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Age- and gender-related differences in visual, auditory, and visual-auditory reaction times: A cross-sectional analytical study

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ABSTRACT

Background: Reaction time is the interval of time between the presentation of the stimulus and the appearance of an appropriate voluntary response. It reflects the speed of neural processing and motor response. Age and gender significantly affect reaction time; however, most investigations have focused on restricted age ranges, single sensory modalities, or laboratory-based assessment systems. Furthermore, normative reaction-time data from simple, low-cost, and easily accessible digital assessment tools remain limited, particularly across different life decades.

Objectives: The study aimed to analyze visual, auditory, and visual-auditory reaction time across healthy age groups from 10 to 90 years and across genders using a practical, low-cost, portable, and simple digital reaction-time assessment suitable for community screening, research, and clinical practice.

Materials and methods: This cross-sectional analytical study included 579 participants aged 10-90 years, stratified into 8 decade-based age groups. The study measured visual, auditory, and visual-auditory RTs using a Reaction Time Software developed by Gary Darby (Copyright © 2001-2011). Each participant had to respond to 10 trials of each stimulus. After the test, the mean of the longest and shortest reaction time durations was measured. An analysis was conducted to compare young, middle-aged, and older adults.

Results: The longest and shortest mean reaction times for visual stimuli were 1.21±0.30 and 0.54±0.10; for auditory stimuli, they were 1.29±0.17 and 0.64±0.08; and for combined visual-auditory stimuli, they were 1.03±0.22 and 0.51±0.09 seconds, respectively. MANOVA demonstrated a significant effect of age on reaction time ($p<0.001$). Univariate analyses showed significant age-related differences across all reaction-time measures ($p<0.001$). Gender significantly affected longest response speed ($p<0.05$). The Age × Gender interaction was not statistically significant ($p>0.05$), indicating similar age-related trends in reaction time among males and females.

Conclusion: Both the longest and shortest visual, auditory, and combined visual-auditory reaction times increase significantly with age, reflecting a decline in sensorimotor processing.

Introduction

Reaction time (RT), a fundamental aspect of human cognition, has long been studied across various disciplines.[1] It is defined as the interval of time between the presentation of the stimulus and the appearance of an appropriate voluntary response in the subject.[2] Psychologists have identified three basic types of reaction time: simple reaction time (one stimulus and one response), recognition reaction time (some stimuli that should be responded to), and choice reaction time (giving a response that corresponds to the stimulus).[1-3]

RT is an important indicator of how efficiently we process information, as it reflects how quickly we interpret a stimulus and prepare a response, comprising two key components - mental processing time and movement time.[4,5] Since RT involves sensory perception as well as motor alertness, the factors affecting the sensory and motor systems can affect reaction time. RT changes with factors such as arousal,[6] age,[7] gender,[8] dominant and nondominant extremity,[9] practice and errors,[10] fatigue,[11] distraction,[12] alcohol and nicotine use,[13] personality type,[14] exercise,[15] learning disorders,[16] brain injury,[17] and illness.[18]

Aging is a multifaceted process characterized by a myriad of physiological and other changes, particularly in the mechanisms of perception and the functioning of the sensory motor system, and therefore response speed.[19] This causes a variability in reaction time to proportionately increase with age at a rate of 2-6 milliseconds per decade for simpler tasks and even greater as the complexity of the task increases.[20] A similar variability in reaction time is seen in adolescents who have slower reaction times than adults.[21] However, age-related changes are not uniform and may differently influence auditory and visual reaction mechanisms. Previous research found that auditory and visual pathways undergo varied age-related structural and functional changes, resulting in modality-specific differences in information processing speed, sensory integration, and therefore reaction-time performance.[22-24]

The stimulus used to measure reaction time may be of any sensory modality and is named as per its modality; for example, visual reaction time (VRT) is the time taken to respond to a visual stimulus. Similarly, an auditory reaction time (ART) is the time taken to respond to an auditory stimulus.[25] The human body responds to different sensory stimuli at varying speeds. Pain and Hibbs reported that simple auditory reaction time was the fastest among the sensory modalities studied.[26] Similarly, Shelton and Kumar observed shorter auditory reaction times compared with visual reaction times.[27] In contrast, Yagi *et al*. and Verleger reported faster responses to visual stimuli than to auditory stimuli.[28,29] Such contradictory findings highlight the variability in existing reaction-time literature and suggest that reaction-time performance may be influenced by participant characteristics, stimulus properties, attentional demands, methodological differences, and experimental conditions.

In addition to age, gender has also been reported to influence reaction-time performance. Previous studies have demonstrated shorter reaction times in males when compared to females across multi-stimuli tasks, due to varied factors like differences in motor response

speed, neuromuscular characteristics, attentional processing, and anthropometric characteristics.[8,30] However, the magnitude of gender-related differences in reaction time reported by these studies is small when compared with the effects of aging.

