spondaic Words and Numbers Tests he demonstrated 100% left neglect.

Only the first administration of the list was analyzed for the effect of semantic cues (Table 2). Severe left auditory neglect was demonstrated on the dichotic word list (100% left neglect), and implicit cuing by semantic category or rhyming word pairs showed no improvement in perception of stimuli presented to the left ear. Table 3 shows the number of words correctly perceived in the right and left ears for each stimulus condition.

TABLE 1
Performance on tests of auditory neglect

| | <i>Bilateral</i> | | | <i>Unilateral</i> | |
|------------------------------|------------------|--------------|-------------|-------------------|--------------|
| | <i>Left</i> | <i>Right</i> | <i>Both</i> | <i>Left</i> | <i>Right</i> |
| <i>Monaural and Binaural</i> | | | | | |
| Pure Tones | 20 | 70 | 10 | 75 | 100 |
| Single Word | 10 | 90 | 0 | 86 | 86 |
| Environmental | 50 | 50 | 0 | 66 | 100 |
| <i>Sounds II</i> | | | | | |
| <i>Monaural and Dichotic</i> | | | | | |
| Environmental | 10 | 70 | 20 | 75 | 86 |
| <i>Sounds I</i> | | | | | |
| Displaced Words | 0 | 100 | 0 | 0 | 100 |
| Displaced Numbers | 0 | 100 | 0 | 0 | 100 |

Note: Values are expressed as percentages. For example, when Pure tones were presented to both ears, W.D. stated that tones were heard in the Right ear 70% of the trials, the Left ear 20% of the trials and Both ears 10% of the trials. For Displaced Words and Numbers, the values indicate that W.D. reported only the stimuli that were presented in the Right ear. Response patterns associated with Environmental Sounds I and II were compared and found to be significantly different ($Z = -2.58$; $p < .01$).

TABLE 2
Percentage of words in the experimental lists heard correctly in the Left and Right ear

| <i>Word types</i> | <i>Left</i> | <i>Right</i> |
|--------------------|-------------|--------------|
| Synonyms | 0 | 100 |
| Antonyms | 0 | 90 |
| Semantic category | 0 | 95 |
| Spondaic | 0 | 90 |
| Rhyming | 0 | 90 |
| Semantic unrelated | 0 | 90 |

Note: Values are percentages. All words were presented in dichotic fashion. W.D. reported no words presented to the Left ear.

TABLE 3
Percentage of words in the experimental lists heard correctly for each sound volume condition

| <i>Sound volume conditions</i> | <i>Left</i> | <i>Right</i> |
|---|-------------|--------------|
| 1. 40 Db Left/ 40 Db Right | 0 | 94 |
| 2. 40 Db Left/ 40 Db Right with command | 0 | 100 |
| 3. 80 Db Left/ 80 Db Right | 0 | 100 |
| 4. 100 Db Left/ 100 Db Right | 0 | 95 |
| 5. 40 Db Left/ 40 Db Right | 0 | 100 |
| 6. 60 Db Left/ 40 Db Right | 0 | 100 |
| 7. 80 Db Left/ 40 Db Right | 10 | 75 |
| 8. 100 Db Left/ 40 Db Right | 0 | 81 |
| 9. 100 Db Left/ 0 Db Right | 100 | — |
| 10. 40 Db Left/ 0 Db Right | 100 | — |
| 11. 40 Db Left/ 40 Db Right | 0 | 100 |
| 12. 100 Db Left/ 40 Db Right | 0 | 100 |

Note: Values are percentages. All words were presented in dichotic fashion.

Commands to listen in the left ear had no effect on performance (Condition 2). At higher Db levels binaurally, neglect was unaffected (Conditions 3 and 4). Progressively increasing the volume in the left, neglecting, ear (Conditions 6, 7, 8 and 12), while maintaining the right ear at minimum volume had minimal effect on the neglect. W.D. heard two words on the left during Condition 7, but otherwise continued to report words only from the right side. Only when the right channel was turned completely off did he consistently perceive left side words (Condition 9). When this occurred, his facial expression and his verbal exclamation also indicated that he heard, 'a very loud sound' in the left ear. His perception of left side words at the lower Db level (40 Db) further supports the conclusion that the deficit was not due to poor acuity (Condition 10). As

soon as the right channel was turned back on, he reverted back to neglecting responses (Condition 11).

DISCUSSION

This case study documents a patient with severe left auditory neglect, for whom implicit and explicit top-down cues were ineffective in increasing left side perception of verbal stimuli. The performance of W.D. may be contrasted with that of similar neglecting subjects who demonstrated improved perception of left side words that were semantically related to the right side words (Coleman & Williams, 2006). W.D. demonstrated a form of auditory neglect that is severe and insensitive to implicit and explicit stimulus cues. This neglect was so remarkable that we decided to examine whether manipulations of volume, a basic bottom-up property of sound, would have any influence on his neglect. Of particular interest was the finding that despite increasing left ear volume to maximum levels while keeping right ear volume at a minimum, the patient continued to demonstrate profound neglect of verbal stimuli presented to the left ear. Only when the volume of the right channel was set to zero, did W.D. perceive words in his left ear. However, this result was clearly not due to deficits in left ear acuity because he correctly perceived low volume, verbal stimuli presented to the left ear, and he had equivalent hearing levels bilaterally on formal acuity testing with unilateral tones.

