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Relationship between sound lateralization abilities and laterality index by Behavioural Inattention Test in unilateral spatial neglect patients

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ABSTRACT

In 36 patients with left unilateral spatial neglect due to right hemispheric damage, a sound lateralization test was conducted as an auditory task, using a Rhion audiometer AA-75. The test results were analyzed in relation to the laterality index calculated from the results of a Behavioural inattention test (a visual task). In the sound lateralization test, the left/right ratio of the inter-aural time difference discrimination threshold was determined, and the percent increase was calculated in the left inter-aural time difference discrimination threshold relative to that on the right. The laterality index is an indicator of the horizontal distribution of erroneous responses to subtests of the Behavioural inattention test and is calculated by dividing the subtest score on the left side by the total test score for both sides. Of the Behavioural inattention test subtests, 3 conventional subtests (line crossing, letter cancellation and star cancellation) and 4 behavioural subtests (picture scanning, menu reading, coin sorting and card sorting) were included to calculate the laterality index, and all 7 subtests were explorative tasks. The left/right ratio of the time difference discrimination threshold did not correlate significantly with the laterality index calculated from any subtests of the Behavioural inattention test. This indicates that in unilateral spatial neglect patients, test results evaluated on the basis of response differences to stimuli between right and left spaces are not always identical between auditory and visual tasks.

KEY WORDS

unilateral spatial neglect, Behavioural inattention test (BIT), auditory deficit

Introduction

In recent years, it has gradually become known that patients with unilateral spatial neglect (USN) also have abnormal responses when presented with auditory tasks. To date, however, few reports have been published concerning the relationship between their performances in auditory and visual tasks designed to evaluate the severity of USN[1-5]. USN is reported to involve the disturbed ability to detect stimuli on the side contralateral to the affected cerebral hemisphere, or to respond to such stimuli[6]. Visual stimulation tests, such as the cancellation test, are generally used to check for symptoms of USN. Data on the Behavioural inattention test (BIT) have often been used as visual task data when comparing the responses of USN patients to auditory tasks with their responses to visual tasks. However, in many visual tasks, the total number of responses to right and left spaces (e.g., the number of cancellations of stimuli) is counted, without considering the difference in the number of responses between right and left spaces.

Some auditory tasks presented to USN patients in-

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volve asking the patient to identify the location of a test sound[3, 7-11], and other tasks involve exposing the patient to different auditory stimuli from their right and left sides and determining whether the patient perceives each pair of stimuli to the same degree[1, 12-15] ; however, few auditory tasks include checking for neglected stimuli, equivalent to checking for omissions in the visual tasks. Thus, many auditory tasks currently used are designed to explore differences in responses by patients to auditory stimuli presented from their right and left sides. In our previous study, designed to evaluate the ability to perceive a sound image shift from the median area to the right or left[16, 17], revealed that the ability of USN patients to perceive sound image shift was weaker on the left side than on the right side. Therefore, when analyzing the relationship between data from auditory and visual tasks, it seems necessary to consider possible differences in the response to visual stimuli presented from the right or left side. In BIT, based on visual tasks, it is possible to calculate the score percentage from the left side among the total scores from both sides for each subtest to explore differences in the error distribution between the right and left sides. This percentage, obtained by dividing the score on the left side by the total score on both sides in each subtest, is called the "laterality index"[18]. This index allows us to determine whether the response of a USN patient to visual stimuli differs between the right and left sides.

We previously conducted a sound lateralization test that involved determining the location of a sound image, using inter-aural time differences as an indicator. That study revealed that the perceived location of sounds shifted to the left side from the center, i.e., it was difficult for USN patients to perceive a sound image shift from the center to their left side[16, 17]. In that test, the minimum time difference needed to perceive a sound image shift was defined as the threshold of inter-aural time difference discrimination. This threshold level was significantly elevated on the left side for USN patients. The ratio of this threshold level on the left side to that on the right side, i.e., the percent increase in the left inter-aural time difference discrimination threshold relative to that on the right, is expected to serve as a useful indicator of differences in response to auditory stimuli between the right and left sides.

This study was undertaken to analyze this ratio in relation to the laterality index calculated from the data from the BIT using visual tasks, with the goal of examining the relationship between visual task data and auditory task data among USN patients while considering the possible differences in responses to stimuli between the right and left sides.

