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Acute Effects of Auditory Motivational Cueing on Speedball Super Solo Performance in Sports Science Students: A Randomized Crossover Study of Hand Dominance and Movement Pattern

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Abstract: Sport performance is shaped not only by technical and physical capacities but also by mo-tivational strategies that can sustain effort and movement quality under time pressure. While auditory motivational cueing (AMC) is commonly used by coaches, its acute effects in technically constrained racket sports and across hand-dominance and movement-pattern demands are not well defined. To determine the acute effects of AMC on speedball super solo performance across four movement patterns and dominant vs. non-dominant hands. Seventy-six sports science students (44 males, 32 females; age: 21.2 ± 0.9 years) completed a randomized, counterbalanced crossover study with a 72-hour wash-out. Participants performed right-hand solo, left-hand solo, two-handed forehand, and two-handed backhand bouts under AMC and control conditions; standardized motiva-tional phrases were delivered every 10 seconds during each 60-second bout. Performance was quantified as total strokes (digital tally counter). Two-way mixed-design ANOVA tested AMC condition × hand dominance and AMC condition × super solo style. Results: Significant main effects were observed for AMC condition (Group A: $F(1,36) = 78.23$, $p < 0.001$, $\eta p^2 = 0.69$; Group B: $F(1,36) = 182.14$, $p < 0.001$, $\eta p^2 = 0.83$) and hand dominance (Group A: $F(1,36) = 13.81$, $p < 0.001$, $\eta p^2 = 0.28$; Group B: $F(1,36) = 75.22$, $p < 0.001$, $\eta p^2 = 0.676$). Across movement patterns and dominance conditions where AMC produced a fa-cilitatory effect, stroke frequency increased by 2.7% to 5.7%; in Group B, AMC produced a differential effect contingent on hand dominance, reflected in a significant AMC × hand dominance interaction rather than a uniform main effect. Dominant-hand performance was consistently higher than non-dominant performance ($p < 0.001$). Two-handed fore-hand performance exceeded two-handed backhand performance under both conditions (Group A: $F(1,36) = 98.06$, $p < 0.001$, $\eta p^2 = 0.73$). AMC meaningfully improves speedball super solo output across different technical demands and hand-dominance conditions, with medium-to-large effects, supporting its use as a practical, low-cost strategy to en-hance training and skill-development in technical precision sports. Findings are limited to acute performance output (stroke frequency) in a university-level student sample with prior speedball instruction and should not be generalized to elite or novice populations without further investigation.

Keywords: Athletic performance, applied biomechanics, auditory motivation, coach–athlete interaction, functional laterality, motor control, psychomotor performance, racquet sports

1. Introduction

Psychological and motivational factors constitute critical determinants of athletic performance, often distinguishing elite competitors from their peers despite comparable physiological capacities and technical proficiencies [1]. Contemporary sports science increasingly recognizes that optimizing human performance requires integrated approaches addressing not only physiological conditioning and technical skill development but also psychological readiness and motivational states [2]. Among various motivational strategies employed in training and competition contexts, auditory motivational cueing delivered by coaches or instructors has emerged as a readily implementable intervention with demonstrated ergogenic potential across diverse sporting disciplines. Motivational cueing encompasses verbal statements designed to enhance effort investment, sustain task engagement, and optimize performance outcomes through psychological and physiological mechanisms [3]. AMC, as operationalized here, is distinguished from generic verbal encouragement by its standardized delivery protocol (fixed phrases, fixed frequency, controlled vocal tone, verified by audio recording), features that reduce variability across participants and increase replicability relative to spontaneous coach feedback studied in prior literature [14, 34].

Accumulating evidence supports the performance-enhancing effects of motivational cueing across team sports. Sahli et al. [4] documented significant elevations in heart rate, blood lactate concentration, and rating of perceived exertion during small-sided soccer games accompanied by verbal encouragement, indicating intensified physiological engagement and subjective effort perception. Subsequent investigations corroborated these findings, with Hammami et al. [5] reporting improvements in physical fitness, technical skill execution, and physiological responses during soccer-specific training when systematic auditory motivational cueing (AMC) was implemented. Selmi et al. [6] extended this line of inquiry, demonstrating that AMCenhances game intensity, technical performance parameters, and psychological responses during soccer training sessions. Similarly, Aydi et al. [7] observed elevated physical and psychophysiological responses during soccer dribbling circuits in physical education settings when AMCwas systematically applied. Collectively, these investigations establish AMCas as an effective modulator of training intensity and performance quality in team sport contexts.