Across research published to date, a variety of tools have been used to measure reaction time, ranging from simple instruments like a 30-meter ruler[31] and finger tapping test[32] to specially designed software like Inquisit 4.0[1] and PC 1000 Hz reaction timer.[33] These software-based tools are valid and reliable for assessing reaction time. The present study utilizes an easy-to-use, accessible software developed by Gary Darby (Copyright © 2001-2011, DelphiForFun)[34] to record auditory, visual, and combined visual-auditory reaction times efficiently and accurately.

Despite the long research tradition and the wealth of evidence on age-related changes in reaction time, the combined influence of age and gender across sensory modalities remains less clear, particularly in studies spanning a broad age range and using standardized digital assessment tools.

The study therefore aims to explore the current state of knowledge and variability in visual reaction time (VRT), auditory reaction time (ART), and VRT+ART across age groups using an easy-to-use, readily available computer software. Therefore, the study seeks to fill the gap in understanding how aging affects different sensory reaction mechanisms.

Materials and methods

Study design

This cross-sectional analytical study used a convenience sample of 579 participants aged 10 to 90 years. The sample consisted of 244 males and 335 females and was stratified into eight age groups (10-20, 21-30, 31-40, 41-50, 51-60, 61-70, 71-80, and 81-90 years). Age group and gender were considered as the primary independent variables. The distribution of participants according to age group and gender is presented in Table 1. The data were collected between July 2024 and September 2025 from schools, colleges, tertiary care centers, physiotherapy OPDs, and geriatric centers in Pune.

Table 1. Age-wise distribution of participants and descriptive statistics for visual, auditory, and visual-auditory reaction times (N=579).

Age range	N	Mean Age	Male	Female	VL (sec)	AL (sec)	VAL (sec)	VS (sec)	AS (sec)	VAS (sec)
10-20	138	15.36	16	122	0.79±0.42	1.08±0.34	0.68±0.32	0.38±0.19	0.51±0.19	0.36±0.16
21-30	81	25.22	47	34	0.69±0.39	1.01±0.36	0.67±0.33	0.40±0.29	0.52±0.24	0.38±0.18
31-40	73	35.72	46	27	1.02±0.47	1.21±0.38	0.95±0.43	0.47±0.21	0.62±0.30	0.47±0.19
41-50	72	45.71	38	34	1.18±0.51	1.26±0.39	1.08±0.48	0.52±0.22	0.58±0.20	0.49±0.19
51-60	69	54.71	40	29	1.31±0.47	1.37±0.41	1.12±0.47	0.58±0.32	0.65±0.32	0.56±0.26
61-70	81	66.31	31	50	1.51±0.34	1.49±0.36	1.25±0.46	0.68±0.30	0.74±0.32	0.68±0.33
71-80	56	75.25	23	33	1.54±0.37	1.51±0.32	1.34±0.39	0.66±0.35	0.75±0.37	0.57±0.27
81-90	9	84.11	3	6	1.59±0.30	1.43±0.39	1.16±0.48	0.65±0.28	0.72±0.20	0.59±0.22
Overall	579	50.30	244	335	1.21±0.30	1.29±0.17	1.03±0.22	0.54±0.10	0.64±0.08	0.51±0.09

Note: Data are presented as mean±SD. VL: visual longest reaction time, AL: auditory longest reaction time, VAL: visual-auditory longest reaction time, VS: visual shortest reaction time, AS: auditory shortest reaction time, VAS: visual-auditory shortest reaction time, N: number of participants, sec: seconds.

Study sample

Healthy individuals aged 10 to 90 years with corrected visual acuity, with or without spectacles, and intact hearing were included. Prior to enrolment, all participants were screened by an independent Co-investigator through a structured interview and observational assessment. Individuals with a history of significant visual impairment not corrected by spectacles, hearing impairment requiring assistive devices (e.g., cochlear implants), diagnosed cognitive disorders, neurological conditions affecting response performance, or upper limb musculoskeletal conditions limiting hand movement were excluded. Cognitive status and upper limb function were screened through participant history and functional observation during the assessment procedure. The sample size was calculated using GPower 3.1 software, where the statistical power was 90%, an effect size of 0.5 was selected based on previous reaction-time studies reporting age-related differences in reaction-time performance, and α of 0.05.[35]

Ethical approval was obtained from the Institutional Ethical Committee, and written informed consent was obtained from each participant. (Reference letter: BVDUMC/IEC/52, dated 13/05/2024.) For participants below 18 years of age, written parental consent and participant assent were obtained.

Reaction time assessment

Reaction time software

In the current study, a software developed by Gary Darby (Copyright © 2001-2011, DelphiForFun)[34] was used to record outcome variables, including auditory, visual, and combined visual–auditory reaction times. Reaction time assessments were performed using the same reaction time software installed locally on two study laptop computers and used throughout the data-collection period. Before data collection, an independent co-investigator verified uniform software settings, display parameters, audio output settings, and response devices across both systems. Standardized software configurations were maintained throughout the study to minimize device- related variability in stimulus presentation. Age and gender were primary variables and were documented at the time of participant inclusion.

