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Review Article

Audio-Visual Reaction Time Differences in Anemic and Non-Anemic Adolescent Girls: A Review

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ABSTRACT:
Anemia is a common nutritional disorder among adolescent girls and remains a significant public health concern due to its potential impact on physical, cognitive, and neurophysiological functioning. Reaction time, defined as the interval between the presentation of a stimulus and the initiation of a motor response, is a simple and sensitive indicator of sensory processing, central nervous system integration, and motor coordination. Audio-visual reaction time assessment provides valuable insight into the functional efficiency of the nervous system and can reflect subtle changes in attention, alertness, and processing speed. This review focuses on comparing auditory reaction time and visual reaction time between anemic and non-anemic adolescent girls and examining the relationship between reaction time and the severity of anemia. Evidence from comparative studies indicates that anemic adolescent girls consistently demonstrate prolonged auditory and visual reaction times when compared to non-anemic controls. These findings suggest a generalized slowing of sensorimotor processing in anemia, likely resulting from reduced oxygen delivery to the brain, iron-dependent alterations in neurotransmitter synthesis, impaired myelination, and decreased neural conduction efficiency. The impact appears to be more pronounced with increasing severity of anemia, supporting a dose–response relationship between hemoglobin levels and reaction time performance. Such neurophysiological changes may translate into difficulties in sustained attention, rapid decision-making, and academic performance during a critical period of growth and development. Audio-visual reaction time testing is non-invasive, cost-effective, and easy to administer, making it a practical functional tool for assessing the neurological consequences of anemia in adolescent populations. Incorporating reaction time measures alongside hematological parameters may enhance the understanding of anemia-related functional deficits and strengthen the rationale for early screening and intervention programs. Overall, this review underscores the importance of timely identification and management of anemia in adolescent girls to improve neurocognitive efficiency, responsiveness, and overall quality of life.
Keywords: Anemia; Adolescent girls; Auditory reaction time; Visual reaction time; Neurocognitive function

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INTRODUCTION

Adolescence is a period of rapid physical growth, endocrine changes, and brain maturation. In girls, the onset of menstruation adds a recurring iron loss at the same time that overall nutrient needs rise, making this age group particularly vulnerable to anemia. Anemia is not a single disease; it is a clinical state in which the number of red blood cells and/or hemoglobin concentration is lower than normal, reducing the blood's oxygen-carrying capacity and, therefore, the oxygen available to tissues. When oxygen delivery is compromised, organs with high metabolic demand—especially the brain—may be affected earlier and more noticeably than other systems. This is one reason anemia in adolescents is increasingly viewed not only as a hematological problem but also as a functional concern linked to day-to-day performance in school, sports, and routine activities.[1]Globally, anemia remains highly prevalent among women of reproductive age, which includes older adolescent girls. Surveillance summaries compiled by international agencies show that anemia continues to affect a substantial proportion of females in the 15–49-year range.[2] While the exact drivers vary by setting—dietary iron inadequacy, parasitic infections, chronic inflammation, hemoglobinopathies, and socioeconomic constraints—iron deficiency remains a common contributor in many adolescent populations. Even when anemia is mild, adolescents may experience symptoms such as fatigue, reduced exercise tolerance, and difficulties with concentration, which can influence academic and social functioning. Importantly, the consequences are not limited to "feeling tired." Oxygen and iron are both central to neuronal energy production and neurotransmitter function; thus, anemia can plausibly influence information processing speed, attention, and sensorimotor integration.Reaction time offers a practical window into these functional outcomes. In human physiology and behavioral science, reaction time represents the interval between the presentation of a stimulus and the initiation of a voluntary response. It is a composite measure that includes sensory detection, neural transmission, central processing (attention, decision-making, and response selection), and motor execution. Because it compresses multiple steps into a single measurable outcome, reaction time is often used as a simple, objective proxy for processing efficiency and psychomotor performance. For adolescents, whose neural circuits are still refining, reaction time can be sensitive to sleep, stress, training, nutrition, and health status. In this context, auditory reaction time (ART) and visual reaction time (VRT) become especially relevant, as they represent two of the most common sensory channels used for learning and interaction in everyday life.Audio-visual reaction time differences matter for both practical and scientific reasons. Practically, adolescents continuously rely on fast and accurate responses—answering in class, reading and copying from boards or screens, navigating traffic, playing sports, and responding to alarms, instructions, or digital notifications. Scientifically, separating auditory and visual responses can help identify whether slower performance is broad (reflecting generalized neural or motor slowing) or modality-specific (reflecting differences in sensory pathways, attention allocation, or stimulus salience). When anemic and non-anemic groups are compared, ART and VRT can therefore serve as functional indicators that complement biochemical measures such as hemoglobin and ferritin.However, to interpret such comparisons meaningfully, anemia must be defined and graded with standard criteria. International guidance has historically provided hemoglobin cutoffs to classify anemia and its severity, which supports consistent categorization across studies and populations.[4] More recently, updated guidance has aimed to refine how hemoglobin concentrations are used for assessing anemia in individuals and populations, with attention to measurement practices and interpretation.[3] Using recognized cutoffs is critical in adolescent research because small shifts in hemoglobin may translate into meaningful differences in physiological reserve during growth, menstruation, and high cognitive demand.A growing body of research links iron deficiency and anemia to altered cognitive performance, including attention and speed of processing. Reviews summarizing evidence across age groups describe associations between iron status and neurocognitive functions, with several studies reporting slower reaction times and reduced efficiency in tasks requiring sustained attention or executive control.[5] These findings provide a mechanistic rationale for examining ART and VRT in adolescent girls, particularly because adolescence is both a high-risk window for anemia and a high-opportunity window for interventions that may improve health and functional outcomes.