Evidence for the efficacy of motivational cueing extends beyond team sports to individual athletic disciplines. Kilit et al. [8] investigated the effects of coach encouragement on psychophysiological responses and performance outcomes in young tennis players, reporting significant improvements in training intensity, performance metrics, and physical enjoyment during tennis-specific drills. Puce et al. [9] demonstrated that AMCattenuated indices of muscle fatigue and enhanced endurance performance in competitive swimming. Hammami et al. [10] documented that AMC, combined with preferred music listening, augmented maximal repeated change-of-direction performance in adolescent elite basketball players. Rendos et al. [11] found that variations in AMCcontent differentially modulate isokinetic performance, with cues emphasizing velocity yielding superior outcomes compared with force-oriented phrasing. These findings collectively indicate the broad applicability of motivational cueing across diverse motor task demands and performance contexts.

Theoretical frameworks propose multiple mechanisms through which motivational cueing influences performance outcomes. Psychological pathways include enhanced intrinsic motivation through the satisfaction of competence and relatedness needs, as articulated in Self-Determination Theory; optimized attentional focus, directing cognitive resources toward task-relevant environmental features rather than internal fatigue sensations; and sustained task engagement, mitigating performance decrements associated with effort perception [12]. Physiological mechanisms potentially include augmented arousal states that facilitate motor unit recruitment, attenuated central inhibitory signals that limit maximal force production, and modulated perception of effort and discomfort [13]. Engel et al. [14] emphasized the importance of establishing evidence-based protocols for AMCimplementation to maximize intervention efficacy and standardize research methodologies.

Despite substantial evidence documenting motivational cueing effects in team sports and select individual disciplines, significant knowledge gaps persist regarding its applicability to technical precision sports, particularly those characterized by fine motor control demands, rapid decision-making, and sustained attention [15, 33]. Speedball, an emerging racket sport combining elements of tennis, badminton, and volleyball, exemplifies contexts in which motivational interventions may differentially influence performance across gross motor activities. Speedball is a racket sport that imposes sustained attentional demands, precise stroke timing, and continuous reversal of ball rotation under time pressure, constituting a technically constrained task context distinct from gross-motor team activities. Stroke frequency in the super solo format is a valid quantitative proxy for technical performance because each valid stroke requires correct rotational mechanics verified by a certified referee, rendering counting errors consequential and the metric sensitive to both effort and execution quality [16, 31]. The super solo assessment comprises four movement patterns executed with varying hand configurations, providing a within-athlete framework to examine motivational cueing effects across technical demand levels.

Lateralization of motor function warrants systematic investigation in motivational cueing research. Neuroanatomical asymmetries in hemispheric organization confer differential motor control capabilities between dominant and non-dominant limbs, with the dominant hand typically exhibiting superior precision, coordination, and force production attributable to contralateral hemisphere specialization [17, 18]. Loffing [19] documented performance advantages associated with handedness in interactive ball games, suggesting that lateralization effects interact with task demands and competitive contexts. Whether motivational cueing differentially influences performance in the dominant versus non-dominant limb remains inadequately characterized, representing a theoretically and practically significant research question.

The present investigation addressed these knowledge gaps by systematically examining the effects of auditory motivational cueing on speedball super solo performance. The study employed a counterbalanced crossover design to evaluate the influence of AMC across four distinct movement patterns (right-hand solo, left-hand solo, two-handed forehand, two-handed backhand), thereby enabling a comprehensive assessment of motivational intervention effects across varied technical demands. Additionally, the design facilitated examination of differential effects of AMC between dominant- and non-dominant-hand conditions, elucidating potential interactions between motivational interventions and motor lateralization. We hypothesized that auditory motivational cueing would significantly enhance performance across all super solo styles and hand-dominance conditions, with effect sizes sufficient to warrant practical implementation in training contexts.