Materials and Methods

1. Subjects

The subjects were patients with USN on the left side due to a cerebrovascular disorder of the right hemisphere in whom at least one parameter of the BIT was below the cut-off level (Table 1). All 36 of these patients satisfied the following : (1) they were right-handed, (2) they had a 20 dB or lower difference in mean hearing threshold level between the right and left sides, (3) their score in the mini-mental state test was above the cut-off level, (4) they did not suffer from dementia and (5) they were able to understand the methods of this study. Furthermore, all patients understood the objectives of the sound lateralization test and gave informed consent to the test in writing.

2. Methods

1) Sound lateralization test

A sound lateralization test program built into the Rhion Audiometer AA-75 unit was used for this test. Continuous sound (500 Hz narrow band noise) was used as the stimulus. Each subject wore a headphone set in a soundproof room and kept their eyes closed during the test, which can be conducted using either the dial method or the self-recording method : We used the dial method. The test was begun with the sound image in the median region, that is, the inter-aural time difference was 0 microseconds. The inter-aural time difference was then manually increased from 0 microseconds for sound sent to the right and left sides. The minimal inter-aural time difference perceived by the subject as a shift of the sound image to either side was adopted as the threshold level. The threshold level was measured for each sound sent to the right and left sides. This test has often been used

Table 1. Characteristics of 36 left-unilateral spatial neglect patients

Sex (male / female)	**22 / 14**	
Age(years)	**65.2 ± 8.5**	
Time post-stroke (months)	**5.0 ± 3.2**	
Causes of brain lesion	**hemorrhage**	**21**
	infarction	**15**
Sound lateralization abilities		
Right inter-aural time difference discrimination (μs)	**63.9 ± 29.5**	
Left inter-aural time difference discrimination (μs)	**149.4 ± 73.5**	
The left/right ratio of time difference discrimination threshold	**2.51 ± 1.00**	

in the field of otolaryngology. In this study, it was performed in accordance with the method reported by Sato et al[19]. and Yahata[20]. Figure.1 shows the details of this test and the characteristics of the USN patients studied.

2) Calculation of the laterality index

The BIT was administered to all subjects and the laterality index was calculated from the results. Of the BIT subtests, 3 conventional subtests (line crossing, letter cancellation and star cancellation) and 4 behavioural subtests (picture scanning, menu reading, coin sorting and card sorting) were included in the calculation of the laterality index. All 7 of these subtests were explorative tasks. The score on the left side was divided by the total score for both sides, and the quotient was carried to two decimal places, yielding the laterality index. It was not possible to calculate the laterality index directly from the BIT scores of the behavioural subtests, and so we used the number of correct answers for the right and left space tests as the score of the corresponding space[21]. The object placed in the center for picture scanning was excluded from the analysis. In accordance with the criteria reported by Halligan et al.[16] and Misonou et al.[22], the following judgments were made, depending on the laterality index : contralateral neglect (laterality index = 0), left bias inattention (laterality index between 0.1 and 0.47), non-lateralized inattention (laterality index between 0.48 and 0.52) and right bias inattention (laterality index over 0.53). A laterality index below 0.47 is reported to indicate inattention, predominantly on the left side. As this index decreases, the number of omissions in the left space, i.e., the number of abnormal responses, increases, and USN symptoms are more severe. If this index is between 0.48 and 0.52, we may conclude that there is no difference in responses between the right and left sides. A score over 0.53 suggests right-predominant inattention. Thus as the laterality index becomes higher, abnormal responses in the right space increase.

3) Statistical analysis

Spearman's rank correlation coefficient was used to analyze the correlation between the laterality index and the left/right ratio of the time difference discrimination threshold.

Results

1. Right and left inter-aural time difference discrimination thresholds and the left/right ratio of the time difference discrimination threshold

For the 36 USN patients, the right inter-aural time difference discrimination threshold ranged from 12 to 138 microseconds, with a mean of 63.9 microseconds and a standard deviation of 29.5 microseconds. The left inter-aural time difference discrimination threshold for the same 36 patients ranged from 40 to 326 microseconds, with a mean of 149.4 microseconds and