Position of the participants

Patients sat comfortably with their elbows supported on a table throughout the test procedure. The laptop screen was positioned at eye level; the mouse, used as the response button, was held securely in the participant's dominant hand, and participants were instructed to press it with their dominant hand (Figure 1). All participants received standardized instructions and completed one practice trial for each reaction time modality before testing to familiarize themselves with the procedure and reduce bias.

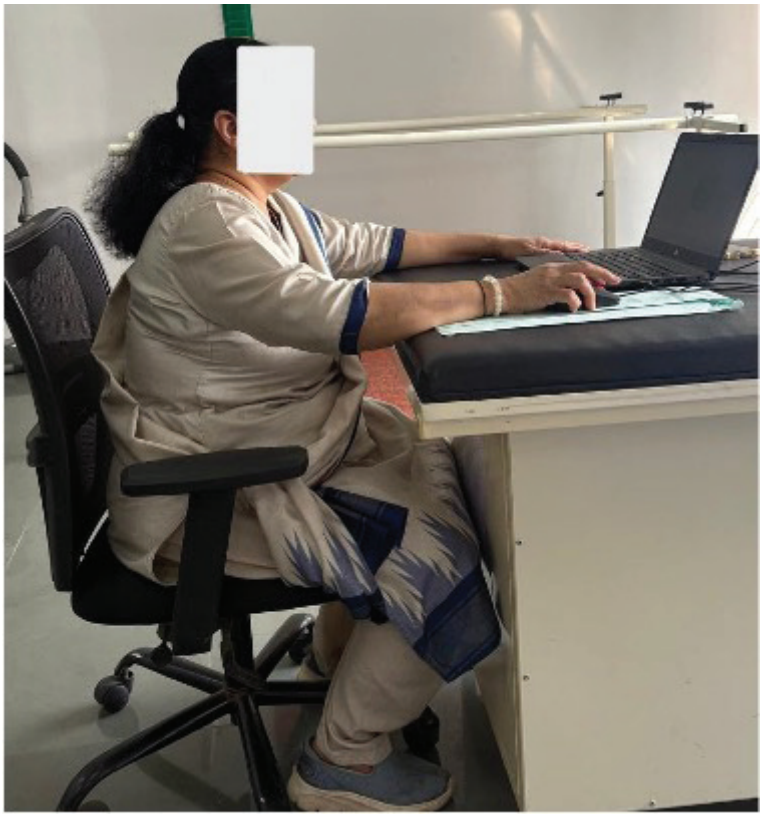


Figure 1. Testing setup demonstrating participant position, laptop placement, and dominant-hand mouse response during reaction time assessment.

Reaction time assessment was performed using digital reaction time software. Visual reaction time (VRT), auditory reaction time (ART), and visual-auditory reaction time (V-ART) were assessed in a fixed order sequence (VRT followed by ART and V-ART) under identical testing conditions for all participants by the same co-investigator who had performed the initial interview and screening.

1. *Visual reaction time (VRT) measurement:* A stimulus in the form of a blue square/circle appeared on the screen, and participants were instructed to press the mouse with their dominant hand as quickly as possible upon seeing the stimulus (Figure 2).
2. *Auditory reaction time (ART) measurement:* A bell-ring tone was played by the software, and participants were instructed to press the mouse with their dominant hand as quickly as possible upon hearing the tone.
3. *Visual and auditory reaction time (V-ART) measurement:* The bell-ring tone and the blue square box appeared simultaneously on the screen, and participants were instructed to press the mouse with their dominant hand as quickly as possible upon hearing and seeing the stimulus.