2. Materials and Methods

1. Participants and Ethical Approval

Seventy-six sports science students (44 males, 32 females; mean age 21.2 ± 0.9 years) from the High Institute of Sport and Physical Education of Kef (Kef, Tunisia) volunteered for this study. Male participants had a mean body mass of 71.1 ± 8.3 kg, a height of 176.2 ± 8.3 cm, and a body mass index of 22.1 ± 2.0 kg·m^{-2}. Female participants had a mean body mass of 59.8 ± 7.3 kg, a height of 166.2 ± 7.8 cm, and a body mass index of 22.9 ± 1.8 kg·m^{-2}. Sample size was determined a priori using GPower 3.1 software [20], with α = 0.05 and Cohen's d = 0.5 yielding a minimum required sample of 54 participants to achieve 95% statistical power. The enrolled sample (n = 76) constitutes a controlled university-level cohort with verified speedball competence and no prior racket sport experience; findings should not be extrapolated to elite or novice populations. Inclusion criteria required completion of three consecutive semesters of speedball instruction within the sports science curriculum, absence of experience in other racket sports, and demonstrated technical proficiency in speedball fundamentals. Exclusion criteria comprised neuromuscular disorders, musculoskeletal injuries affecting the lower limbs (ankles, knees, hips), or any contraindications identified during pre-participation medical screening. Handedness was assessed prior to enrolment using the Edinburgh Handedness Inventory; only right-handed individuals (laterality quotient > 40) were eligible. Throughout this manuscript, "dominant hand" denotes the right hand and 'non-dominant hand' denotes the left hand. All participants underwent a physician-supervised medical examination to confirm eligibility. Written informed consent was obtained from all participants after a detailed explanation of study procedures and associated risks. The institutional Ethics Committee of the High Institute of Sports and Physical Education of Kef, University of Jendouba, approved the protocol (ISSEPK-0082/2024). All procedures conformed to the ethical standards of the latest revision of the Declaration of Helsinki.

2.2. Experimental Design

This study employed a randomized crossover design with a 72-hour washout period between conditions. Participants were randomly allocated to two groups using computer-generated randomization sequences: Group A (n = 37; 22 males, 15 females) and Group B (n = 39; 20 males, 17 females). Group A performed four super solo movements under auditory motivational cueing (AMC) conditions, followed 72 hours later by identical movements under control conditions (without AMC). Group B executed the reverse sequence, performing movements first under control conditions, then under AMC conditions after the washout period. This counterbalanced design controlled for order effects, practice effects, and temporal confounding. The 72-hour interval mitigated residual physiological fatigue and neuromuscular adaptation [21], ensuring independence between experimental conditions. Both testing sessions occurred on the same day of the week (Monday and Thursday) at the same time (09:00 h) to minimize circadian variation.

2.3. Auditory Motivational Cueing Intervention

In the AMC condition, a male physical education instructor (age 33) who had competed internationally in speedball delivered standardized motivational cues throughout each movement. The instructor received structured training four days per week for four weeks (a total of eight hours) prior to data collection. Training focused on consistent verbal content, elimination of non-verbal cues (gestures, body language, facial expressions), and standardized vocal tone across all participants. Auditory cues were delivered in Tunisian Arabic dialect and comprised four standardized phrases: "Well done", "Keep going", "Faster", and "Don't give up". The instructor personalized motivation by incorporating each participant's first name once per movement (e.g., "Faster, [name]"). All auditory feedback was delivered in an energetic, enthusiastic tone at sufficient volume to ensure audibility across the testing area. AMC frequency was standardized at approximately one statement per 10 seconds of performance. Audio recordings of all AMC sessions were obtained via a wearable microphone (Sennheiser, Wennebostel, Germany) to verify protocol adherence. Cue content was identical across all bouts and all participants. Delivery frequency was maintained at one statement per 10 seconds (six cues per 60-second bout), verified post-hoc from audio recordings. Vocal intensity was standardized to a conversational-to-loud range (approximately 70–80 dB at 1 m), assessed during instructor training sessions.

