Indian J Physiol Pharmacol 2001; 45 (1) : 63–70

# LATERAL DIFFERENCE IN REACTION TIMES TO LATERALIZED AUDITORY STIMULI

BORIS J. GUTNIK*, HAMISH W. MACKIE,
WEI GUO AND JUDY NICHOLSON

*The Department of Health Sciences,*
*Faculty of Health Science and Technology,*
*UNITEC, Auckland, New Zealand*

**( Received on April 3, 2000 )**

**Abstract :** Evidence suggests that Reaction time (RT) is affected by human behaviour in that stimuli are processed and conducted faster and more accurately when they are presented directly to the specialised hemisphere and responded to more quickly when stimulus and response are mediated by the same hemisphere. The purpose of the current study was to investigate the effect of laterality using one parameter-reaction time (RT) on ipsilateral reactions to monuaural latralized stimuli. Twenty-four undergraduate polytechnic students and 10 representative level Rugby players participated in the study by reacting unilaterally to single and choice RT using simple and complicated sensor motor reactions (SMR). Results Shorter reaction times by the dominant hand while testing simple and complicated audio SMR, without reference to sex and sport skills results have been explained in terms of specialisation of left hemisphere in different aspects of information processes mechanisms, geared towards programming of the movement.

**Key words :** stimulus hemisphere reaction time sensor motor reactions

## INTRODUCTION

Reaction time (RT) or the interval between the receipt of signal and the required motor response is of concern to industrial and sport psychologists and ergonomists. The time required for integration of sensory inputs and motor outputs may be affected by human behaviour (1, 2, 3, 4, 5, 6). According to the models of relative hemispheric specialisation (7, 8, 9) stimuli are processed and conducted faster and more accurately when are presented directly to the specialised hemisphere and responded to more quickly when stimulus and response are mediated by the same hemisphere (10).

The vast majority of researchers prefer to investigate the difference in unilateral motor reactions and the visual modality stimuli in terms of visual pathways which is strongly lateralized and easier to explain in terms of the difference between hand response and contralateral to the stimulus. (11, 12, 10).

---

*Corresponding Author

Experiments using lateralized non-verbal audio stimuli on brain patients have shown no significant difference in latency period of the simplest sensory/motor reactions. In this situation nervous inputs have bilateral access to both hemispheres (12). Although the sensory pathways from each ear are projected on both hemispheres the counter lateral projections seems to be stronger than ipsilateral projections (13) which are associated with faster ipsilateral motor reaction by distal muscles.

Some studies have shown the subject's unilateral response, using the right hand (with side response) when the signal was presented to the right ear, and left hand (with left side response) when the signal was presented to the left ear, has not been significantly different (14). This may be because subjects have not been strictly considered as right and left handed.

Unfortunately the difference between auditory reaction time has been the focus of researchers in this area. The few researchers that have investigated the latency period of auditory ipsilateral sensory motor reactions have shown contradictive results (15, 16, 17). It seems that this gap in the research is mostly attributible to researchers using previously used experimental design (frequency and delay of stimulus and level of handedness) rather than new experimental protocols. In order for RT in humans to be more fully understood there is clearly a need for research addressing the lateral difference in latency periods between pure left and right ipsilateral monaural-motor reactions to non verbal stimuli in simple and choice reactions.

The purpose of the current study was to investigate the effect of laterality using one parameter-reaction time (RT) on the model of ipsilateral reaction to monaural lateralized stimuli.

## METHODS

Participants included 24 undergraduate polytechnic students (13 male and 11 female) without high level sporting skills ranging in age form 18 to 36 years and 10 representative level Rugby players (all male) aged between 18 and 20 years. All participants were naive to the task as developed by Oldfield (18). All participants were in good health.

Specialised software and hardware developed for digitising auditory stimuli with ±0.5 ms were tested and used for data collection. The data were then downloaded to desktop computer for analysis.