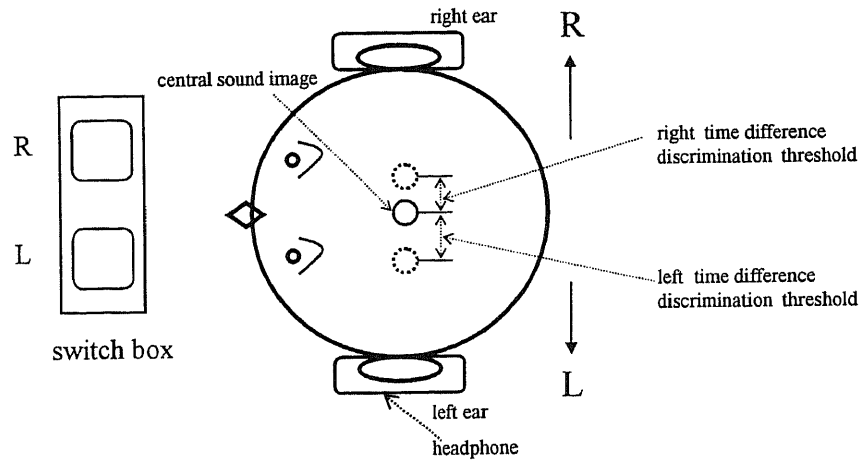


Figure. 1 Method of administering the sound lateralization test and the characteristics of unilateral spatial neglect patients

The magnitude of the inter-aural time difference that results in the patient perceiving a given shift of the central sound image is determined for both right and left directions, to calculate the inter-aural time difference discrimination threshold. In patients with left-unilateral spatial neglect, a greater inter-aural time difference is needed for the subject to perceive a sound image shift from the median area to the left side than to the right side, resulting in a higher left inter-aural time difference discrimination threshold.

a standard deviation of 73.5 microseconds. There was a significant difference between this parameter for the right and left sides ($P < 0.01$).

The left/right ratio of the time difference discrimination threshold ranged from 1.20 to 5.72, with a mean of 2.51 and a standard deviation of 1.00.

2. Laterality index

For tasks whose score exceeded the cut-off level, it was not possible to calculate the laterality index. Therefore, the number of cases in which the laterality index was calculated differed among different tasks. This number was 13 for the line crossing, 31 for letter cancellation, 25 for star cancellation, 32 for picture scanning, 18 for menu reading, 29 for coin sorting and 29 for card sorting. For each subtest, Table 2 shows the number of cases with the score below the cut-off level and the laterality index.

3. Relationship of the laterality index to the left/right ratio of the time difference discrimination threshold

1) Relationship of the laterality index in conventional subtests to the left/right ratio of the time difference discrimination threshold (Figure. 2)

When the relationship of the laterality index in conventional subtests to the left/right ratio of the time difference discrimination threshold was analyzed, the correlation coefficient was 0.13 for the line crossing, −0.15 for letter cancellation and −0.02 for star cancellation. Thus, there was no significant correlation between the laterality index for any conventional subtests and the left/right ratio of the time difference discrimination threshold.

2) Relationship of the laterality index in behavioural subtests to the left/right ratio of the time difference discrimination threshold (Figure. 3)

When the relationship of the laterality index in behavioural subtests to the left/right ratio of the time difference discrimination threshold was analyzed, the correlation coefficient was 0.09 for picture scanning, −0.03 for menu reading, 0.14 for coin sorting and 0.07 for card sorting. Thus, as in conventional

Table 2. The laterality index and number of cases with scores on BIT subtests below the cut-off level

Subtests	Number of cases with scores on BIT subtests below the cut-off level	Number of cases			
		CN	LBI	NLI	RBI
Line crossing	13	3	8	1	2
Letter cancellation	31	6	15	4	6
Star cancellation	25	5	13	4	3
Picture scanning	32	0	18	9	5
Menu reading	18	4	5	7	2
Coin Sorting	29	0	25	0	4
Card Sorting	29	0	23	4	2
Total	177	18	107	29	24

CN (contralateral neglect) : laterality index =0 (total neglect of stimuli on the left side)
LBI (left bias inattention) : laterality index between 0.1 and 0.47 (inattention predominant on the left side ; a lower laterality index is related to more omissions in the left space)
NLI (non-lateralized inattention) : laterality index between 0.48 and 0.52 (there is no difference in responses between the right and left sides)
RBI (right bias inattention) : laterality index over 0.53 (suggesting inattention predominant on the right side)

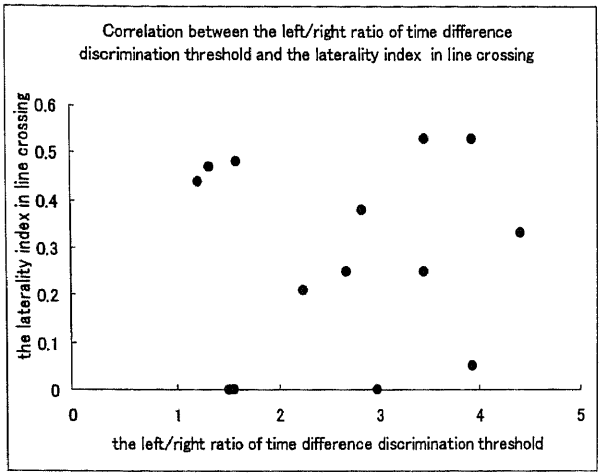
subtests, there was no significant correlation between the laterality index for any behavioural subtest and the left/right time difference discrimination threshold.

