

THE MOZART EFFECT: AN INVESTIGATION INTO CONTRIBUTIONS OF THE LEFT AND RIGHT HEMISPHERE

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Abstract

This study was conducted to examine the nature of the Mozart effect, and to determine the inter and intrahemisphere effects that lateralizing different types of musical stimuli may have on spatial-temporal reasoning. Participants were 49 college students from a small, liberal arts university in central New York. Participants were randomly assigned to a Mozart, jazz, or a control condition and asked to complete a number of paper-and-pencil and computerized tasks involving spatial transformations while music was played to alternate ears. Results show the predicted interaction between music condition and ears was observed only for the reaction times of left handers, and occurred in both the Mozart and jazz conditions. Implications for the nature of brain asymmetry among left handed individuals and for further research are discussed.

Introduction

Research in the past decade has provided conflicting evidence regarding the enhancing effect of Mozart's music on cognitive task performance. Rauscher, Shaw, and Ky (1993) originally found a substantial increase in spatial-temporal IQ scores on a subtest of the Stanford-Binet Intelligence Scale following exposure to Mozart's music compared to either silence or relaxation music. Subsequent research both supports and fails to support the occurrence of this so-called Mozart effect. In accordance with the original study, Rauscher, Shaw, and Ky (1995), Rideout, Dougherty, and Wernert (1998), and Rideout and Taylor (1997) presented subjects with a paper folding and cutting task, a measure of abstract/spatial reasoning with internal manipulation of spatial-temporal patterns, and found a significant increase in task performance after listening to Mozart. Other studies have used the Raven Advanced Progressive Matrices, a general test of intelligence that requires spatial aptitude, inductive reasoning, and perceptual accuracy as assessed by matrix/symbol completion tasks, and failed to observe any improvement in performance following exposure to Mozart's music (Newman, Rosenbach, Burns, Latimer, Matocha, & Vogt, 1995; Stough, Kerkin, Bates, & Mangan, 1994). Steele, Ball, and Runk (1997) used a backwards digit span task, a correlate of Raven's Progressive Matrices involving rotation or transformation of sequence as a measure of temporal reasoning, and also failed to find evidence of a Mozart effect. Such contradictions indicate that the effect may not be robust or may be limited to a subclass of spatial abilities.

In an attempt to reconcile the disparate evidence regarding the Mozart effect, Rauscher and Shaw (1998) specify that the essential components required to produce the effect include tasks involving spatial imagery and mental transformation of form. Such tasks would include paper folding and maze tasks, and would exclude digit span, pattern analysis, and Raven's tests because they measure analytic intelligence rather than spatial-temporal ability. Rauscher and Shaw propose that the enhancing effect of Mozart's music on this type of cognitive task is due to an organizing effect on cortical neurons involved in spatial-temporal processing.

It is possible, however, that the beneficial effect of music, if replicated, occurs for other reasons, such as a general increase in arousal or reduction of competition between the cerebral hemispheres for spatial processing. Farah (1986) claims that there is a left hemisphere locus for the ability to generate a spatial mental image, while Corballis (1997) and Ditunno and Mann (1990) argue for relative right hemisphere specialization in visual-spatial transformations. Research on the differential processing capacities of the cerebral hemispheres for melodic stimuli suggests right hemisphere superiority for the holistic processing that is characteristic of nonmusicians (Bever & Chiarello, 1974). In addition, it has been shown that the amplitudes of event-related potentials are greater for the right compared to the left hemisphere while listening to a melody (Thomas & Shucard, 1983). Such evidence implies a right hemisphere bias in processing musical stimuli in musically naïve listeners.