For the data collection protocol each participant sat in a comfortable upright position in an armchair. Listening through earphones, an auditory pure tone of 1000 Hz and 30 db was presented for 60 ms to the left oɪ to the right ear of each participant. Two hand held buttons connected to micro-switches were used for the motor response. All subjects were instructed to push the appropriate button without lifting their forearm form the arm rests. The response key measured 1 cm in diameter and were calibrated so that gap between contacts were maintained at 1 mm and a pressure of 50 g were sufficient to make the micro switches contact.

Participants reacted unilaterally by thumb at the level of the phalangeal using a nearly isometric contraction of the agonistic first interosseouse muscles (first dorsal interosseous, adductor policis and other). Stimuli were presented to the subject between 3 to 8 seconds after the motor response from the previous trial in order to reject the signs of irritation of the central nervous system (CNS) after the previous stimulus.

Two variations of the trial were used, single and choice RT using simple and complicated sensor motor reactions (SMR). For the simple TR trials only one stimulus could be presented to the subject and the same response was always required. In this case either one block 15–20 auditory stimuli were presented to the right ear and the participant was to react as quickly as possible using the right hand, or the same block of 15–20 stimuli were presented to the left ear and the participant was to react as quickly as possible using the left hand. For the choice RT trials each person was instructed to push a button as quickly as possible in response to each stimulus: by right hand if the stimulus is presented on right ear and vice versa. Thirty to forty left or right sided stimuli (with equal lateral probability) were presented to each participant (Table I). A rest of 10 minutes was allowed between simple and choice RT trials. If an error occurred in any trial, the RT for that trial was automatically discounted and an additional stimulus was presented to the participant.

TABLE 1: The number of stimuli in Simple and Choice RT trials.

| *Trial type* | *Simple reaction time* | *Choice reaction time* |
|---|---|---|
| 1. Unimanual<br>Right ear stimuli-<br>Right hand response | 15–20 | – |
| 2. Unimanual<br>Left ear stimuli-<br>Left hand response | 15–20 | – |
| 3. Unimanual<br>a. Right ear stimuli-<br>Right hand response or<br>b. Left ear stimuli-<br>Left hand response | – | 30–40 |

**Data analysis**

Reaction times below 100 ms were considered as anticipatory error and were automatically removed form the analysis. Reaction times of more than 500 ms were also removed from the analysis. Because mode has been suggested as the most stable descriptive statistical summary of this sort of data (19) the range of RT (s) was divided into three equal intervals and the interval mode of RT (where more than 67% of trials existed in one interval) was calculated and then the individual mean from this interval was determined. In cases where there is no obvious mode, the entire range of RT (s) from all three intervals were included.

The combinations of experimental factors [2 trial types (simple and choice RT) × 2 side (left and right) × 3 groups of persons (non sport male, non sport female, and rugby players)] where analysed using a three way ANOVA.

## RESULTS

Using an ANOVA we did not receive significant lateral difference in RT between males and females (Females$_{\text{-females}}$ = 0.073, P>0.05). The analysis of variance also showed the following results: $F_{(1)} = 55.8$ (P<0.001)-the difference between RT of variants of performances with simple and complicated SMR, $F_{(2)} = 0.23$ (P>0.05) the difference between RT od left and right sided ipsilateral performances; $F_{(3)} = 35.6$ (P<0.001)-the difference of RT between groups of performers. From the original data

TABLE II : Simple and choice RT's for non trained males and females and rugby players.