2.4. Super Solo Testing Protocol

Following a standardized 10-minute warm-up comprising dynamic stretching, coordination drills, and progressive-intensity movements, each participant performed four distinct super-solo movements in a fixed order: right-hand solo, left-hand solo, two-handed forehand, and two-handed backhand. The fixed movement order was retained across all participants to standardize testing conditions and minimize administrative complexity; the 30-second passive recovery intervals between movements were considered sufficient to limit local fatigue carryover, consistent with recovery protocols used in comparable fine-motor assessment batteries. Each movement was performed continuously for 60 seconds, separated by 30-second passive recovery intervals. Right-hand solo required alternating backhand and forehand strokes using only the dominant hand. The left-hand solo employed the same mechanics as the non-dominant hand. Two-handed forehand involves simultaneous alternating forehand strokes with both hands, each holding one racket. A two-handed backhand requires alternating backhand strokes executed with both hands. Super solo technique mandates reversing ball rotation with each stroke while maintaining continuous alternating patterns. A certified referee, positioned 2 meters from the court perimeter, recorded valid strokes using a digital tally counter (precision ±1 stroke) and documented the results on standardized score sheets. Invalid strokes (pre-start or post-termination hits, support-hand contact with racket, incorrect rotation reversal) incurred penalties deducted from valid stroke totals according to International Speedball Federation regulations. The referee provided auditory start signals at 10 seconds and 5 seconds prior to each movement, initiated timing with a whistle, and terminated each 60-second bout with a second whistle (Figure 1).

Figure 1: Visual Representation of Speedball Super Solo Movement Configurations: (A) Unilateral Right-Hand Execution, (B) Unilateral Left-Hand Execution, (C) Bilateral Two-Handed Forehand Technique, and (D) Bilateral Two-Handed Backhand Technique.

2.5. Equipment and Testing Environment

All testing occurred on an outdoor athletic court at the High Institute of Sports and Physical Education of Kef during the fourth week of January 2023. Environmental conditions were monitored and recorded (temperature, humidity, wind speed) to ensure consistency across sessions. Speedball equipment conformed to International Speedball Federation specifications: rackets fabricated from rigid perforated plastic (length 40.5 cm, width 24.5 cm, flat striking surface), elliptical hollow rubber balls (diameter 63 mm, mass 39 g), nylon cord (diameter 2 mm, length 1.50 m), and a metallic pole (height 1.7 m, diameter 3 cm). The ball is attached to one cord terminus via a ring mechanism, with the opposite terminus secured to a rotating spool atop the pole.

2.6. Statistical Analysis

Normality of distribution was assessed using the Shapiro-Wilk test ($\alpha = 0.05$). For normally distributed data, paired-samples t-tests were used to compare performance between the AMC and control conditions. Non-parametric alternatives (Wilcoxon signed-rank tests) were applied when normality assumptions were violated. Two-way mixed-design analysis of variance (ANOVA) examined main effects and interactions for: (1) AMC condition (with vs. without) × hand dominance (dominant vs. non-dominant), and (2) AMC condition (with vs. without) × super solo style (two-handed forehand vs. two-handed backhand). Effect sizes were quantified using partial eta-squared (ηp^2), with thresholds of 0.01 (small), 0.06 (medium), and 0.14 (large). Post hoc pairwise comparisons employed Bonferroni correction to control the familywise error rate. To assess crossover design integrity, sequence effects (Group A vs. Group B) and period effects (first vs. second testing session) were examined by including group allocation and session order as between-subjects and within-subjects factors, respectively, in supplementary ANOVA models. No significant sequence or period effects were identified (all $p > 0.05$), supporting the adequacy of the 72-hour washout interval. Statistical significance was set at $\alpha = 0.05$ for all analyses. Two separate two-way mixed-design ANOVAs were specified a priori rather than a single three-way model because the four super solo movements form two structurally distinct and non-interchangeable factorial pairs: unilateral hand dominance (right-hand solo vs. left-hand solo) and bilateral movement pattern (two-handed forehand vs. two-handed backhand). Collapsing these pairs into a single factor would conflate non-equivalent movement structures, introducing a design confound. All computations were performed using IBM SPSS Statistics version 29.0 (IBM Corp., Armonk, NY, USA).