It has also been noted that bimodal hemispheric stimulation of the right hemisphere with music and tactual stimuli presented to the left ear and left hand, respectively, results in an interference effect, which reduces the efficacy of the right hemisphere in processing the latter (Smith, Chu, & Edmonston, 1977). A decrement in performance on the haptic task was not observed during bimodal stimulation of the left hemisphere, relative to the control condition of no music, probably because of a floor effect. On the other hand, where music was played to the left ear during right hand discrimination of complex Braille forms, an improvement in performance occurred relative to the control condition or when music was presented to the right ear. It was hypothesized that the beneficial effect of music played to the contralateral ear on right hand performance involved reduction of interhemispheric competition for control of tactual processing, by providing the right hemisphere with its own task (music). Extending this line of reasoning, there may or may not be an effect of music on performance of a spatial task, depending on whether there is competition within hemispheres for allocation of its attentional resources and whether there is hemispheric rivalry for control of task performance.

The present study investigated these alternative explanations for the Mozart effect while attempting to replicate it. We sought to test the conflicting hypotheses presented by Farah (1986), that the left hemisphere is required for mental image generation, and by Corballis (1997) and Ditunno and Mann (1990), that there is a right hemisphere advantage for mental rotation, in order to determine the relative contributions of both hemispheres to spatial processing, and whether these contributions are affected by musical stimuli during spatial task performance. It is possible, however, that the mode of problem solving previously tested differs in terms of the cognitive strategies demanded by the tasks, causing them to be lateralized differently. Mental image generation requires the ability to reconstruct the appearances of objects and scenes not currently in view from long-term memory representations of them (Farah, 1986), while mental rotation is a visual-spatial transformation that requires the ability to construct a mental image of a presented stimulus, mentally turn, twist, or rotate this image, and match the manipulated image to a presented standard (Ditunno & Mann, 1990). These alternate spatial tasks may benefit from distinctly different strategies that may be mediated by different hemispheres, therefore accounting for the variations in results regarding the functional asymmetry of the cerebral hemispheres.

To test the hypotheses, participants completed a baseline measure of their ability to perform on spatial tasks involving mental transformation. Subsequently, they listened to classical music, jazz, or white noise during as well as immediately before performance of similar spatial tasks. Music was lateralized to the left ear/right hemisphere or right ear/left hemisphere in order to examine whether music has a facilitating or inhibiting effect on spatial performance, depending on the hemisphere to which it is directed.

Since the spatial transformation task in the present experiment coincides with those utilized by Corballis (1997) and Ditunno and Mann (1990), we expected to find a similar right hemisphere bias for spatial processing. Specifically, we predicted that performance on spatial tasks would be impaired when music was directed to the left ear/right hemisphere, due to competition for the same hemisphere's attentional mechanisms, while there would be no decrement in performance in the right ear/left hemisphere conditions. We expected that the latter condition would provide each hemisphere with its own stimulus to process, consequently eliminating any intrahemispheric competition that could negatively affect task performance. Adopting another perspective, Rauscher and Shaw (1995) hypothesize that Mozart exploits the inherent repertoire of spatial-temporal firing patterns in the cortex, leading to an organizational effect on these firing patterns so that they are excited and primed for the execution of higher brain functions, like the right hemisphere processes of spatial-temporal reasoning. This hypothesis results in the contrary prediction that when music is directed to the left ear/right hemisphere there will be a greater enhancement in performance during exposure to Mozart than during exposure to jazz or white noise.

Method

Participants

Forty-nine (13 males and 36 females) undergraduate student volunteers at a highly-selective liberal-arts institution in upstate New York.

Materials

Apparatus. Two rooms were used for this experiment, both containing the same apparatus. Each room had in it two tables and two chairs. On the first table was a pencil as well as a brief description of our experiment, a consent form, a handedness survey, and a twenty question test taken from the Differential Aptitude Test. On the other table was a computer with a keyboard. The computer was used to present two sets of problems adapted from the Differential Aptitude Test and to record accuracy and latency of participants' responses. Also on the table was a tape recorder with a set of headphones attached, and connected to the headphones was a switch controlling which ear the music from the tape recorder was played into. In each tape recorder was a tape containing one side of Mozart's music recorded from "Mozart For Your Mind", and one side of the Miles Davis Quintet recorded from "Round About Midnight."