| *Trial type* | *Simple reaction time (milliseconds)* | | | *Choice reaction time (milliseconds)* | | |
|---|---|---|---|---|---|---|
| *Group* | $L_{ear}$–$L_{hand}$ | $R_{ear}$–$R_{hand}$ | *Δ* | $L_{ear}$–$L_{hand}$ | $R_{ear}$–$R_{hand}$ | *Δ* |
| Non trained males | 172.0 | 162.3 | 9.7 | 270.2 | 243.5 | 26.7 |
| | 170.4 | 155.6 | 14.8 | 265.2 | 248.7 | 16.5 |
| | 199.6 | 190.6 | 9.6 | 265.8 | 253.0 | 12.8 |
| | 168.9 | 164.6 | 4.3 | 302.2 | 304.3 | 2.2 |
| | 162.1 | 160.1 | 2 | 259.6 | 237.5 | 22.1 |
| | 175.3 | 166.5 | 8.8 | 257.5 | 231.6 | 25.9 |
| | 178.4 | 177.3 | 1.1 | 236.5 | 203.5 | 33 |
| | 142.6 | 134.0 | 8.6 | 240.3 | 219.6 | 20.7 |
| | 188.8 | 190.5 | –1.7 | 250.4 | 206.7 | 43.7 |
| | 168.4 | 151.4 | 17 | 300.0 | 256.9 | 43.1 |
| | 155.7 | 152.0 | 3.7 | 236.0 | 237.4 | –1.4 |
| | 182.4 | 177.5 | 4.9 | 233.7 | 230.7 | 3 |
| | 145.2 | 141.7 | 3.5 | 190.3 | 169.8 | 20.5 |
| | X = 170 | X = 163.4 | | X = 254.4 | X = 234.1 | |
| X ± SE | 166.6±3.2 | | | 244.3±6.1 | | |
| Non trained females | 179.1 | 172.0 | 7.1 | 230.6 | 210.3 | 20.3 |
| | 172.6 | 171.1 | 1.5 | 239.1 | 231.5 | 7.6 |
| | 196.5 | 189.0 | 7.5 | 242 | 233.7 | 8.3 |
| | 241.6 | 234.4 | 7.2 | 315.5 | 331.9 | 19.6 |
| | 187.5 | 175.9 | 11.6 | 239.9 | 235.6 | 4.3 |
| | 172.7 | 162.8 | 9.9 | 250.1 | 233.4 | 16.7 |
| | 168.4 | 157.4 | 11 | 287.6 | 279.6 | 8 |
| | 145.9 | 144.8 | 1.1 | 231.1 | 218.5 | 12.6 |
| | 140.8 | 139.3 | 1.5 | 261.9 | 219.3 | 42.6 |
| | 195.1 | 227.0 | –31.9 | 244.0 | 228.2 | 15.8 |
| | 193.7 | 181.5 | 12.2 | 274.6 | 248.2 | 26.4 |
| | X = 181.3 | X = 177.7 | | X = 259.2 | X = 242.7 | |
| $X_{group}$ ± SE | 179±5.9 | | | 251.0±7.4 | | |
| Male rugby players | 127.5 | 125.0 | 2.5 | 224.0 | 216.6 | 7.4 |
| | 160.3 | 154.1 | 6.2 | 224.2 | 194.7 | 29.5 |
| | 155.3 | 160.8 | 5.5 | 214.7 | 210.5 | 4.2 |
| | 149.6 | 142.2 | 7.4 | 247.0 | 222.4 | 24.6 |
| | 162.2 | 150.8 | 11.4 | 227.0 | 195.2 | 31.8 |
| | 178.3 | 181.5 | 3.2 | 317.0 | 266.3 | 50.7 |
| | 150.0 | 145.1 | 4.9 | 258.5 | 243.7 | 14.8 |
| | 158.2 | 155.3 | 2.9 | 201.1 | 214.8 | –13.7 |
| | 159.3 | 151.9 | 7.4 | 194.8 | 218.6 | 23.8 |
| | 159.3 | 158.4 | 0.9 | 240.7 | 248.9 | –8.2 |
| | X = 156 | X = 152.5 | | X = 234.9 | X = 223.2 | |
| $X_{group}$ ± SE | 154.2±2.9 | | | 229±6.4 | | |

TABLE III : Number of participants showing greater reaction times for the left side than the right side.

| Pattern | *Simple reaction time* | | *Choice reaction time* | |
|---|---|---|---|---|
| | *Number of persons with this patter* | *Total number of subjects in experiment* | *Number of persons with this patter* | *Total number of subjects in experiment* |
| Non-trained males where $RT_{left\ ear-left\ hand} > RT_{right\ ear-right\ hand}$ | 12<br>$P<0.01$ | 13 | 12<br>$P<0.01$ | 13 |
| Non training females where $RT_{left\ ear-left\ hand} > RT_{right\ ear-right\ hand}$ | 10<br>$P<0.01$ | 11 | None<br>$P<0.01$ | 11 |
| Sportsmen (male) $RT_{left\ ear-left\ hand} > RT_{right\ ear-right\ hand}$ | none<br>$P<0.01$ | 10 | 8<br>$P<0.05$ | 10 |

we can see that the majority of participants perform this task much faster with the right hand. (Table II& III). However, because of large individual variation of data using the two way ANOVA method we did not detect *significant* lateral difference. According to the requirements of statistics the sign criterion might be useful when data changes changes mostly in one direction (increasing – '+' or decreasing – '-').