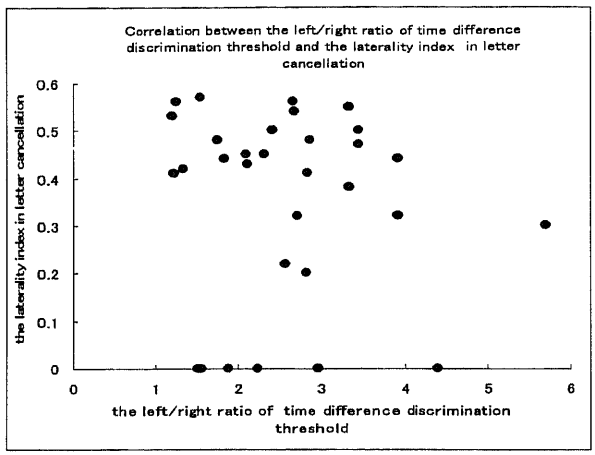
Discussion

In this study, the difference in responses to auditory and visual tasks between the right and left spaces was analyzed in USN patients and correlation between the responses to auditory and visual tasks was analyzed. The left/right ratio of the time difference discrimination threshold did not correlate significantly with the laterality index for any of the 7 BIT subtests, indicating that in USN patients, responses to stimulation of the right space differ from responses to stimulation of the left space, and responses to both auditory and visual tasks are lower in the left than in the right space, but the degree of reduced response in the left space is not always identical between auditory and visual tasks.

Of the previous reports on the relationship between the results of auditory and visual tasks in USN patients, some demonstrated a correlation between the results of these two task types[1-3,5], while others showed no correlation[4], thus, there is a discrepancy among previous reports. Among reports showing a correlation between the results of these two task types, the number of patients subjected to each task was often small (about 10), and the auditory task results sometimes differed markedly from the visual tasks. Therefore, it seems likely that the difference in the number of patients studied affected the differences in the task results. Furthermore, in most studies using visual tasks, the total number of responses in the right and left spaces (e.g., the BIT scores) was adopted as responses to the tasks, and there are few studies in which the tasks were selected with adequate consideration of possible differences in the responses between right and left spaces.

We previously examined the relationship between scores on auditory tasks used in the present study and the total BIT scores[4]. In that study, no significant correlation was observed between the auditory task scores and the total BIT scores. The BIT scores represent the total of responses to horizontal space (righ





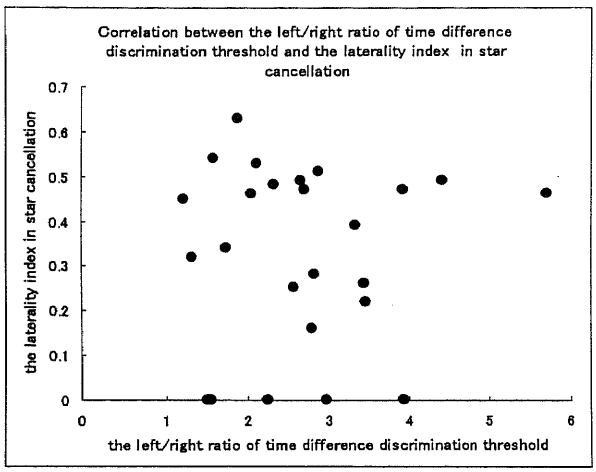


Figure. 2 Correlation between the left/right ratio of the time difference discrimination threshold and the laterality index in BIT conventional subtests

and left fields). Therefore, this score alone does not suffice as an indicator of differences between the right and left spaces in the responses of USN patients. In the present study, the laterality index was used so that differences in responses between right and left spaces would be reflected in the test results. This study endorsed the previous finding that, among patients with USN, the response to the visual task differed from the response to the auditory task. Auditory tasks used in recent studies of patients with USN are often designed to check for differences in responses to stimuli between the right and left spaces. It is therefore desirable to also design visual tasks to check for differences in responses between the right and left spaces. When BIT is to be performed, the use of the laterality index is expected to allow more definite determination of differences in response between the right and left spaces than does the use of the total score. BIT with laterality index therefore seems more suitable for analysis of correlation with auditory task scores.

