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The Neurocognitive Effect Of Augmented Visual Feedback On Learning The Back Handspring Skill In Gymnastics Among College Students Diverse Learning Methods

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Abstract

Study purpose. This study examines the impact of enhanced visual feedback on learning the back handspring in gymnastics among female students, focusing on the interaction between learning styles (visual, auditory, sensory/kinesthetic) and performance improvement.

Materials and methods. Thirty second-year female students were divided into three groups based on their learning style (visual, auditory, sensory/kinesthetic). The study used the VARK scale, EMG device for muscle response measurement, slow-motion video for visual feedback, and performance evaluation forms. Pre- and post-tests were conducted, with feedback tailored to each group's learning style.

Results. Significant improvements were observed in all groups. The Visual Group showed the highest improvement ($p < 0.01$), followed by the Kinesthetic Group ($p < 0.01$), and the Auditory Group ($p < 0.05$). ANOVA revealed significant differences between groups ($p < 0.01$). The Visual and Kinesthetic Groups showed an inverse relationship between response time and performance accuracy, while the Auditory Group did not.

Conclusions. The study concluded that visual feedback significantly enhances motor skill learning, particularly for visual learners. Sensory feedback also contributed to performance improvement. The Visual Group showed the best results, highlighting the importance of aligning teaching methods with learning styles for optimal performance. EMG data confirmed that visual and sensory feedback improves neuromuscular response speed and accuracy.

Keywords: Motor Skills, Electromyography, Visual feedback, Learning, Learning Styles

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Introduction

Learning motor skills is one of the main pillars of physical education and plays a central role in gymnastics, which requires high neuromuscular coordination, precision in performance, and quick motor responses. One of the complex skills that requires gradual acquisition is the back handspring, which is a clear example of motor learning based on feedback and cognitive-neural organization of movement.

Recent research in motor learning has shown that providing visual feedback, especially reinforced feedback, is one of the most effective ways to consolidate motor representations in the central nervous system, as it allows learners to correct errors by closely observing their performance in comparison to the ideal model (Sidarta et al., 2018). Cognitive neuroscience studies have also indicated that the pattern of neural processing of information changes depending on the type of visual, auditory, or tactile perception, which is consistent with the classification of learning styles according to the VARK model, which shows that optimal learning is greatly influenced by the means of presenting information (Shalja et al., 2018; Uher et al., 2025).

The importance of integrating visual feedback and diverse learning styles into the motor learning process has increased with the development of measurement and analysis tools, including digital visual analysis, slow motion video, and instant visual review, which play a dual role in strengthening neural responses on the one hand and stimulating cognitive motivation on the other (Mödinger et al., 2022; Potdevin et al., 2018).

From a neurocognitive perspective, the brain does not process feedback in a uniform manner; rather, motor perception is processed according to the learner's pattern of information reception. Therefore, the variation in response time and performance accuracy among learners can be explained in part by differences in their neurocognitive styles (Iuculano et al., 2020; Liu et al., 2023).

From this perspective, this research examines the effect of enhanced visual feedback on specific neurocognitive variables within the context of learning the back handspring skill, and according to the classification of learning styles, which contributes to the development of field teaching methods in gymnastics and enhances our scientific understanding of how the human brain responds to motor learning stimuli.

The research problem concerns the difficulty of learning the back handspring in gymnastics among female students at the Faculty of Physical Education and Sports Sciences, where a difficulties in acquiring and executing the skill correctly is observed despite repeated training. It is believed that this weakness is not only related to the complex nature of the skill, but also to the incompatibility of the method of presenting information or feedback with the student's learning style. Studies indicate that learning styles (visual, auditory, sensory/kinesthetic) affect information absorption, and that reliance on traditional feedback may prevent students from building an accurate motor image. Therefore, this study aims to examine the effect of enhanced visual feedback on skill learning among female students according to their different learning styles (El-Saftawy et al., 2024).

Research objectives: 1. To identify the effect of enhanced visual feedback on learning the back handspring skill in gymnastics among female students at the College of Physical Education and Sports Sciences, University of Baghdad. 2.To identify the interaction between learning style and enhanced visual feedback in improving response time and motor performance accuracy. 3.To identify differences in the level of learning the back handspring skill in gymnastics among female students at the College of Physical Education and Sports Sciences according to different learning styles (visual, auditory, sensory/motor).