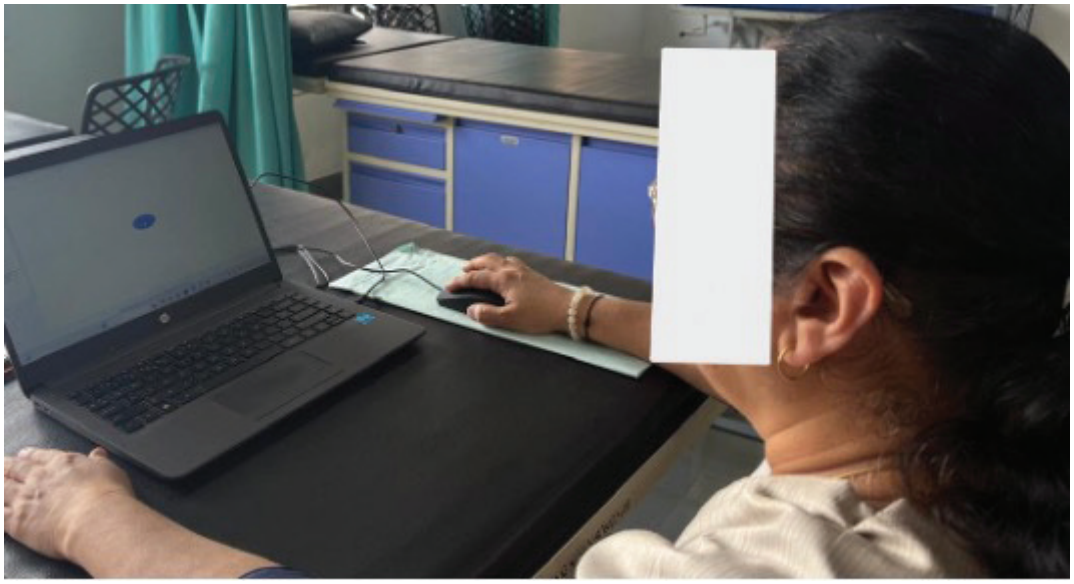


Figure 2. Visual reaction-time assessment showing the appearance of the visual stimulus on the computer screen and participant response using the mouse.

Ten trials for each modality of reaction time in a fixed order were performed to obtain a representative measure of reaction time among younger and older individuals and to account for intra-individual variability. After the 10th trial, the software automatically generated recordings of the mean reaction time, the longest reaction time, and the shortest reaction time.

The mean reaction time was the average of 10 trials performed by the subject

The longest reaction time refers to the slowest response recorded across trials. The shortest reaction time refers to the fastest response recorded across trials. For analysis, the six reaction-time variables were designated as longest visual reaction time (VL), shortest visual reaction time (VS), longest auditory reaction time (AL), shortest auditory reaction time (AS), longest combined visual–auditory reaction time (VAL), and shortest combined visual-auditory reaction time (VAS).

The total duration of testing was approximately 15-20 minutes per participant. A uniform rest interval of 2 mins was provided between reaction time modalities for all participants to minimize fatigue and maintain attention throughout the assessment. All measurements were recorded under similar conditions, in a quiet indoor environment with adequate ambient lighting. Efforts were made to minimize external visual and auditory distractions during the procedure. All assessment and testing were conducted during routine daytime hours. These readings were recorded and analyzed.

Results

A Total of 579 participants aged 10-90 years, comprising 244 males and 335 females, were enrolled in the study. They were further stratified into eight decade-wise age groups, and the distribution of participants according to age group and gender, along with descriptive reaction-time measures, is presented in Table 1. For all enrolled participants, reaction time was assessed using visual, auditory, and combined visual-auditory stimuli, recorded as the longest (slowest time to respond across 10 trials) and shortest (fastest time to respond across 10 trials) reaction times for each. Further mean scores of visual, auditory, and visual-auditory reaction times were calculated across all decade-wise stratified age groups

Table 1 demonstrates age-wise differences in visual, auditory, and visual-auditory reaction times. A progressive increase in both longest and shortest reaction times was observed with advancing age across all stimulus modalities. The lowest reaction times were observed in participants aged 10-30 years, whereas the highest reaction times were observed among participants aged 61-90 years. Across all age groups, auditory reaction times were generally higher than visual and visual-auditory reaction times, while visual-auditory reaction times were comparatively lower.

The data collected were statistically analyzed using IBM Statistical Package for the Social Sciences (SPSS) for Windows, Version 26.0 (IBM Corp., Armonk, NY, USA).

The data were checked for normality using the Shapiro-Wilk and Kolmogorov-Smirnov tests. To examine the combined effects of age group and gender on reaction time, a multivariate analysis of variance (MANOVA) was performed with age group and gender as fixed factors and six reaction-time variables of reaction time (visual longest (VL), visual shortest (VS), auditory longest (AL), auditory shortest (AS), visual-auditory longest (VAL), and visual-auditory shortest (VAS) as dependent variables.

The MANOVA revealed a statistically significant effect of age on the combined reaction time (p<0.001), indicating that overall reaction-time performance differed

significantly across age groups (Table 2). Gender also showed a statistically significant effect (p=0.022), although the effect size was small. In contrast, the age and gender interaction was not statistically significant (p=0.826), suggesting the effect of aging on reaction times was consistent across males and females.

Subsequent univariate analyses of age, gender, and age × gender Interaction with varied reaction time measures showed significant age-related differences across all six reaction-time measures (Table 3). The effect of age was largest for visual longest reaction time, followed by visual-auditory longest reaction time and auditory longest reaction time (p<0.001). Significant age effects were also observed for visual-auditory Shortest reaction time, followed by Visual Shortest reaction time and auditory shortest reaction time (p<0.001), indicating that age exerted a moderate-to-large influence on reaction time, particularly for longer response time.

Table 2. Multivariate effects of age, gender, and age × gender on reaction time measures (N=579).