Pavani et al.[5] analyzed the relationship between the results of multiple auditory tasks (identifying a sound location and identifying changes in a continuous sound location) and the results of visual tasks in USN patients. Their analysis revealed a significant correlation for 10 of the 14 combinations analyzed. In their study, a cancellation test was used as the major visual task. The responses to this task were calculated based on the difference in the number of cancellations between the right and left spaces, thus considering possible differences in the responses between right and left spaces ; however, responses to the auditory task were calculated only based on erroneous responses to the stimuli presented in the left space. In this respect, their study differs from our study in which possible response differences between right and left space were considered for both auditory and

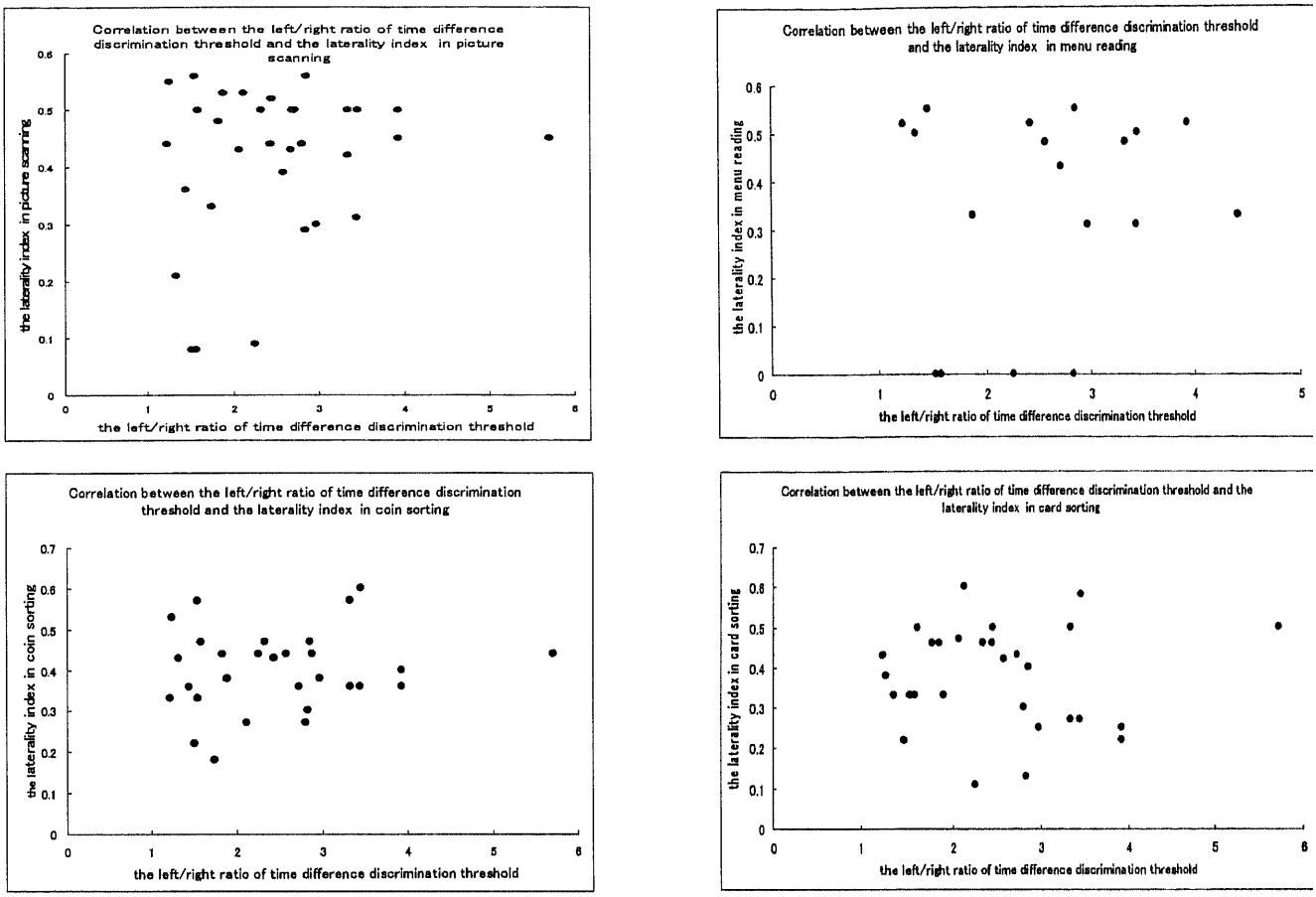


Figure. 3 Correlation between the left/right ratio of the time difference discrimination threshold and the laterality index in BIT behavioural subtests