Research hypotheses: H1. There are significant differences between the pre-test and post-test in learning the rear wheel skill in favor of the post-test. H2. There are significant differences in the level of learning among students according to learning styles. H3. There is an interactive effect between the type of visual feedback and learning style in improving cognitive motor performance.

The research sample included second-stage female students from the Faculty of Physical Education and Sports Sciences for women, University of Baghdad, conducted in the college's gymnastics hall between February 1 and April 1, 2025.

Materials and methods

Given the nature of the research problem, which involves measuring the "effect" between two variables (enhanced visual feedback and learning styles) and their impact on learning a motor skill (back handspring), a pre-post experimental design with equal groups was chosen. This design is considered the most appropriate for measuring the effect of a specific independent variable (feedback pattern) on a dependent variable (level of skill and neurocognitive performance), ensuring control of environmental conditions and accurate comparison of differences.

Study participants

The research community consists of second-year female students at the College of Physical Education and Sports Sciences, University of Baghdad. The research sample was selected intentionally, as the students are taking technical gymnastics at this level, and there are 30 students in total. They were divided into three equal groups (10 students per group), according to the results of the VARK learning styles assessment, as follows:1- Group (A): Visual style. 2- Group (B): Auditory style. 3- Group (C): Kinesthetic/sensory style.

The sample size of 30 participants was determined based on the study's objectives and feasibility considerations. This number ensures sufficient statistical power to detect meaningful differences while maintaining practicality in terms of time, resources, and participant availability. Additionally, the size is consistent with similar experimental studies in physical education, providing a representative group that reflects the characteristics of the target population.

Study organization

Equipment and tools used

1. VARK scale: to determine the dominant learning style of each student.
2. EMG (Electromyography) device: to measure muscle response time during performance.
3. High-definition video with slow motion analysis: to provide enhanced visual feedback.
4. Technical performance observation forms for the back handspring skill, prepared in accordance with International Gymnastics Federation standards.

Validity and reliability of research tools: This is the degree to which a tool measures what it is intended to measure, i.e., the extent to which the tool's items represent the concept or behavior to be measured. Validity is a prerequisite for the integrity of research results. Types of validity include content validity, criterion validity, and construct validity. Reliability is the degree to which the results of the tool are consistent when reapplied in similar circumstances. It refers to the extent to which the tool is free from random variation. The most common methods of calculating reliability are test-retest and Cronbach's alpha coefficient. As shown in Table 1.

Table 1. Shows the type of honesty and consistency used in the research.

Type of Tool	Type of Validity	Reason for Use	Type of Reliability	Reason for Use
Skill Performance Evaluation Form	Content Validity	To verify that the items cover the skill dimensions related to the back handspring through expert opinions.	Test-Retest Method (Reliability Coefficient 0.88)	To assess the consistency of the sample's performance when the evaluation is repeated using the

				same tool under the same conditions.
VARK Learning Styles Questionnaire	Content and Construct Validity	Since the questionnaire is translated from a reliable source, and its cultural appropriateness for the target group has been ensured.	Reliability Supported by Scientific Sources	Because the questionnaire has demonstrated high reliability in previous educational psychology research studies.

The research tools (questionnaires + performance guide) were presented to five experts specializing in motor learning and technical gymnastics, who made minor adjustments and approved them, thereby enhancing the validity of the content. The stability of skill performance was verified by applying the tool twice to a pilot sample, with an appropriate time interval, and the stability coefficient (0.88) was calculated, which is acceptable in educational statistical standards. The VARK scale used is the approved international version, which has been translated with academic approval and is documented in terms of validity and reliability in several previous studies.