The results, as computed by sign criterion (19) showed some advantage of the left hemispheric system in terms of faster organisation of simple audio motor reactions. Therefore, our results have shown shorter reaction times by the dominant hand while testing simple and complicated audio SMR, without reference to sex and sport skills.

## DISCUSSION

Lateralized auditory information has been shown to have simultaneous access to both hemispheres if the stimulus is both strong enough (60 db) and long enough in duration (100 ms) (12). But if the stimulus is shorter in duration (60 ms) and weaker in intensity (30 db) as has been used in our case the more stronger counter lateral projection have an advantage in delivering information to the opposite hemisphere (13). However, in our experiments we used a unimanual key processing response, consisting of a single, weak, isometric contraction of the distal interosseous muscles of thump, which are exclusively guided by the contra lateral hemisphere (20, 21). Thus we have been able to compare the participation of the left and right hemispheric systems in simple and choice motor reactions.

Left and right hand movement were due to the simplest isometric muscle contractions and the motor component of such responses seems to be very simple and might not require entire complex cognitive processing in simple and possibly in choice motor reactions. In this case the primary motor-cortex may be the main controller and organiser for these kinds of motor executions. The primary motor cortex is reported to be mostly responsible for primitive motor responses (22).

According the information processing concept (3, 5, 23, 24) as expressed classically in Hick's law the choice SMR paradigm comprises more processing stages than simple SMR. According to Henry and Rogers (25) in modification of welford (26), Grandjean (27), Fischman (28), Cristina and Rose (29), Harington and Haaland (30), Schmitdt and Lee (24) a longer program (reflection the greater number of response variations) takes more time to prepare an adequate response than a shorter one. We can therefore understand why RT for lateral choice reaction is longer than for simple, but we cannot simply explain the lateral difference for the same type of reactions. It is assumed that in both simple and pools in left and right muscles would be required.

Left and right hand movements in both the simple and choice situations resulted in simple isometric muscle contraction with a small force. Because RT is ultimately derived from central processing events (4, 5, 6, 27, 31, 32) we could assume that the processes in the right hemisphere of right handed people take more time than in the left hemisphere and it is not because one lateral motor program is more complicated then the other, but because the left hemisphere in more specialised for time of organisation programming processes (30, 33, 34). Recent research by Levanen (35) has shown different activation patterns of the human left and right auditory cortex and suggests stronger involvement of the right hemisphere may take longer. In one experiment (30) with patients affected by lateral simple movements. Left hemispheric damage may disrupt patient ability to effect scheduling of motor programs and its time's derivatives. (30, 36). Shorter RT to lateralized flashing of light with a key like pressing response were also exhibited by right handed unaffected subjects using their dominant hand (37) and by commissutoromized patients (38). Callan et al (39) used a separated monoaural high intensive stimulus (90 db). Perhaps because of irradiation of activation to the contralateral hemisphere subjects do not demonstrate significant difference in RT between left and right sided action. Besides, the experiments with left ear preference effect shown callan also may due to tonal discrimination, where the right hemisphere is more successive.

But for a reaching movement (model of a protracted arm) involving the entire extremity, the left hand has some advantage in RT (10). Therefore, in comparing our results with those of the studies we always have to draw attention to the nature of the response.

In their early work Fisk and Goodale (40) found that the right hemisphere is mostly involved in determining spatial position if the target, whereas the left hemisphere is more in controlling of time of movement execution. In our study there were no particular spatial requirements in the task but there were particular requirements to push the button as quickly as possible. In this case the left hemisphere would be better able to compare kinaesthetic and tactile signals from previous reactions in order to reduce reaction time; According to Flowers (41) the right hand (left hemispheric) system may be superior in processing sensory feedback. All these reason some what explain our results by showing an obvious advantage of the dominant hand in RT.