Procedure. Subjects were brought into the room and seated at a table where they read a brief synopsis of our experiment, and were asked to sign a consent form. Subjects were then given a short questionnaire to determine handedness, following which they were administered a paper and pencil test consisting of 20 items from the Differential Aptitude Test. In this test the subject was shown a pattern on the left and four comparison stimuli on the right. Subjects had to determine which of the four objects on the right was created from the pattern on the left. Upon completion of the written portion, subjects were placed into one of three groups (classical music, jazz music, or white noise) based on the number of errors made on the paper and pencil test. An effort was made to construct groups so that they had the same average performance on the Differential Aptitude Test.

After subjects were placed into a music or noise group, they were seated at a computer and asked to place a set of headphones over their ears. Depending upon which group the subjects were placed in, they heard that specific type of music or white noise through the headphones. Each subject was asked to complete two sets of items equivalent in difficulty, taken and modified from the Differential Aptitude Test. Unlike the written portion of our experiment, the subjects were shown a pattern on the left side of the computer screen and only one object on the right hand side of the computer screen. Due to the fact that there was no lateralization, subjects were given an unlimited amount of time to determine whether or not the object on the right was created from the pattern on the left. Subjects were asked to either strike the key labeled "same" or another key labeled "different", each with a different hand. As a way of counterbalancing for hand, half of the subjects were made to hit the "same" key with their left hands and half of the subjects were made to hit the "same" key with their right hands. Upon hitting either the "same" or "different" key, the following question would come up on the screen. Throughout the first set of 20 questions, the music or white noise was played through the headset into only one ear. After the first set, a notice appeared on the computer screen telling the subjects to take a break if necessary, and when ready, flick the headphone switch over to the opposite side and proceed to the next set of questions. For the subsequent set of 20 items the subject listened to the same type of music or white noise, but the sound was played into the ear opposite to the one receiving music during the first set of questions. The computer recorded the number of correct and incorrect answers as well as the response times for each item.

Results

We hypothesized that stimulation of the right hemisphere with music presented to the left ear would interfere with spatial processing. Our hypothesis also stated that stimulation of the left hemisphere, with music presented to the right ear, and would cause a reduction in intrahemispheric competition for control of spatial processing. Our main predictions, based on these hypotheses, were that music played to the left ear would decrease performance on a spatial task and that music played to the right ear would enhance performance on a spatial task. We further predicted that Mozart's music would have a greater effect than both jazz and the control condition. For our main prediction of a music x ear interaction, no significant results were found for errors or reaction time, nor was there a main effect of music or ear. However, a significant interaction was found involving music, handedness, and ear, $F(1, 39)=4.37, p<0.05$ (see Figures 1,2, and 3). A breakdown of the analyses into musical conditions revealed no main effects for reaction time in the Mozart group, $F(1, 12)=.277, p>0.05$, the jazz group, $F(1, 11)=.675, p>.05$ or the white noise group, $F(1, 11)=.925, p>0.05$. Left handed participants in each group were found to display a significant effect of ear for reaction time, $F(2, 9)=4.89, p<0.05$, while right handers were not. Upon further analysis, the ear differences for the left handers in the Mozart group were found to be statistically significant, $F(1, 3)=70.18, p<0.05$, with enhanced performance when the music was played to the right ear. Left handers in the jazz condition showed a significant effect for differences of ear for reaction time, $F(1,$

3)=3.28, $p < 0.05$ in the opposite direction, with increased performance when music was played to the left ear. For left handers in the control condition, no significant effects were found for differences of ear for reaction time. No significant effect for differences of ear reaction time, in any of the three music conditions, were found for right handers. No significant main effect was found for music or ear, and no statistically significant interactions involving music and ear for errors were found.