3. Results

3.1. Effects of Auditory Motivational Cueing and Hand Dominance on Super Solo Performance

Two-way mixed-design ANOVA revealed significant main effects and interactions across experimental groups. For Group A, significant main effects emerged for hand dominance ($F(1,36) = 13.81$, $p < 0.001$, $\eta p^2 = 0.28$) and AMC condition ($F(1,36) = 78.23$, $p < 0.001$, $\eta p^2 = 0.69$), indicating large effect sizes for the motivational intervention and medium effects for hand dominance. The interaction term (hand dominance × AMC) was not statistically significant in Group A. Conversely, Group B demonstrated significant main effects exclusively for hand dominance ($F(1,36) = 75.22$, $p < 0.001$, $\eta p^2 = 0.676$) alongside a significant interaction between hand dominance and AMC condition ($F(1,36) = 79.04$, $p < 0.001$, $\eta p^2 = 0.687$), both exhibiting large effect magnitudes. The non-significant AMC main effect in Group B is consistent with the significant AMC × hand dominance interaction ($F(1,36) = 79.04$, $p < 0.001$, $\eta p^2 = 0.687$): when AMC produces opposing directional effects across hand conditions (dominant hand improved; non-dominant hand decreased), the averaged main effect is attenuated toward non-significance, while post-hoc comparisons, which isolate AMC effects within each hand level, correctly yield significance at both levels.

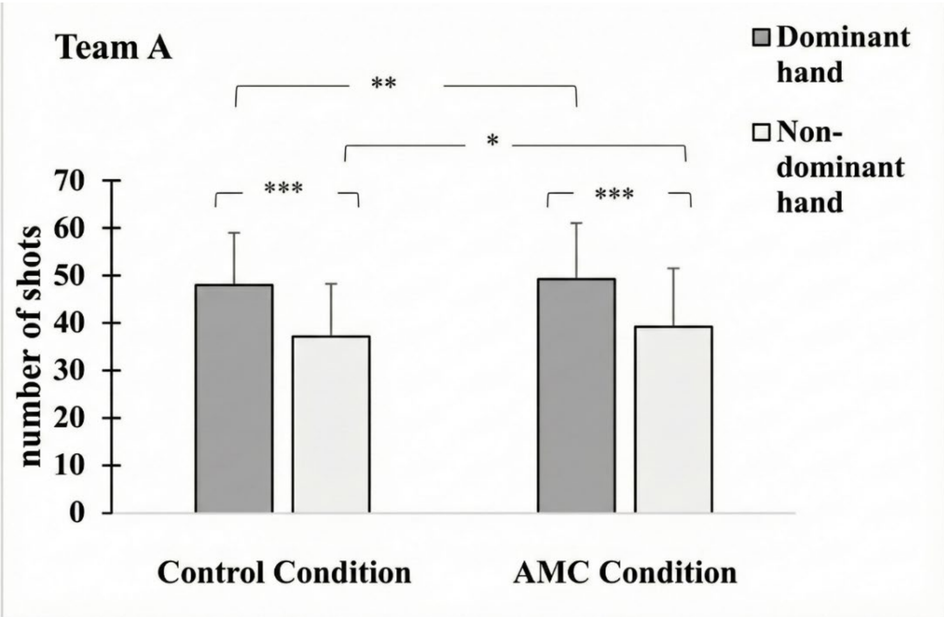

Figure 2: Differential Effects of Auditory Motivational Cueing on Dominant and Non-Dominant Hand Stroke Frequency in Group A: Comparison of Performance Under Control and Experimental Conditions (*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$).

Bonferroni-corrected post hoc pairwise comparisons for Group A revealed significantly elevated stroke frequencies under AMC conditions relative to control conditions for both dominant and non-dominant hands (Figure 2). Dominant-hand performance without AMC yielded 47.92 ± 12.08 strokes, increasing to 49.19 ± 13.81 strokes with AMC implementation ($p < 0.01$). Non-dominant hand performance exhibited a parallel enhancement, progressing from 37.14 ± 12.86 strokes under control conditions to 39.27 ± 11.73 strokes with AMC ($p < 0.001$). Dominant-hand performance consistently exceeded non-dominant performance across both experimental conditions ($p < 0.05$), confirming the expected laterality effect.