	Wilks' Λ	F Statistic	*p* value
Age	0.526	F (42, 2607) = 9.106	<0.001*
Gender	0.974	F (6, 555) = 2.489	0.022*
Age × Gender	0.942	F (42, 2607) = 0.794	0.826

Note: MANOVA results for effects of age, gender, and age × gender on the combined reaction-time measures. Wilks' Λ: Wilks' lambda, F: F statistic. *Statistically significant at p<0.05.

Table 3. Univariate effects of age, gender, and age × gender on visual, auditory, and visual-auditory reaction time measures (N=579).

Variable	Age F Stat	Age *p* value	η^2	Gender F Stat	Gender *p* value	η^2	Age × Gender F Stat	Age × Gender *p* value	η^2
Visual longest	F (7,560) = 43.2	<0.001*	0.351	F (1,560) =5.19	0.023*	0.009	F (7,560) =0.07	0.999	0.001
Visual shortest	F (7,560) = 14.8	<0.001*	0.156	F (1,560) =0.21	0.647	0.000	F (7,560) =0.50	0.835	0.006
Auditory longest	F (7,560) = 20.9	<0.001*	0.207	F (1, 560) =12.5	<0.001*	0.022	F (7,560) =1.00	0.430	0.012
Auditory shortest	F (7,560) = 8.9	<0.001*	0.101	F (1, 560) =0.42	0.519	0.001	F (7,560) =0.84	0.551	0.010
Visual-auditory longest	F (7,560) = 30.7	<0.001*	0.278	F (1, 560) =3.50	0.062	0.006	F (7,560) =1.92	0.490	0.011
Visual-auditory shortest	F (7,560) = 19.5	<0.001*	0.196	F (1, 560) =0.07	0.793	0.000	F (7,560) =1.13	0.344	0.014

Note: Univariate analyses of the effects of age, gender, and age × gender on individual reaction time; η^2: eta squared; *Statistically significant at p<0.05.

Gender showed significant effects on visual longest reaction time (p=0.023) and auditory longest reaction time (p<0.001), whereas no significant gender effects were observed for shortest reaction time across all 3 sensory modalities and visual-auditory longest reaction time (p>0.05). However, the corresponding effect sizes were small, suggesting that gender accounted for only a limited proportion of variance in reaction-time performance.

The interaction between age and gender was not statistically significant across reaction-time measures (p>0.05), indicating that age influenced reaction-time performance similarly in both sexes.

Bonferroni-adjusted pairwise comparisons showed significant age-group differences across stimulus conditions (Supplementary Table S1 and Figure 3). Significant differences were most consistently observed between younger (10-20 and 21-30 years) and older age groups, particularly for VL (p=0.019 to p<0.001), AL (p=0.029 to p<0.001), and VAL (p=0.019 to p<0.001). Significant differences were also observed for VS (p=0.012 to p<0.001) and -AS (p<0.001), whereas fewer differences were observed for AS (p=0.026-0.036). Overall, between-group differences increased with advancing age, with the most pronounced differences between younger and older participants.

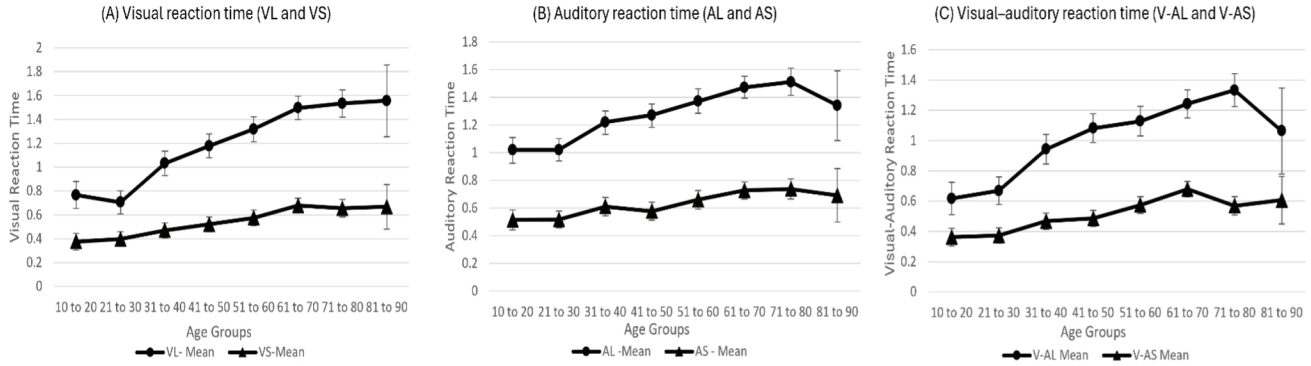


Figure 3. Estimated marginal means of reaction time across age groups for visual, auditory, and visual-auditory stimuli. Values are represented as estimated marginal means. Error bars indicate 95% confidence intervals. VL: visual longest reaction time, VS: visual shortest reaction time, AL: auditory longest reaction time, AS: auditory shortest reaction time, VAL: visual-auditory longest reaction time, VAS: visual-auditory shortest reaction time.