The most widely adopted theory of the neural mediation of volume is that the sound wave propagated in the cochlea displaces the basilar membrane and associated hair cells according to the energy in the fluid wave (Zeng, Galvin, & Zhang, 1998). Sounds with higher amplitude displace the basilar membrane against the tectorial membrane to a great degree, and consequently cause more neurons to respond. This increase in neuronal firing results in a greater spreading activation around the characteristic frequencies of the sound. The increased firing across a larger set of neurons is perceived by the central auditory processing centers as an increase in sound volume (Moore, 2003). The perception of loudness varies according to the duration and frequency range of the sound, the spread of excitation among the neurons and the degree of phase locking of the firing rate to the frequencies in the sound (Carlyon & Moore, 1984; Moore, 2003; Moore & Raab, 1974; Viemeister, 1988).

Sound volume is not represented within the central nervous system as an analog facsimile of the energy in the sound wave and this has implications for the design of cochlear implants. This sound volume representation occurs in the peripheral components of the hearing apparatus: using a hearing aid to increase the volume of a stimulus increases the accurate perception of sound among patients with impairment of peripheral hearing. The hearing aid increases the amplitude of the sound wave. After the sound wave amplitude is encoded by the cochlea, volume is represented by encoded firing patterns. Cochlear implants are usually designed such that volume is represented by small changes in electrical intensity. Some of these methods represent volume as small changes in electric current; other methods involve current pulse patterns programmed over time. One of the most difficult problems in the design of cochlear implants is the correct encoding of sound volume and many patients who get implants complain that sounds are loud and aversive (Zhang & Zeng, 1997). The sound volume encoding patterns mediated by the cochlea and auditory nerve are largely unknown (Popper & Fay, 1992). This study suggests that the incorrect perception of sound volume may result from the incorrect encoding of volume by the implant device. Rather than focus on small changes in electrical intensity, developers of the implants should focus on replicating the firing patterns of neurons in the auditory nerve.

The extreme nature of the imperception across the two ears in this case reinforces what is probably a unique, interactive aspect of hearing across the two hemispheres. In order to perceive sound locations, the auditory system must analyze and compare small differences in frequency phase and volume levels across the ears with great time precision. Some of this integration occurs in the auditory nuclei in the brainstem and the remainder presumably occurs in the cerebral cortex (Wightman & Kistler, 1993). The results of this case reinforce these findings and illustrate how sensitive the integration is to brain illness. This case may illustrate a primary defect in the integrating mechanisms at the level of the cortex.

Although auditory neglect has been reported after lesions to the inferior parietal-superior temporal region (Heilman & Valenstein, 1972), right pulvinar, right frontal lobe (Hugdahl, Wester, & Asbjornsen, 1991), external capsule, anterior right internal capsule, (Junque & Marti-Vilalta, 1990), and striatum (Castro-Caldas, Guerreiro, & Confraria, 1984; Eustache, Lechevalier, Viader, & Lambert, 1990),

it is not known how lesion location, the extent of the lesion or variability in cerebral perfusion affect the manifestation of neglect. Across six tests of auditory neglect, W.D. demonstrated considerable variation in the degree of left neglect, ranging from minimal left neglect on a bilateral presentation of pure tones to profound left neglect of dichotic words and numbers. Even on similar tests there was variation. When environmental sounds were presented dichotically he had a majority of left side errors, but when the same environmental sounds were administered in a bilateral simultaneous presentation, in which both ears hear the same sound, he had an equal number of right and left side errors. Although other investigators reported using a variety of tasks to measure auditory neglect or extinction (Heilman & Valenstein, 1972), very few reported discrepancies in performance between different methods of presentation or type of stimuli. Our findings are consistent with those of Tanabe, Nishikawa, Okuda, and Shiraishi (1986) who reported that neglecting subjects demonstrated differing levels of auditory imperceptions of verbal and nonverbal dichotic stimuli. The auditory system is complex, having subsystems for the perception of pure tones and complex sounds, such as rhythm patterns and language (Yost & Sheft, 1993). Other systems allow for processing of spatial relationships of sounds in the environment (Pinek, Duhamel, Cave, & Brouchon, 1989). Some environmental sounds, such as glass breaking or car horns, may have connections to emotion processing centers in the limbic system that are not characteristic of sounds such as pure tones or recited numbers. It is possible that selective lesion of certain auditory areas or systems may result in neglect of different stimuli or different manifestations of neglect depending on the testing model used (e.g., dichotic versus binaural).

There are numerous other explicit cuing methods that could be applied to cases such as W.D. For example, top-down somatosensory and motor procedures could be attempted, such as touching the side of the face or headphones corresponding to the stimulus. It is also important to verify that the patient actually participated in the explicit cuing by assessing evidence in behavior, such as monitoring whether the patient actually remembers and obeys the instruction by looking toward the left, touching the left headphone and other signs. This was not done in this case and perhaps a more intensive, thorough assessment of explicit cuing will reveal that it has an influence when applied in a very systematic manner.

Finally, severity and extent of the lesion may be a critical factor in defining neglect. W.D. had extensive brain damage affecting a large area of the right hemisphere. The magnitude and nature of the neglect may have resulted from the multiple auditory perceptual systems involved in such a large lesion. A severe lesion may result in extensive disconnection of residual intact processing centers in the lesioned hemisphere from other areas of the brain. W.D. may not have benefited from semantic cues because healthy language centers in the left hemisphere were completely disconnected from the residual auditory perception areas in the right hemisphere. Future studies of the multiple systems involved may discover new knowledge about how they all interact. The end result may be a formulation of sensory imperception and neglect that is much more complex than the models generated from the imperception of simple pure tones or similar sounds presented across the two ears. It is striking that auditory neglect has been defined largely by the methods used to examine it. If the investigator presents only pure tones across the two ears, then auditory neglect will be defined as a very lateralized syndrome involving the perception of pure tones. Expansion of the methods to include all the stimuli unimpaired subjects can actually hear may result in more complex models of auditory imperception.

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