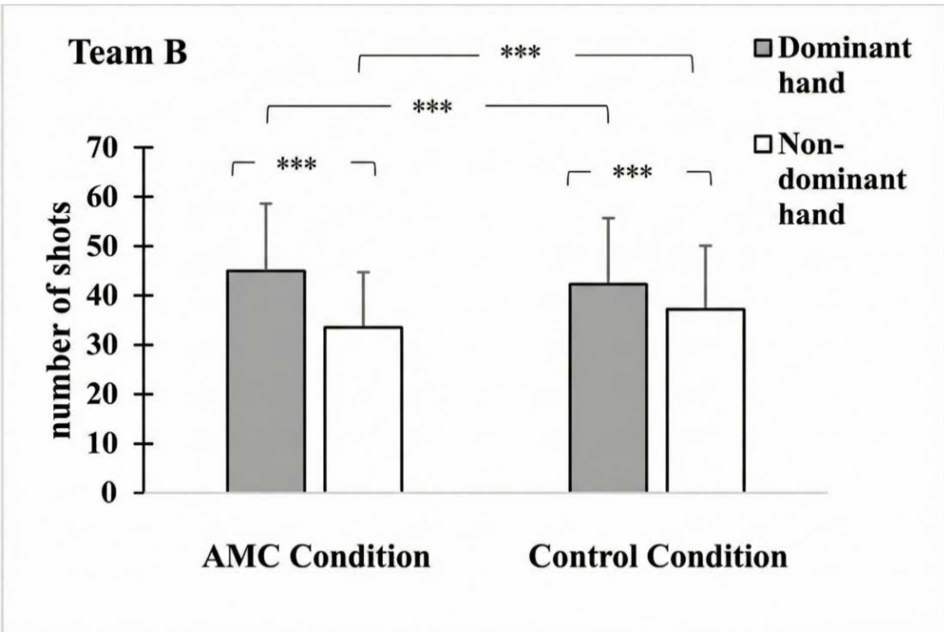

Figure 3: Hand Dominance-Specific Performance Responses to Auditory Motivational Cueing in Group B: Counterbalanced Assessment of Dominant and Non-Dominant Limb Stroke Production (***$p < 0.001$).

Group B demonstrated AMC-mediated performance enhancement patterns comparable to those of Group A (Figure 3). Dominant-hand stroke frequency increased from 42.19 ± 14.81 strokes under control conditions to 44.84 ± 16.57 strokes with AMC provision ($p < 0.001$). Non-dominant hand performance decreased from 37.24 ± 13.76 strokes under control conditions to 33.43 ± 11.57 strokes under AMC ($p < 0.001$), a directional reversal that drives the significant interaction and attenuates the AMC main effect in Group B. Dominant-hand superiority persisted across conditions ($p < 0.001$), replicating the lateralization observed in Group A.

3.2. Effects of Auditory Motivational Cueing and Super Solo Style on Performance

Analysis of super solo style variations revealed significant main effects for both experimental factors across groups. Group A exhibited significant main effects for AMC condition ($F(1,36) = 19.00$, $p < 0.001$, $\eta p^2 = 0.35$) and super solo style ($F(1,36) = 98.06$, $p < 0.001$, $\eta p^2 = 0.73$), with super solo style demonstrating the larger effect magnitude. Group B similarly displayed significant main effects for AMC condition ($F(1,36) = 182.14$, $p < 0.001$, $\eta p^2 = 0.83$) and super solo style ($F(1,36) = 49.80$, $p < 0.001$, $\eta p^2 = 0.58$), although the relative magnitude of effects differed between groups. Neither group demonstrated a significant interaction between AMC condition and super solo style, indicating additive rather than synergistic effects.