Overall, reaction time increased with advancing age across visual, auditory, and visual–auditory modalities. Age emerged as the principal determinant of reaction-time performance, demonstrating significant effects across all longest and shortest measures. Although significant gender differences were identified for selected longest reaction-time measures, the effect size was small. Furthermore, the non-significant age × gender interaction indicates that age-related slowing of reaction time follows a similar trajectory in either gender.

Discussion

The present study investigated age- and gender-related differences in visual, auditory, and visual-auditory reaction times across a broad age range of 10 to 90 years. The findings showed increases in both the shortest and longest reaction times with advancing age across all sensory modalities. Multivariate analysis confirmed a significant overall effect of age and gender on reaction-time performance; however, the univariate effect sizes for gender were small and varied across reaction-time measures. Furthermore, the age × gender interaction was not statistically significant, indicating that age-related changes in reaction time did not differ between males and females.

The current study demonstrated a significant multivariate effect of age on the visual, auditory, and visual-auditory reaction-time measures (Table 2), indicating an association between age and reaction-time performance across stimulus conditions. Across the reaction-time measures, the lowest estimated marginal means were generally observed among participants aged 10-30 years, whereas longer reaction times were predominantly observed among participants aged 61-80 years (Figure 3). Univariate analyses further confirmed significant age-related differences across all longest- and shortest-reaction-time variables (Table 3). This change may be attributed to multiple physiological mechanisms, such as degeneration and reduction in the number of sensory receptors, delay in information processing speed, reduced efficiency of sensory integration, reduced neuromuscular transmission, and changes in motor recruitment patterns. Previously reported studies have similarly reported age-related slowing of reaction time and processing speed. Woods *et al*. reported that increasing age is associated with slower response selection and therefore response production, while Hardwick *et al*. associated this change with slower motor preparation rather than delayed movement initiation.[20,36] Salthouse also supported this by proposing that slowing of information processing is a fundamental characteristic of cognitive aging.[22] Collectively, these findings support the present results and suggest that reaction-time slowing reflects age-associated changes occurring throughout the sensory-motor system.

The current study assessed both the shortest and longest reaction times, providing insight not only into optimal performance but also into response variability. Both the shortest and longest reaction times increased progressively with age across all sensory modalities. The shortest reaction time reflected an individual's optimal processing capability, whereas the longest reaction time reflected occasional inconsistency in attention, processing, or response execution.[1,32] Therefore, age-related increases in both measures not only suggest slower responses but also variability in performance. Previous studies have similarly demonstrated increased intra-individual variability in reaction time among older adults and linked it to reduced neural efficiency and age-related structural and functional changes across various anatomical modalities.[7,38,39] However, the effect size across all reaction-time measures and ages ranged from 0.101 to 0.351, indicating moderate-to-large age-related effects. The largest age effect was for visual longest (η^2=0.351), followed by visual-auditory longest (η^2=0.278) and auditory longest (η^2=0.207) (Table 3). These findings suggest that age influences longer responses involving greater attention or processing demands. Importantly, significant age effects (p<0.001) were observed across visual, auditory,

and visual-auditory modalities, indicating that aging affects generalized sensory processing and response execution rather than any selectively or specific sensory system. Similar observations have been reported by Der and Deary, who demonstrated age-associated slowing across multiple reaction-time modalities.[8]

The results show that visual reaction time means were shorter than auditory reaction time means across most age groups (Table 1). In the present study, participants responded more rapidly to visual stimuli despite previous reports suggesting faster auditory reaction times under simple reaction-time conditions.[26,27] This may be attributed to the nature of the testing and the spatially directed cue present in the form of visual stimuli on the screen in front of the individuals. A spatial visual cue on a screen directly within the participant's field of view may have facilitated faster motor planning and execution in the testing environment. Tang *et al*. also showed that visual spatial cues can enhance stimulus processing and improve response efficiency by directing participants' attention toward the anticipated stimulus, thereby affecting response speed.[40] Therefore, differences between the current findings and previously reported studies may be due to variations in task design, stimulus presentation, attentional demands, and testing conditions rather than sensory processing speed alone.

The mean auditory reaction time was consistently longer than the means of visual and visual-auditory reaction time across all age groups (Table 1). This may be due to several factors, such as the absence of a spatial visual cue during stimulus presentation, delayed auditory processing through both peripheral and central mechanisms, individual variation in attention, and hearing capabilities. Previous studies have demonstrated that structural and functional age-related changes within auditory pathways may have contribute to delayed stimulus detection and processing.[23] However, interpretation of these findings requires caution because formal hearing assessment was not feasible in the present study. Consequently, the prolonged auditory reaction time observed among older participants may reflect age-related hearing impairment rather than delayed sensory-motor processing alone.