Alternatively, the faster right simple ipsilateral reaction in our experiment is consistent with finding of callan et al (39) and may explain the faster responses to right ear stimulation. This phenomenon reflects the hypothesis regarding attentional preference for the left hemisphere (7, 9, 33, 42).

In our experiment, like the non-trained subjects, the rugby players also demonstrated right handed superiority in RT. However they showed a significantly shorter RT for both (left and right) sides. The effect of physical training on sped of information processing can be explained as shift in activation of the different of CNS (31, 43, 44, 45, 46).

In conclusion, our results suggest that information processing a result of a simple key-like repsonse to weak auditory stimuli by strong right handed subjects occurs more quickly within the left hemispheric system irrespective of the complexity of the response.

## REFERENCES

1. Braun CMJ. Estimation of interhemispheric dynamics from simple unimanual reaction time to extrafoveal stimuli. *Neuropsychology Review* 1998; 3 (4): 321–365.
2. Brebner JMT, Welford AT. Introduction: An Historical Background Sketch In : Reaction times. AT Welford (ed.) Academic Press. 1980: P. 1–24.
3. Sanders M, Mc Cormic EJ. Human factor in engineering and design. Mc. Graw Hill. INC, 1993.
4. Latash ML. Neuropsychological bases of movement. *Human Kinetics* 1999.
5. Margill RA Motor Learning (concepts and applications). Mc-Graw Hill. International Edition 1998.
6. Schmitdt RA, LEE TD. Motor control and Learning. A Behavioral Emphasis. Third Ed. *Human Kinetics* 1999.
7. Springer SP & Deutsch G. Left brain, right brain. San Francisco, CA: Freeman 1981.
8. Bouma A. Lateral asymmetries and hemispheric specialisation. Theoretical model and research. Swets & Zeitlin Ger BV. LSSE Publishers. Amsterdam 1990.
9. Kolb B& Whishaw JQ. Human Neuropsychology (4th ed.) W. H. Freeman and Co. 1995.
10. Velay JL, Benoit-Dubrocard SB. Hemispheric asymmetry and interhemispheric transfer in reaching programming. *Neuropsychology* 1998; 37: 895–903.
11. Milner Ad, Lines CR. Interhemispheric pathways in simple reaction time to lateralized light flash. *Neuropsychology* 1982; 20: 171–179.
12. Lacoboni M, Zaidel E. The crossed–uncrossed difference in simple reaction time to lateralized auditory stimuli is not a measure of intrahemispheric transmission time: Evidence from the split brain. *Experimental Brain Research* 1999; 128 : 421–425.
13. Rozenzweig MR. Representation of two ears at the auditory cortex. *American Journal of Physiology* 1951; 167: 147–158.
14. Symon JR. Ear preference in the simple reaction time task. *Journal of Experimental Psychology* 1978; 75: 49–55.
15. Pieters JM. Ipsilateral and contralateral reactions to monoural lateralized stimuli. *Cortex* 1979; 15(2): 313–320.
16. Misra N, Mahajan KK, Maini BK. Comparative study of visuals and auditory reaction time of hands and feet in males and females. *Indian J Physiol Pharmacol* 1985; 29(4): 213–218.
17. Takaoka Y. A study of measurement of auditory reaction time. *Nippon Jibiinkoka Gakkai Kaiho* 1990; 93 (5): 746–755.

18. Oldfield RC. The assessment and analysis of handedness. *The Edinburgh inventory. Neurophysiology* 1971; 9: 97–113.

19. Downie NM, Heath RW. Basic Statistics methods (3rd Ed.). New York: Harper international Ed 1970.

20. Penfield W, Jasper H. Epilepsy and the functional anatomy of the human brain. Boston. Little Brown 1954.

21. Laplane D, Talairach J, Meninger V, Bancaud J, Bouchareine A. Motors consequences of oblation of motor area in man. *Journal of Neurological Science* 1977; 31: 29–49.

22. Ghez C. Voluntary movement. In: E.R. Kandel, Schwartz, J.H., Jessel T.M (eds) Principles of neural Science (Third Ed.) 1991; P. 610–624.