MATERIAL AND METHODS

This review was conducted in the Department of Physiology at **Index Medical College Hospital & Research Centre, Indore (MP)**. Relevant original research articles, review papers, and observational studies related to audio-visual reaction time and anemia in adolescent girls were identified through standard electronic databases. Studies comparing auditory and visual reaction time in anemic and non-anemic adolescent girls and those analyzing the association with anemia severity were included. Articles published in peer-reviewed journals and available in full text were considered for analysis. Data were qualitatively synthesized to summarize trends, mechanisms, and outcomes related to reaction time differences.

Adolescence, functional performance, and why reaction time matters

Adolescence is a "high-demand" stage: the body is building bone mass, expanding blood volume, and supporting hormonal changes, while the brain is simultaneously strengthening long-range connectivity and refining executive control. These developmental processes coincide with expanding academic expectations and increased participation in competitive physical and social activities. In this setting, functional measures—those that capture how well an adolescent can perform real-world tasks—become valuable complements to laboratory biomarkers. Reaction time is one such measure because it integrates sensory input, central processing, and motor output into a single, quantifiable endpoint.From a public health perspective, anemia is common in adolescent girls in many regions, and it frequently coexists with factors that also influence performance, such as dietary inadequacy, sleep disruption, and high psychosocial stress. Community-based studies in adolescent girls demonstrate that anemia prevalence can be substantial, including a notable proportion with mild or moderate anemia.[6] When anemia is widespread, even modest decrements in performance per individual may scale into meaningful population-level effects on learning and productivity.[7] Reaction time is particularly relevant because it reflects processing speed and attention allocation. In education, faster and more consistent responses support reading fluency, note-taking, and classroom participation. In daily safety and sports, reaction time can influence balance corrections, avoidance behavior, and coordinated movement. Moreover, reaction time has the advantage of being relatively quick to measure, non-invasive, and repeatable, which makes it suitable for adolescent field settings when careful protocol control is used.[8]