Discussion

This study tested predictions of the beneficial effects of music on spatial task performance, which were based on two competing hypotheses. Smith, Chu, and Edmonston (1977) suggest that bimodal stimulation of the right hemisphere with music and tactual stimuli results in an interference effect that impairs performance on a haptic discrimination task. Therefore, since both spatial-temporal reasoning (Corballis, 1997; Ditunno & Mann, 1990) and processing of melodic stimuli (Bever & Chiarello, 1974; Thomas & Shucard, 1983) are primarily functions of the right hemisphere, we predicted that when music is directed to the left ear/right hemisphere during spatial tasks, performance will be impaired due to competition within the right hemisphere for its attentional resources. In contrast, Rauscher and Shaw (1995) hypothesize that Mozart's music facilitates the hemispheric synchronization of cortical firing patterns involved in spatial-temporal task performance, thereby enhancing spatial-temporal reasoning ability. While their study looks at the overall effect of music on both hemispheres, we make the assumption in the present study that Mozart can have the same effect on cortical firing patterns within each hemisphere individually. In accordance with this theory, we predicted that music directed to the left ear/right hemisphere will produce a greater improvement in spatial task performance during exposure to Mozart than during exposure to jazz or white noise.

No main effect of music was found in the present study. However, an interaction among handedness, music, and ear was found for reaction time. Further analysis indicated that an interaction between music and ear occurred for the reaction times of left handers only. We found that left handed participants in both the Mozart and jazz conditions had significantly different reaction times depending on which ear/hemisphere the music was directed to. Participants had a slower reaction time when Mozart was played into the left ear than when jazz or white noise were played into the left ear. Conversely, participants showed a faster reaction time when Mozart was directed to the right ear, compared to when jazz or white noise were directed to the right ear.

Left handed participants showed a significantly slower mean reaction time when music was played into the left ear in the Mozart condition compared to the white noise condition. They showed a significantly faster reaction time when Mozart was played into the right ear than when white noise was directed to the right ear. Left handed participants in the jazz condition, however, showed a significantly faster mean reaction time when music was played into the left ear compared to when white noise was played into the left ear. Participants in the jazz condition also showed a significantly faster mean reaction time when music was directed to the right ear than controls. This was an unexpected observation since we had expected the jazz and white noise conditions to show similar results. While the direction of the interaction for the white noise condition was the same as that for the jazz condition, there were no significant ear differences for the reaction times of controls.

The interaction observed in the Mozart condition coincides with our first prediction that spatial task performance would be impaired relative to controls when music is directed to the left ear/right hemisphere. In accordance with the hypothesis proposed by Smith, Chu, and Edmonston (1977), intrahemispheric competition for the same attentional mechanisms may explain the observed decrement in spatial task performance in the Mozart condition compared to the white noise condition. While this result is consistent with their findings, nothing conclusive is established by our results since we do not know the nature of the brain symmetry among these left handed individuals in our study.

On the other hand, it must be taken into consideration that left handed individuals are known generally to have less lateralization of spatial and linguistic abilities than right handed individuals. Thus there may be a greater tendency for both cerebral hemispheres to compete for processing spatial information. By playing music into the hemisphere less proficient for spatial processing, we occupy it and prevent it from interfering with right hemisphere processing, thereby resulting in improved spatial performance. This may account for the improved performance observed when left handed individuals received Mozart directed to the right ear/left hemisphere.

The results of this study are inconsistent with the prediction, based on Rauscher and Shaw's (1995) hypothesis, that when music is directed to the left ear/right hemisphere there will be a greater enhancement in performance during exposure to Mozart than during exposure to jazz or white noise. These researchers propose that Mozart's music facilitates the cortical firing patterns of the cerebral hemispheres, in effect enhancing spatial-temporal reasoning ability. The Mozart effect was not replicated in this study, in that an enhancing effect of Mozart occurred only when it was directed to the hemisphere not thought to be predominantly engaged in spatial processing. Yet such an effect was observed when jazz was directed to the left ear/right hemisphere, suggesting that this musical stimulus may have interacted with right hemisphere neurons to facilitate the spatial-temporal reasoning response. On the other hand, there is the possibility that in our particular sample of left handers, brain organization for spatial functions may have been reversed with verbal, lateralized to the left hemisphere. If this is indeed the case, Rauscher's hypothesis is consistent with our results. In the absence of independent measures of lateralization patterns for spatial functions in this study, no definitive conclusions can be drawn.