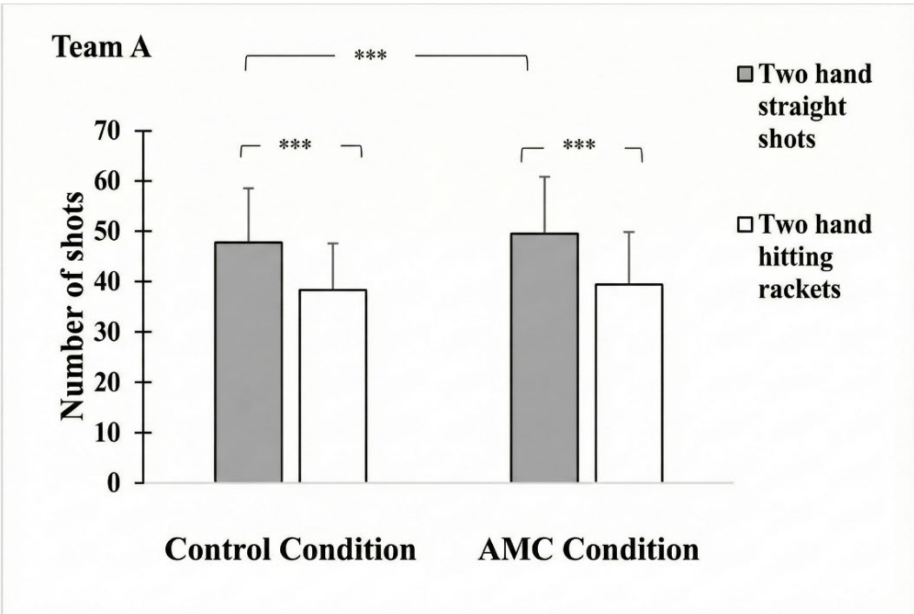

Figure 4: Style-Specific Performance Modulation by Auditory Motivational Cueing in Group A: Comparative Analysis of Two-Handed Forehand Versus Two-Handed Backhand Stroke Frequencies Under Control and Experimental Conditions (***$p < 0.001$).

Post hoc analyses for Group A documented superior performance in the two-handed forehand relative to the two-handed backhand across both experimental conditions (Figure 4). Under control conditions, two-handed forehand yielded 47.81 ± 11.19 strokes compared with 38.28 ± 10.72 strokes for two-handed backhand ($p < 0.001$). AMC implementation elevated performance in both styles: two-handed forehand increased to 49.56 ± 12.44 strokes, while two-handed backhand reached 39.42 ± 11.58 strokes ($p < 0.001$ for both within-style comparisons). The magnitude of AMC-induced improvement was comparable across styles, supporting the absence of interaction effects.

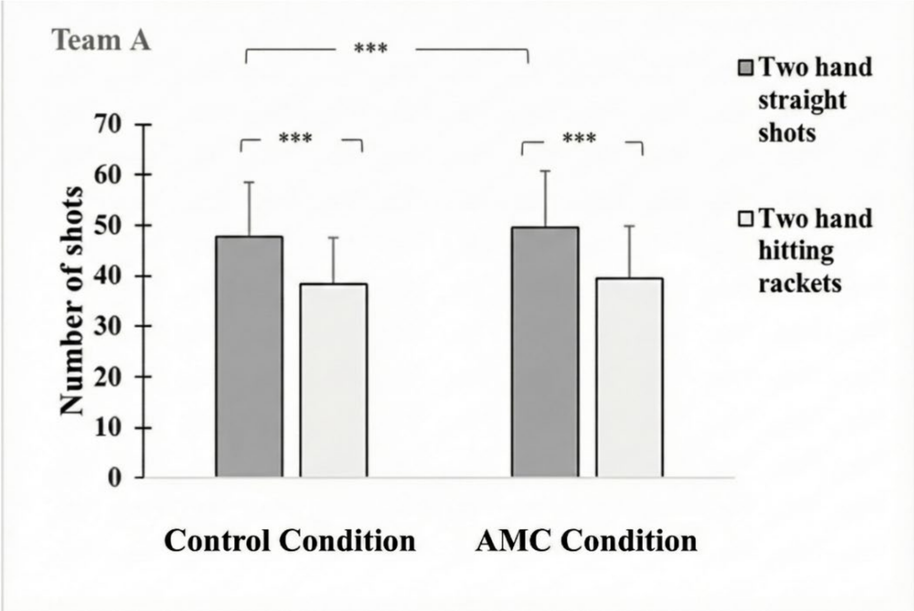

Figure 5: Movement Pattern-Dependent Effects of Auditory Motivational Cueing in Group B: Quantitative Assessment of Two-Handed Forehand and Two-Handed Backhand Performance Across Experimental Conditions (***$p < 0.001$).