Anemia-related mechanisms that can influence neural processing speed

To understand why reaction time may differ between anemic and non-anemic adolescent girls, it helps to map plausible mechanisms from physiology to behavior. Reaction time depends on (1) the detection of a stimulus by sensory receptors, (2) transmission through afferent pathways, (3) central processing and response selection, and (4) motor execution. Anything that reduces the efficiency of these steps can lengthen the measured response.Anemia reduces oxygen delivery, potentially limiting aerobic energy production in neurons and glial cells. While the brain is protected by autoregulation, sustained reductions in oxygen-carrying capacity may still influence performance during tasks that require attention, speed, and coordination—especially when combined with other adolescent stressors like sleep restriction and intense study schedules. Iron deficiency can add a distinct layer: iron is involved in mitochondrial enzymes, myelin formation, and neurotransmitter synthesis. When iron is insufficient, neural signaling can become less efficient, and synaptic transmission may be altered, increasing the time needed for information processing and response initiation.[6,9] These mechanisms are consistent with findings that iron deficiency anemia may be associated with slower responses in tasks requiring executive function and psychomotor speed.[6] Additionally, in adolescent populations, menstrual blood loss can act as a recurring drain on iron stores; if dietary intake does not compensate, iron deficiency may progress from depleted stores to frank anemia, potentially producing a dose–response pattern in functional outcomes.Reaction time testing becomes useful because it can capture subtle slowing that may not be obvious clinically. When carefully standardized (same stimulus intensity, consistent practice trials, controlled environment), reaction time can detect small differences that align with physiological constraints. Protocols using auditory tones and visual light stimuli, for example, allow relatively direct comparisons across modalities while keeping the motor response constant.[8]

Auditory reaction time: pathways and typical patterns

Auditory reaction time (ART) is often faster than visual reaction time in healthy individuals, largely because auditory transduction and central processing can reach decision thresholds quickly for simple stimuli. Experimental studies comparing modalities frequently show shorter mean latencies for auditory stimuli than for visual stimuli under similar conditions.[7] This difference is helpful in anemia research because it offers a known baseline pattern: if both ART and VRT are prolonged in anemia, it suggests generalized slowing; if one modality shows disproportionate delay, it may indicate modality-specific attentional or sensory processing effects.The auditory pathway begins with sound wave transduction in the cochlea and proceeds through brainstem nuclei to auditory cortex. Although reaction time tasks are not direct tests of "hearing acuity," they are influenced by stimulus clarity, intensity, and the participant's alertness. Educational physiology materials that summarize auditory and visual pathways emphasize that reaction time measurement is an applied way to observe how quickly sensory signals can be translated into a voluntary motor output.[10] In practical testing, ART is commonly measured using tones of defined frequency and intensity presented through headphones or speakers, with a response recorded via a button press. Protocol choices matter: unpredictable timing is used to prevent anticipation, and several trials are averaged to improve reliability.[8]In adolescents, ART can be influenced by fatigue, prior exposure to loud noise, stress, and practice effects. Therefore, studies that compare anemic and non-anemic groups need to match participants on age range, ensure standardized instructions, and include familiarization trials.

Visual reaction time: pathways, task demands, and interpretive value

Visual reaction time (VRT) involves phototransduction in the retina, transmission through optic pathways, and cortical processing that is often more dependent on stimulus properties such as brightness, contrast, and color. In many simple reaction time paradigms, VRT is slower than ART, reflecting additional processing demands in the visual system and differences in how quickly the brain can interpret and respond to a visual cue.[7] This typical ordering (ART faster than VRT) provides a useful reference when comparing health states.Visual reaction time tasks vary widely: some use simple light flashes, others use colored stimuli, patterns, or screen-based cues. Studies measuring VRT frequently control ambient lighting and ensure consistent viewing distance because these factors can affect detection and processing speed.[8] Beyond sensory detection, VRT can be more sensitive to attentional fluctuations—if an adolescent's focus drifts, visual cues may be missed or processed more slowly, increasing the average reaction time. Educational resources describing visual pathways highlight that visual processing is layered, involving early detection of a stimulus and then higher-level interpretation.[12] While basic VRT tasks are “simple” compared to complex cognitive tests, they still require sustained alertness, rapid stimulus discrimination, and efficient motor output. Therefore, VRT can be informative in conditions where attention and processing speed may be subtly impaired.In the context of anemia, prolonged VRT may reflect reduced cerebral oxygenation reserve or iron-related neurochemical changes that affect attention and response selection. Research in adolescents with iron deficiency anemia has reported significantly increased VRT, suggesting slower psychomotor responses.[9] Similar findings appear in comparative work focused on adolescent girls, where lower hemoglobin levels are discussed in relation to attentiveness and neuronal metabolic activity—factors that can plausibly influence visual response speed.[10]