Further research regarding the functional asymmetry of the cerebral hemispheres for spatial-temporal reasoning ability in left handed individuals would be worthy of investigation in order to explain the differential results obtained from people who are right handed versus those who are left handed. Such an investigation should replicate this experiment only in left handed individuals in order to obtain a larger sample size. Future research may also be interested in lateralizing spatial stimuli to the right and left cerebral hemispheres separately in left handed people, in order to determine cerebral dominance for spatial-temporal processing. In addition, the interaction between jazz music, ear, and reaction time is also an interesting effect worthy of further investigation. It may be that other types of music, in addition to Mozart, affect spatial-temporal processing and subsequent task performance for different reasons.

Mozart Condition

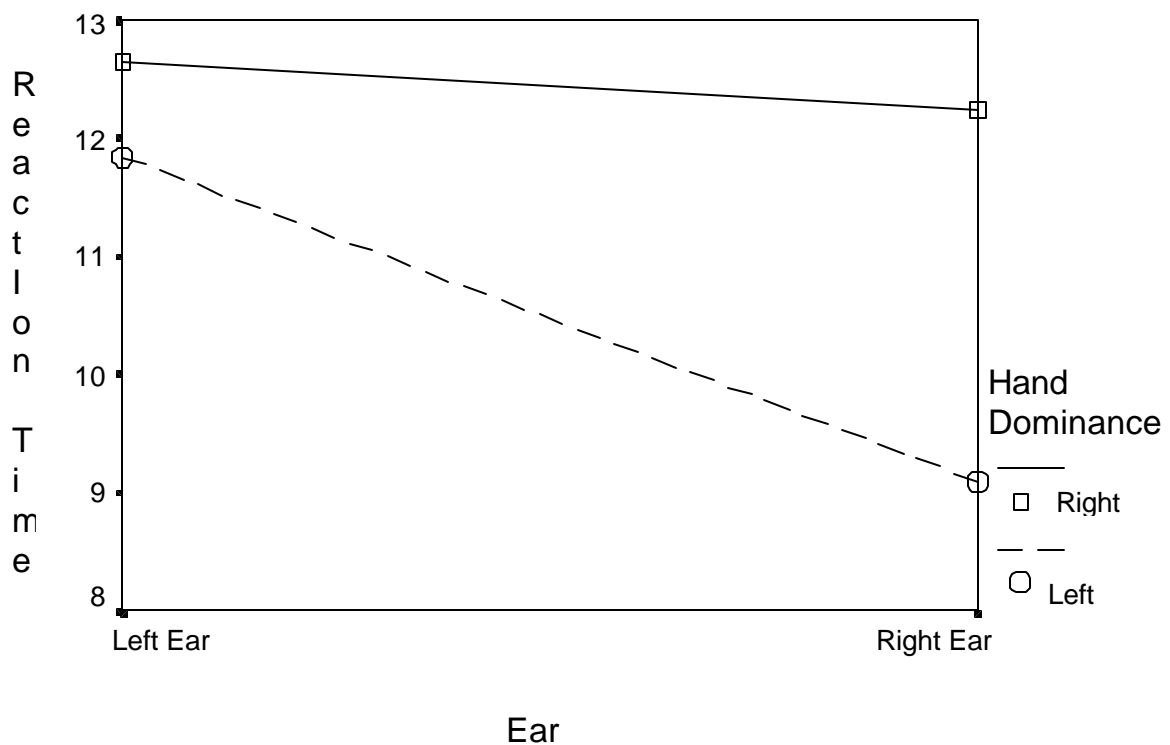


Figure 1. Reaction time as a function of ear for right and left handed participants listening to Mozart.