The means of visual-auditory reaction-time measures demonstrated values that were generally faster than the means of auditory reaction time and similar to or faster than visual reaction time in several age groups (Table 1). This may be due to the involvement of Multisensory stimuli and their integration facilitating response time. Convergent sensory information has been shown to enhance stimulus detection and decision-making processes.[24,41] Mahoney *et al*. demonstrated that combined audiovisual stimuli produce faster responses than a single sensory stimulus in both younger and older adults, while Diederich *et al*. reported that older adults continue to benefit from multisensory stimulation despite overall age-related slowing of sensory-motor processing.[24, 41] Importantly, these findings do not infer preservation of sensory-motor function with aging, but rather indicate that multisensory stimulation may partially compensate for age-related declines in sensory processing. The fluctuations observed after the seventh decade may also reflect that the oldest age groups included fewer participants who met the study's inclusion criteria.

Gender-related differences were considerably smaller than age-related differences. Although a significant multivariate effect on the combined reaction-time measures was observed (Table 2), its corresponding univariate effects were very small (η^2=0.000-0.022), with significant differences observed only for Visual Longest (p=0.023) and Auditory Longest (p<0.001) reaction time (Table 3). No significant gender differences were observed across other sensory modalities (p>0.05). These findings indicate that gender contributes minimally to variability in reaction time as compared with age. Previous studies have reported inconsistent sex-related differences in reaction time, with some demonstrating slightly faster responses among males and others reporting small or inconsistent differences.[8, 30,37,42] The current findings suggest that any gender-related differences are likely to be of limited clinical significance.

Importantly, the age × gender interaction was not statistically significant for any reaction-time variable, with small effect sizes (η^2=0.001-0.014) (Table 3) indicating that the effect of age on reaction time was comparable in males and females, and a similar age-related pattern of sensory-motor slowing is followed across both genders. Although small gender-related differences were observed for selected variables, the associated effect sizes were small, suggesting limited practical significance. These findings are consistent with previous studies reporting that age-related increases in reaction time occurred similarly in males and females across reaction time measures.[8,30]

A major strength of the present study is its large sample size (N=579) spanning eight decade-wise age groups from 10 to 90 years, enabling comprehensive evaluation of age-related changes in reaction time across the lifespan. The detailed analysis of reaction time across all sensory modalities, such as visual, auditory, and visual-auditory combined, along with analysis of both shortest and longest reaction times, enhanced the study results by providing insights not only into optimal responses but also into variability in reaction time. This broadened understanding of sensory-motor processing and its age-related changes. This broad spectrum of variability extends beyond reaction time studies that relied on smaller age groups and a single sensory modality. This strengthens the study's validity by supporting a decline in sensory-motor integration and reaction time with advancing age across all sensory modalities.

Limitations

The present study has several limitations. Firstly, its cross-sectional design limits the ability to infer causal relationships between reaction time changes and age and does not account for cohort effects. Secondly, unequal participant distribution across age groups, particularly among individuals aged 70-90 years, may have influenced the effect size for older adults. Thirdly, formal assessment of hearing sensitivity and visual acuity was not performed. Consequently, prolonged reaction times observed in older adults, particularly for auditory stimuli, may partly reflect age-related sensory decline rather than sensory-motor processing alone. Future studies should incorporate simple sensory screening procedures, such as hearing and vision assessments, for these confounders. In addition, individual factors such as alertness, attention, and medication use were not formally controlled and may have contributed to variability in reaction-time measures.

Future study

Future research should focus on longitudinal designs to better characterize age-related trajectories of reaction time. Future research should develop age-specific normative values and cut-off scores for various modalities, types, and task-based reaction time. Further investigations should also explore the relationship between reaction time and functional outcomes such as balance, gait performance, falls risk, and mobility. Finally, interventional studies studying reaction time-based training programs and their effectiveness are also recommended.

Conclusion

The study aimed to explore the current trends in visual, auditory, and combined visual-auditory reaction time among a wide spectrum of the 10-90 years age group using an easy-to-use, reliable software. The results showed significant differences in reaction time by age and an age-related increase across all variables, reflecting a decline in sensorimotor processing. In contrast, gender had only limited effects on selected reaction-time variables, and the age × gender interaction was not significant, indicating a similar age-related decline in males and females. The multisensory modality-specific differences in the study add to our understanding of the complexity of sensory-motor processing associated with aging. Overall, the study refocuses on the dominant influence of age on reaction time and contributes valuable normative data across varied sensory modalities and age groups, thereby enhancing our understanding of sensory-motor changes associated with aging.

Ethical approval

The study was approved by the Institutional Ethics Committee, Bharati Vidyapeeth (Deemed to be University) Medical College on 13.05.2024. (Reference letter: BVDUMC/IEC/52)

Declaration of generative AI and AI-assisted technologies

During the preparation of the manuscript, the authors used AI for language editing and improvement of clarity. The authors reviewed and revised the content and take full responsibility for the accuracy, integrity, and final content of the manuscript.

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Conflict of Interest

The authors declare no conflicts of interest.