Audio-visual reaction time differences: integrating modalities in interpretation

When studies report both auditory and visual reaction times, the combined pattern can clarify what aspect of performance is most affected. Audio-visual reaction time (AVRT) in many adolescent studies is not a single “combined stimulus” task but rather an interpretive pairing: ART and VRT are measured separately and compared to understand modality-specific and overall psychomotor speed. The repeated observation that ART is faster than VRT in healthy groups provides a baseline expectation.[7]Ifanemia increases both ART and VRT, the most straightforward interpretation is generalized slowing—potentially due to reduced oxygen delivery or iron-dependent inefficiencies in neural processing.[6],[9] If VRT is disproportionately affected, researchers may consider whether attentional load, visual pathway processing, or environmental testing variability played a greater role. If ART is disproportionately affected (less common), auditory stimulus design or participant familiarity with the task might need scrutiny.Methodologically, reaction time is sensitive to device latency, stimulus presentation timing, and response recording resolution. Studies comparing modalities often emphasize careful standardization so that differences are physiological rather than technical. Protocols using defined tones and controlled light stimuli (often via dedicated reaction time apparatus) aim to reduce bias. Work exploring auditory and visual reaction time relationships in healthy samples provides background norms and demonstrates how stimulus parameters can influence measured latency.[11,12] For adolescents, the interpretive value is amplified because reaction time reflects both biological status and day-to-day functioning. A mild increase in reaction time may not appear clinically “abnormal,” yet it can still affect classroom responsiveness and coordination in sports. In populations where anemia is common, even small performance shifts may influence educational outcomes at scale.[11]

Measuring ART and VRT in adolescents: protocols, reliability, and confounders

Accurate reaction time measurement requires more than a stopwatch and a cue. Reaction time is influenced by anticipation, learning effects, fatigue, and motivation, so protocol design matters. Most studies employ multiple trials per modality, discard outliers (e.g., accidental button presses), and use the mean or median as the participant’s representative value. A brief practice period is essential because first-trial delays often reflect unfamiliarity rather than physiology.[8]Stimulus control is equally important. For ART, tone frequency and intensity should be standardized; for VRT, luminance, contrast, and color should be consistent. The testing environment should minimize distractions and maintain stable lighting and noise conditions. Equipment differences can create systematic bias: some digital interfaces have display and input lag, while dedicated reaction-time apparatus can offer more consistent timing. When comparing anemic and non-anemic groups, ideally both groups are tested on the same device, in the same environment, and at similar times of day to reduce circadian effects.[8],[13]Participant selection and screening reduce confounding. Uncorrected visual refractive errors can slow VRT; hearing problems or recent loud-noise exposure can affect ART. Caffeine intake, acute illness, sleep restriction, and anxiety can alter reaction time in either direction. Adolescents may also differ in baseline physical activity and sports training, which can influence psychomotor speed. Thus, studies often exclude participants with neurological disorders, acute infections, or medication use that affects the central nervous system, and they standardize pre-test instructions (e.g., avoid heavy exercise immediately before testing).[8]

Evidence base: reaction time differences in iron deficiency anemia

Among studies directly connecting anemia to reaction time, research on iron deficiency anemia (IDA) is particularly informative because it links a common adolescent nutritional problem to measurable psychomotor outcomes. A focused study examining the effect of iron deficiency anemia on audiovisual reaction time in adolescents reported significantly prolonged ART and VRT in the anemic group, suggesting deterioration in sensorimotor performance associated with reduced iron status.[9] This kind of evidence supports the core premise of comparative work in adolescent girls: anemia may be reflected not only in laboratory values but also in functional speed of responding.Comparative studies in adolescent girls also describe similar patterns and discuss plausible explanations such as decreased attentiveness and lower neuronal metabolic activity when hemoglobin is reduced.[10] While such interpretations must be cautious—because attention and motivation can also shift reaction time—the consistent directionality across ART and VRT strengthens the argument for a physiological contribution.It is also important to view these findings within broader developmental literature. Reviews of iron deficiency and cognition have described associations between anemia and poorer cognitive and motor outcomes, including slower reaction time performance in certain tasks, reinforcing that psychomotor speed can be sensitive to iron status.[6] Together, these sources suggest that anemia-related slowing may represent a functional signal of compromised neural efficiency.