Jazz Condition

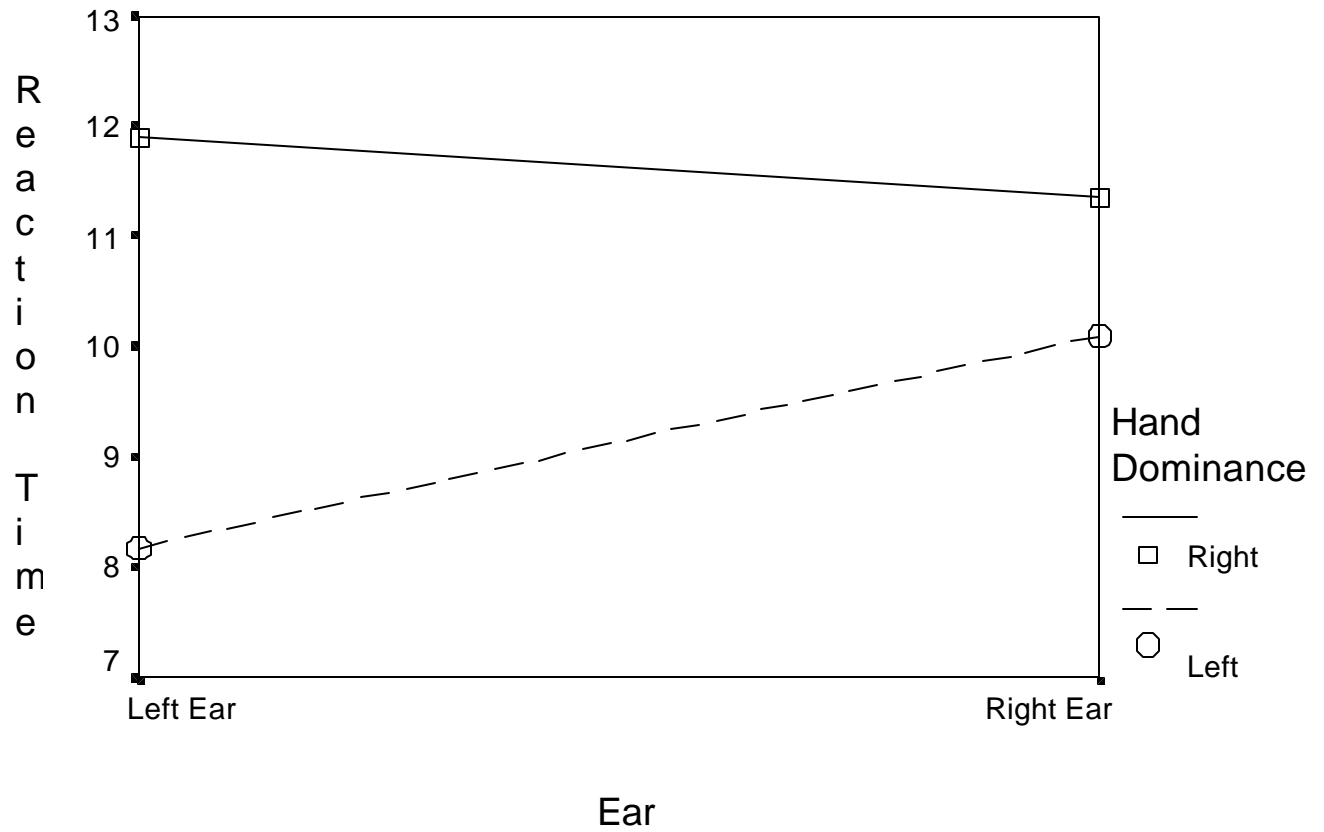


Figure 2. Reaction time as a function of ear for right and left handed participants listening to jazz.