Procedures

After preparing the hall and equipping the gymnastics hall with the necessary tools (floor mats, cameras, computers). Prepare correct performance models by recording and filming an expert trainer performing the back handspring from different angles to prepare visual material for the presentation. The EMG device was set up and calibrated according to the company's instructions, with surface electrodes attached to the target muscles (quadriceps and popliteus) after appropriate skin preparation, sampling frequency (1000 Hz), signal processing with a bandpass filter (20-450 Hz), full rectification, and smoothing with a 50 ms RMS window. The device measures the electrical activity of the muscle during contraction to determine the neural response time and activation intensit (Konrad, 2005). .To enhance reliability, a pilot test was conducted on (n = 30) participants with identical conditions. The results showed internal correlation coefficients (ICC) ranging from 0.86 to 0.93, standard error of measurement (SEM) of 4.8 ms, and coefficient of variation (CV) of 7.5%, confirming good to excellent reliability of the EMG measurements in this study. The device attaches surface electrodes to the skin over the target muscles (e.g., quadriceps, psoas, hamstrings) and monitors the nerve signals sent from the brain to the muscle during movement. It is used to determine the response onset time and degree of muscle activation during the performance of the 'back handspring' skill, providing an accurate indicator of the efficiency of neuromuscular coordination associated with learning. After preparing all the tools, the pre-test for each student began, as follows:

1. Preliminary test for all students: At 9:00 a.m., after all students had arrived, a back handspring skill test was conducted for each student and their performance was recorded on camera. EMG data was also recorded during the test. Performance was then evaluated by a committee of trainers using a technical performance evaluation form.
2. VARK test for all students: They were classified into three groups according to their learning style (visual, auditory, or kinesthetic).
3. Field implementation and application of the VARK scale: The original version of the VARK scale, designed for university students, was used, with a certified translation adapted to the educational environment of the students. A suitable room was prepared for conducting the test in a group setting. Sufficient copies of the questionnaire (paper version) were printed, and a brief explanation was given to the students about the nature of the scale and the importance of identifying learning styles in performance development. The scale contains approximately 13 to 16 multiple-choice questions, as

shown in table 2, and students are asked to select one or more answers that represent their actual learning behavior. There are no "right or wrong" answers; rather, the focus is on the recurring response pattern. After collecting the answers, they are analyzed according to the official approved correction key, and the total for each style (visual, auditory, sensory) is calculated. Students are classified according to the highest total into one of three groups:

1. Visual group
2. Auditory group
3. Sensory/kinesthetic group. To classify the sample, the data is entered into a special record.

The sample is divided into three homogeneous groups according to style:

1. Visually oriented learners
2. Auditory learners
3. Sensory/kinesthetic learners

Table 2. Learning Style Preferences and Their Influence on Motor Skill Acquisition in Gymnastics

No	Question Focus	Visual	Auditory	Kinesthetic/Tactile
1	Learning a new skill	Watching a video	Listening to explanation	Practicing it myself
2	Studying scientific content	Drawing diagrams	Listening orally	Using tools/movement
3	During a lecture	Seeing pictures	Clear verbal explanation	Performing activities
4	Remembering instructions	Visualizing movement	Repeating orally	Practicing physically
5	If not understood	Watching again	Asking for repetition	Doing it practically
6	Practical exams	Watching model	Listening carefully	Repeating performance
7	Written instruction sheet	Checking illustrations	Reading aloud	Performing steps
8	Class attention	Visual aids	Instructor's voice	Activities/practices
9	Correcting errors	Watching video + explanation	Verbal correction	Guided correction
10	Theoretical exams	Diagrams	Oral study	Acting/movement link
11	Gymnastics lectures	Images/slides	Lecture audio	Practiced skills
12	Thinking of an answer	Mental image	Internal voice	Bodily feeling
13	Improving performance	Videos/diagrams	Recorded explanation	Repetition practice

All students were confirmed to understand the nature of the questions before starting. No student is excluded even if she shows a tendency toward two styles; rather, the predominant style is adopted according to the highest score. This classification helps link the learning style to the visual feedback method later in the training stages, which is the essence of the problem and the objectives of the research. Each group underwent a special program according to its learning style and schedule, as shown in table 3.

Table 3. Shows the program according to learning style

No	Group	Feedback Method	Execution Mechanism
1	Visual	Slow-motion video + angle correction	Errors highlighted and model analysis shown after each attempt
2	Auditory	Audio description + instructor's guidance	Instructions replayed during execution
3	Kinesthetic	Touch instruction + manual correction	Physical assistance to feel correct posture with exercises

Each session included a warm-up, a brief explanation, attempts at execution, feedback after each attempt, collection of EMG data for the first and last performances, and video recording of each student's performance.

A post-test was conducted at around 9 a.m. at the designated location, and the researcher was able to verify the temporal, spatial, and environmental conditions to ensure the stability of the test. The post-test phase included the following: 1- testing the back handspring with video recording. 2- New EMG recording. 3- Technical reassessment by the same committee.