Correlating reaction time with anemia severity: conceptual and analytic notes

One of the most meaningful extensions of a simple anemic vs non-anemic comparison is to test whether reaction time varies with anemia severity. Conceptually, a severity gradient is plausible. Lower hemoglobin reduces oxygen-carrying capacity, and more severe anemia may restrict physiological reserve more strongly during tasks that require sustained attention and rapid motor initiation. For iron deficiency anemia, severity may also reflect longer duration or deeper depletion of iron stores, which can influence myelination, neurotransmitter systems, and overall neural energetic efficiency.[6],[9]Analytically, severity correlation is not always straightforward. Hemoglobin is a strong classifier for anemia status, but it is not a perfect proxy for iron status or for the functional impact on the nervous system. Two adolescents with similar hemoglobin may differ in ferritin, inflammation status, sleep quality, and stress—factors that can alter reaction time. Still, within a well-defined sample, correlations can provide useful evidence of dose–response and strengthen causal plausibility.Studies that examine RT alongside hematological indices often emphasize consistent measurement conditions because RT variance can be large. Protocol papers and correlational studies in healthy populations illustrate that stimulus parameters and individual differences can shift RT values, which is why multiple trials and standardized conditions are essential before attributing differences to anemiaseverity.[8],[13]

Contextual factors in adolescent girls: menstruation, nutrition, and daily routines

In adolescent girls, anemia risk and reaction time performance are embedded in a real-life context shaped by menstruation patterns, diet quality, and routine pressures. Menstruation can introduce recurring iron loss, and in settings where dietary iron intake is limited or dominated by low-bioavailability sources, adolescents may gradually move from low iron stores to iron deficiency and then to anemia. This progression matters for reaction time research because iron depletion may affect cognition and attention even before hemoglobin falls substantially, while frank anemia may amplify effects through reduced oxygen delivery.[6],[9]Nutrition is not only about iron quantity but also about absorption and co-nutrients. Diets low in heme iron or high in absorption inhibitors can contribute to deficiency. Additionally, adolescents often have irregular meal patterns, skip breakfast, or consume energy-dense but micronutrient-poor foods—habits that can influence both anemia risk and acute testing performance (e.g., hypoglycemia, fatigue). Sleep restriction is another common adolescent factor; sleep loss can slow reaction time substantially and may confound anemia comparisons if not measured or controlled.[14,15] Socioeconomic context can compound these influences. Studies describing anemia prevalence in adolescent girls often link higher anemia rates with broader determinants such as lower socioeconomic status, highlighting that anemia may cluster with other stressors that affect cognitive performance.[11] Therefore, reaction time studies benefit from collecting basic contextual data (sleep duration, recent illness, dietary patterns, physical activity) so that anemia-specific associations can be interpreted more confidently.

Implications for screening, interventions, and research directions

The evidence that anemia—particularly iron deficiency anemia—can be associated with slower auditory and visual reaction times suggests that adolescent anemia may have functional consequences beyond traditional clinical symptoms.[9],[10] For clinicians and school health programs, this supports the view that anemia screening is not only about preventing severe outcomes but also about protecting everyday cognitive and psychomotor performance. Where anemia prevalence is high among adolescent girls, integrating hemoglobin assessment with broader nutrition and health education may offer meaningful gains in learning readiness and well-being.[11],[15]For interventions, the practical question is whether improving iron status leads to measurable improvements in reaction time. While this review focuses on differences rather than treatment effects, reaction time could be a useful outcome in intervention studies because it is objective, quick, and can be repeated across follow-up points. To build stronger evidence, future studies should incorporate standardized reaction time protocols, robust anemia classification, and (where feasible) iron indices such as ferritin, alongside careful control of sleep, acute illness, and stimulant intake.[8],[9]

CONCLUSION

This review highlights that anemic adolescent girls consistently exhibit prolonged auditory and visual reaction times compared to their non-anemic counterparts, indicating reduced sensorimotor and cognitive processing efficiency. The slowing of reaction time appears to correlate with the severity of anemia, emphasizing the functional impact of reduced hemoglobin and iron status on the nervous system. Audio-visual reaction time assessment thus serves as a simple and effective functional marker of neurocognitive performance in adolescents. Early identification and appropriate management of anemia may help improve reaction time, attentional capacity, and overall academic performance in adolescent girls.

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