visual tasks. When analyzing the relationship between responses to visual and auditory tasks in USN patients, it seems essential to reflect possible response differences between right and left spaces in responses to both auditory and visual tasks.

A variety of auditory tasks for USN patients has been devised, including sound location, checking for perception differences of an auditory stimulus presented separately from the right and left, assessing the ability to perceive a shift in sound image caused by inter-aural time difference or inter-aural intensity difference in the sound applied to both ears, and so on[7,16,17,23-25]. Studies using these tasks showed that USN patients sometimes perceived the sound (applied to the left side) in a direction biased to the right side or had difficulty perceiving an auditory stimulus presented on the left side. According a more recent report, which asked subjects to answer whether the location of two consecutively presented sounds (using invisible speakers) was identical[26], USN patients ha difficulty distinguishing between the two sounds whe they were applied to the left side. Another task ha also been reported in which the subject was aske whether the sound was located above or below th visual line (a task to judge the sound location on vertical line)[27]. Using this task, USN patients ofte made errors in the sound location presented on th left space and required more time to respond.

As described above, auditory tasks for USN pa tients are designed to examine whether the ability t respond to stimuli differs between the right and le spaces (based on an assumption that subjects can hea the stimulus sound), instead of evaluating whether th subject can detect the stimulus, that is, the subjec does not overlook the stimulus (an evaluation mad with visual tasks). If multiple stimuli are presented i visual tasks, the total number of cancellations (indica tor of the number of stimuli detected) is used as

parameter. In most auditory tasks, on the other hand, the subject's ability to perceive the direction or movement of a single stimulus (which has been confirmed as heard by the subject) is evaluated. Thus, auditory tasks seldom investigate stimulus neglect by subjects, and the results are often calculated based on response differences to stimuli between right and left spaces. Therefore, when examining the correlation between results of auditory and visual tasks, it is necessary to calculate the results based on response differences to stimuli between right and left spaces, even for visual tasks. The laterality index used in this study meets this requirement and it seems advisable to use this index in combination with scores when performing BIT.

In USN patients, this study revealed no significant correlation between auditory task results and USN severity as assessed using visual tasks. This suggests that patients with severe USN with a low laterality index sometimes show only mild abnormalities in auditory tasks. In such cases, the utilization of auditory stimuli in treatment can compensate for USN symptoms. It seems important to devise auditory tasks that can reveal response differences to stimuli between right and left spaces so that the responses can be reflected in the results of the entire evaluation. It also seems necessary to identify tasks to which USN patients show comparably good responses in both right and left spaces and to analyze the results of these tasks in relation to visual tasks.

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半側空間無視患者における音の方向感検査所見と laterality index との関係

砂原　伸行，能登谷晶子

要　　旨

右半球損傷後の左半側空間無視36例に対し，聴覚課題として音の方向感検査（リオン製AA-75）を実施し，その検査成績と視覚課題の BIT 行動性無視検査結果から算出した laterality index との関係を検討した。音の方向感検査では左右の時間差音像移動弁別閾値を測定した上で，右の閾値を基準とした場合の左の閾値の増大率（閾値の左右比）を算出し検査成績とした。laterality index は BIT 下位検査での誤反応の左右分布を表す指標であり，各々の下位検査での左側の得点を左右両側の得点で除して求めた。laterality index を求めた下位検査は線分抹消試験，文字抹消試験，星印抹消試験，写真課題，メニュー課題，硬貨課題，トランプ課題の７つの課題であり，いずれも探索的課題である。検討の結果，閾値の左右比と７つの BIT 行動性無視検査下位検査における laterality index とのいずれとの間にも有意な相関はみられなかった。以上より，半側空間無視例では検査成績を左右各々の空間における刺激に対する反応の違いから算出した場合，その成績の程度は聴覚，視覚の両課題間で必ずしも一致しないことがわかった。