Statistical analysis

The t-test was used for paired samples to compare pre- and post-measurements within each group. Analysis of variance (ANOVA) was also applied to compare the three groups after the application. To extract the significance of post-test differences between patterns, the LSD test was used. In addition, Pearson's correlation coefficient was used to analyze the relationship between response time and performance accuracy. All analyses were performed using SPSS version 26.

Results

The results in Table 4 show statistically significant differences between the pre- and post-tests, but to a lesser extent than in the visual group. This is because the auditory method is less interactive in learning complex motor skills that require visual perception of body movement in space. Auditory learners may understand the instructions, but they lack the motor imagery provided by visual media.

Table 4. Shows The Arithmetic Mean, Standard Deviation, Calculated T-Value, And Significance For The Auditory Experimental Group.

No.	Test Type	Mean	S.D.	t Value	p Value
1	Pre-test	6.25	0.68	4.61	0.001
2	Post-test	7.22	0.55		
*: significant at p<0.05					

The results are shown in Table 5 that there was a significant improvement in the performance level of the sensory-motor group. This is attributed to the fact that this group learns better through direct practice and motor sensation during performance. Manual correction and motor guidance contributed to building the appropriate muscle-motor sensation for performing the skill.

Table 5. Shows the arithmetic mean, standard deviation, calculated t-value, and significance for the sensory/motor experimental group.

No.	Test Type	Mean	S.D.	t Value	p Value
1	Pre-test	6.14	0.66	6.97	0.0001
2	Post-test	8.12	0.52		
*: significant at p<0.05					

Table 6 presents the comparison between the three groups (Visual, Auditory, and Kinesthetic) in mean performance. The Visual group recorded the highest mean (8.91) and was significantly superior to both other groups (p = 0.0005). The Auditory group achieved a mean of 8.12 and was superior only to the Kinesthetic group (p = 0.002). In contrast, the Kinesthetic group obtained the lowest mean (7.22) without significant superiority over the others.

Table 6. Shows the arithmetic mean results, the calculated f value, and the significance level for the three groups.

No.	Group	Mean	Comparison of Differences	p Value
1	Visual	8.91	Superior to Kinesthetic and Auditory	0.0005
2	Auditory	8.12	Superior to Kinesthetic only	0.002
3	Kinesthetic	7.22	—	—
4	F Value	—	8.35	0.001
*: significant at p<0.05				

Table 7 shows a strong negative correlation between neural response time and technical performance for the Visual and Kinesthetic groups, both statistically significant. This indicates that faster neural responses were associated with higher performance accuracy in these groups. In contrast, the Auditory group showed a weaker negative correlation that was not statistically significant. This may be due to the reliance on verbal instructions alone, which provides less concrete or immediate feedback for correcting complex motor skills like the back handspring. Unlike visual or kinesthetic feedback, auditory guidance may not sufficiently engage the neural pathways required for rapid sensorimotor integration, resulting in a less consistent relationship between response speed and performance accuracy. These findings highlight the importance of matching feedback type to learning style to optimize neuromuscular adaptation and skill acquisition.

Table 7. Correlation Coefficients of Different Groups and Their Significance

No	Group	Correlation Coefficient (R)	P Value
1	Visual	-0.74	0.002
2	Kinesthetic	-0.65	0.010
3	Auditory	-0.48	0.084
*: significant at p<0.05			

Discussion

The results showed statistically significant differences between the pre-test and post-test for the visual group, with the post-test showing better technical performance in the back handspring. This is consistent with the first research hypothesis, which states that enhanced visual feedback positively affects skill learning. This can be explained by the fact that the use of slow motion video and detailed motion analysis provides learners with a visual opportunity to correct errors immediately and directly, which enhances the construction of correct motor representations in the brain (Khalaf et al., 2024). This result supports the findings of (Unell et al., 2021), who indicated that visual feedback increases the effectiveness of motor learning, especially in complex skills that require precise movement control. This is consistent with the findings of (Shafer et al., 2019), who found that neural processing of motor stimuli is enhanced when visual feedback is used, leading to faster response times and improved performance accuracy. These effects explain the significant superiority in technical performance improvement of the visual group.