White Noise Condition

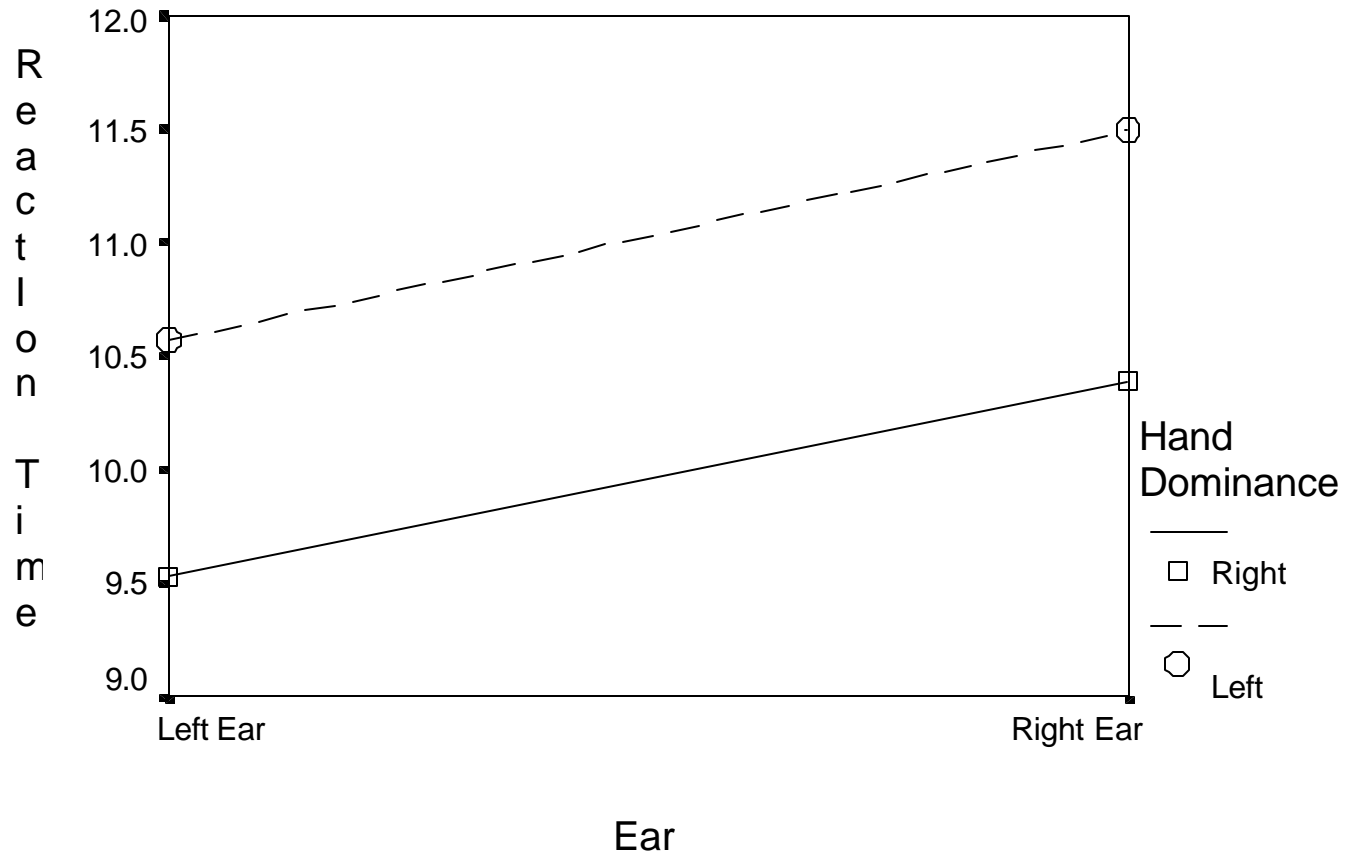


Figure 3. Reaction time as a function of ear for right and left handed participants listening to white noise.

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