CRediT authorship contribution statement

Swati Bhise: conceptualization, funding acquisition, methodology, data curation, project administration, supervision, writing-review and editing; **Apurva Jadhav:** funding acquisition, investigation, data curation, formal analysis, writing-original draft; **Varsha Kshirsagar:** data curation, software, formal analysis, writing-review and editing; **Rachana Dabadghav:** formal analysis, writing- original draft, review and editing; **Aditya Bhise:** investigation, data curation, software management; **Nitin Talekar:** investigation, data curation, software management.

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Supplementary

Table S1. Bonferroni-adjusted post hoc comparisons between age groups for reaction-time measures.

Reaction-time measure	Significant age-group comparison	Mean difference (I–J)	Adjusted *p*
Visual longest reaction time	10-20 vs 31-40	-0.265	0.019
	10-20 vs 41-50	-0.411	<0.001
	10-20 vs 51-60	-0.551	<0.001
	10-20 vs 61-70	-0.730	<0.001
	10-20 vs 71-80	-0.766	<0.001
	10–20 vs 81–90	−0.789	<0.001
	21-30 vs 31-40	-0.327	<0.001
	21-30 vs 41-50	-0.472	<0.001
	21-30 vs 51-60	-0.612	<0.001
	21-30 vs 61-70	-0.791	<0.001
	21-30 vs 71-80	-0.827	<0.001
	21-30 vs 81-90	-0.850	<0.001
	31-40 vs 51-60	-0.286	0.004
	31-40 vs 61-70	-0.465	<0.001
	31-40 vs 71-80	-0.501	<0.001
	31-40 vs 81-90	-0.524	0.034
	41-50 vs 61-70	-0.319	<0.001
	41-50 vs 71-80	-0.355	<0.001
Visual shortest reaction time	10-20 vs 51-60	-0.199	0.001
	10-20 vs 61-70	-0.302	<0.001
	10-20 vs 71-80	-0.280	<0.001
	21-30 vs 51-60	-0.177	0.003
	21-30 vs 61-70	-0.280	<0.001
	21-30 vs 71-80	-0.258	<0.001
	31-40 vs 61-70	-0.208	<0.001
	31-40 vs 71-80	-0.187	0.004
	41-50 vs 61-70	-0.157	0.012
Auditory longest reaction time	10-20 vs 41-50	-0.247	0.004
	10-20 vs 51-60	-0.353	<0.001
	10-20 vs 61-70	-0.456	<0.001
	10-20 vs 71-80	-0.492	<0.001
	21-30 vs 31-40	-0.197	0.029
	21-30 vs 41-50	-0.246	<0.001
	21-30 vs 51-60	-0.352	<0.001
	21-30 vs 61-70	-0.454	<0.001
	21-30 vs 71-80	-0.490	<0.001
	31-40 vs 61-70	-0.258	<0.001

Reaction-time measure	Significant age-group comparison	Mean difference (I–J)	Adjusted *p*
	31-40 vs 71-80	-0.294	<0.001
	41-50 vs 61-70	-0.209	0.013
	41-50 vs 71-80	-0.245	0.005
Auditory shortest reaction time	10-20 vs 61-70	-0.214	<0.001
	10-20 vs 71-80	-0.224	<0.001
	21-30 vs 61-70	-0.211	<0.001
	21-30 vs 71-80	-0.221	<0.001
	41-50 vs 61-70	-0.151	0.026
	41-50 vs 71-80	-0.161	0.036
Visual-auditory longest reaction time	10-20 vs 31-40	-0.326	<0.001
	10-20 vs 41-50	-0.464	<0.001
	10-20 vs 51-60	-0.511	<0.001
	10-20 vs 61-70	-0.625	<0.001
	10-20 vs 71-80	-0.716	<0.001
	21-30 vs 31-40	-0.274	0.002
	21-30 vs 41-50	-0.413	<0.001
	21-30 vs 51-60	-0.459	<0.001
	21-30 vs 61-70	-0.574	<0.001
	21-30 vs 71-80	-0.665	<0.001
	31-40 vs 61-70	-0.299	<0.001
	31-40 vs 71-80	-0.390	<0.001
	41-50 vs 71-80	-0.252	0.019
Visual-auditory shortest reaction time	10-20 vs 51-60	-0.211	<0.001
	10-20 vs 61-70	-0.317	<0.001
	10-20 vs 71-80	-0.206	<0.001
	21-30 vs 51-60	-0.202	<0.001
	21-30 vs 61-70	-0.307	<0.001
	21-30 vs 71-80	-0.196	<0.001
	31-40 vs 61-70	-0.211	<0.001
	41-50 vs 61-70	-0.193	<0.001

Note: Values are based on estimated marginal means. Mean differences represent the difference between the first (I) and second (J) age groups. *p* values are Bonferroni-adjusted for multiple pairwise comparisons. Only statistically significant comparisons ($p<0.05$) are presented.