The results also showed statistically significant differences between the pre- and post-tests of the auditory group, but to a lesser extent compared to the visual group. This can be explained by the fact that learners who rely on the auditory style benefit from verbal instructions, but may have difficulty visualizing the three-dimensional movement necessary to perform fine motor skills such as the back handspring.

This is consistent with the recommendations of (Rogowsky et al., 2015), which showed that auditory learning is less effective in acquiring complex skills than visual and sensory learning, especially when teaching relies solely on verbal description. This points to the importance of integrating multimedia, so that feedback is not limited to the auditory modality alone, but is supported by visual images or sensory stimulation to reinforce learning.

The kinesthetic group showed improvement between the pre- and post-tests, indicating the effectiveness of teaching methods that rely on touch and sensory correction in enhancing motor skill learning. This is consistent with (Matsuura et al., 2023) finding that kinesthetic learners rely on direct physical sensation in learning skills, and that interventions focusing on manual posture correction and practical guidance contribute significantly to performance improvement. This improvement can also be explained by the enhancement of sensory and muscular perception in the students, which improves the muscular and nervous coordination required to successfully perform the back handspring (Hassan & Musharef, 2024; Muttib et al., 2024).

The analysis of variance also showed clear statistically significant differences between the three groups in the post-test, with the visual group outperforming the sensory group, followed by the auditory group in last place. This superiority is due to the fact that complex motor skills such as back handsprings rely heavily on visual perception, which provides an accurate perception of the required movement and real-time error correction, which is provided by the enhanced visual feedback method. This is supported by the VARK model, which highlights that the compatibility between an individual's learning style and the educational presentation method has a fundamental impact on the quality and effectiveness of learning (Tomić et al., 2023). This difference in results confirms that choosing a learning strategy tailored to the learning style can increase the efficiency of acquiring mathematical skills, which calls for the need to design training programs that take these individual differences into account (Cardino Jr & Cruz, 2020).

The analysis of the correlation between response time and performance accuracy based on EMG data showed that there was a statistically significant inverse relationship between neural response time and technical performance accuracy in the visual and sensory groups, while the relationship in the auditory group was less clear (Kania et al., 2024; Waleed Abdulkareem & Sattar Jabbar, 2025). This result shows that training using visual or sensory feedback not only improves skill quality, but also enhances neuromuscular response speed, indicating the development of cognitive neural adaptation as a result of intensive practice (Abdulghani et al., 2025; Krigolson et al., 2015). These results are consistent with the research of (Barradas et al., 2023; Sanford et al., 2022), who showed that exercises supported by effective feedback improve the central nervous system's ability to activate muscles more quickly and accurately, which is crucial in performing gymnastic skills that require perfect timing.

Conclusions

The use of video-enhanced visual feedback and slow-motion techniques in learning the back handspring among female students of the Faculty of Physical Education and Sports Sciences produced a significant positive neurological effect. This approach facilitated technical skill acquisition and reduced neural response latency, demonstrating its effectiveness in accelerating the learning process and improving performance. Students with a visual learning style benefited most, highlighting the importance of aligning instructional methods with individual learning preferences.

These findings confirm that combining sensory correction with motor training significantly enhances skill execution, supporting the integration of such techniques into gymnastics training programs. Incorporating visual and sensory feedback promotes overall performance improvement and more efficient neuromuscular coordination.

Ultimately, the evidence indicates that training with targeted feedback not only improves performance speed and consistency but also produces measurable neurological benefits. These results emphasize the value of designing training interventions that leverage cognitive and sensory mechanisms to optimize motor learning.

Practical Implications

Coaches and physical education teachers can apply the findings of this study by incorporating visual feedback techniques into training sessions, such as slow-motion video and detailed motion analysis, to allow immediate error correction and enhance the formation of accurate motor representations. Training programs should be designed to accommodate different learning styles, emphasizing visual feedback for complex skills while supporting auditory or kinesthetic modalities according to individual learner needs. Additionally, the use of tactile and sensory guidance for kinesthetic learners can improve muscle awareness and neuromuscular coordination. Employing multi-modal instructional strategies helps bridge the gap between students' learning preferences and the demands of motor skills, thereby promoting more precise, rapid, and consistent performance.

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Conflict of interest

The authors have no conflicts of interest to declare.

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