23. Hick WE. On the rate of gain of information. *The Quarterly Journal of Experimental Psychology* 1952; 4: 11–160.

24. Schmitdt RA, Lee TD. Motor control and Learning. A Behavioral Emphasis. Third Ed. *Human Kinetics* 1999.

25. Henry FM, Rogers DE. Increased response latency for complicated movement and a "memory drum" theory of neuromotor reaction. *Research Quarterly* 1960; 31: 448–458.

26. Welford AT. Choice reaction time. Basic concepts. In reaction times. A. T. Welford (ed.) Academic Press 1980: P. 75–128.

27. Grandjean E. Fitting the task to the man. An ergonomical approach. Taylor & Francis. London 1980.

28. Fischman MG. Programming time as a function of number of movement parts and changes in movement direction. *Journal of Motor Behaviour* 1984; 16: 405–423.

29. Cristina RW, Rose DJ. Premotor and motor reaction time as function of response complexity. *Research Quarterly for Exercises and Sport* 1985; 54 (4): 306–315.

30. Harrington DL, Haaland KY. Hemispheric specialization for motor sequencing abnormalities in levels of programming. *Neuropsychologia* 1991; 2: 147–163.

31. Pashella RG. The interpretation of reaction time in information processing research. In B.H. Kantowitz (ed.) *Human information processing: Tutorials in performance and cognition. Hillsdale. NJ Erlbaum* 1974; p. 81–42.

32. Smith EE. Choice reaction time: An Analysis of the major theoretical positions. *Psychological Bulletin* 1968; 69: 77–110.

33. Roy EA. Attention sequencing and lateralized cerebral damage: Evidence for asymmetries in control. In attention and performance XI. J. Long & A. Baddely (Eds). Lawrence Erlbaum. Hillsdale 1981; pp. 487–500.

34. Haaland KY, Delaney HD. Motor deficit after Left and right hemisphere damage due to stroke or tumour. *Neuropsychologia* 1981; 19: 17–27.

35. Levanen S, Ahonen A, Hari R, McEvoy L, Sams M. Deviant auditory stimuli activate human left and right auditory cortex differently. *Cerebral Cortex* 1996; 6(2): 288–296.

36. DeRenzi E, Faglioni P, Lodesani M, Vecchi A. Performance of left damage patients on imitation of single movements and motor sequences. Frontalo and parietal-impaired patients compared. *Cortex* 1983; 19: 333–343.

37. Bouma A. Lateral asymmetries and hemispheric specialization. Theoretical model and research. Swets & Zeitlin Ger BV. LSSE Publishers. Amsterdam 1990

38. Sergent J, Myers JJ. Manual, blowing and verbal simple action to lateralized flashes of light in commisurotomized patients. *Perception and Psychophysics* 1985; 37: 571–578.

39. Callan J, Klisz D, Parsons OA. Strength of Auditory stimuli response compatibility as a function of task complicity. *Journal of Experimental Psychology* 1974; 102 (6): 1039–1045.

40. Fisk JD, Goodale MA. The effect of unilateral brain damage on visually guided reaching: hemispheric difference in the nature of the deficit. *Experimental Brain Research* 1988; 72: 425–435.

41. Flowers K. Handeness and controlled movement. *British Journal of Psychology.* 1975; 66: 39–52.

42. Kinsbourne M. The Cerebral bases of lateral assymmetries in attention. *Acta Psychologica* 1970; 33: 193–201

43. Pass FGWC, Adam JJ. Human information processes during physical exercise. *Ergonomics* 1991; 34: 1385–1397.

44. Mc Morris T, Keen P. Effect of exercise on simple reaction times of recreational athletes. *Perceptual and Motor Skills* 1994; 78: 123–130.

45. Mc Morris T, Craydon J. Effect of exercise on soccer decision-making tasks of different complexities. *Journal of Human Movement Studies* 1996; 30: 177–193.

46. Arcelin R, Delignieres D, Brisswalter J. Selective effects of physical exercise on choice reaction processes. Perceptual and motor Skill 1998; 87: 175–185.