Group B replicated the stylistic performance hierarchy observed in Group A (Figure 5). Two-handed forehand performance consistently exceeded two-handed backhand performance under both control (47.81 ± 11.19 vs. 38.28 ± 10.72 strokes, $p < 0.001$) and AMC conditions (49.56 ± 12.44 vs. 39.42 ± 11.58 strokes, $p < 0.001$). AMC provision significantly enhanced stroke frequency within each style classification ($p < 0.001$ for both comparisons). These results confirm the facilitatory effect of AMC on stroke frequency across both movement-pattern styles.

4. Discussion

The primary objective of this investigation was to examine the effects of auditory motivational cueing on speedball super solo performance across four distinct movement patterns: right-hand solo, left-hand solo, two-handed forehand, and two-handed backhand. Additionally, this study evaluated the differential effects of AMC between dominant- and non-dominant-hand conditions, illuminating the nuanced interplay between motivational interventions and motor lateralization. AMC produced medium-to-large effects on stroke frequency ($\eta p^2 = 0.28–0.83$) across movement patterns and hand conditions. Performance increases ranged from 2.7% to 5.7%, where AMC exerted a facilitatory main effect; in Group B, a significant AMC × hand dominance interaction indicated that AMC effects were hand-specific rather than uniform, a distinction reported and interpreted in the Results. These findings are confined to acute stroke-frequency output and do not extend to stroke accuracy, movement efficiency, or long-term skill acquisition.

These findings align with investigations documenting the ergogenic potential of motivational cueing in racket sports. Kilit et al. [8] reported that coach encouragement significantly enhanced psychophysiological responses, performance intensity, and physical enjoyment during tennis-specific drills in young players. The observed congruence between AMC effectiveness in speedball and similar effects in tennis likely reflects shared underlying psychological mechanisms characteristic of racket sports, including precision demands, rapid decision-making, and sustained attentional focus. Hammami et al. [5] extended these observations to team sport contexts, documenting significant improvements in physical fitness, technical skill execution, and physiological responses during small-sided soccer games accompanied by verbal encouragement. The cross-sport applicability of motivational cueing strategies suggests generalized psychological and physiological pathways mediating performance enhancement rather than sport-specific mechanisms.

Theoretical frameworks provide coherent explanations for observed AMC effects. Self-Determination Theory posits that motivational cueing addresses fundamental psychological needs, including competence and relatedness, thereby augmenting intrinsic motivation and task engagement [22, 32]. Positive verbal feedback validates performance competence, whereas personalized encouragement that incorporates participants' names enhances perceptions of relatedness. These psychological processes theoretically increase effort investment and persistence during physically demanding tasks. Rendos et al. [11] demonstrated that variations in AMCcontent modulate isokinetic performance outcomes, with cues emphasizing high-speed efforts yielding superior results compared with force-oriented phrasing. This finding underscores the specificity with which motivational interventions influence motor output, suggesting that cueing strategies should align with task-specific performance objectives.

Attentional focus theory offers complementary explanations, proposing that external motivational cues direct attention toward task-relevant environmental features rather than internal bodily sensations associated with fatigue [23, 30]. This attentional redirection theoretically optimizes movement execution efficiency and delays performance decrements accompanying accumulating physiological strain. The approximately 10-second cueing frequency employed in the present protocol likely provided sufficient motivational reinforcement to sustain elevated arousal and attentional engagement throughout 60-second performance bouts, thereby mitigating the decrements in stroke frequency typically observed during sustained maximal efforts.

Physiological mechanisms complement psychological pathways in mediating the effects of AMC. Sahli et al. [4] documented elevated heart rate and oxygen consumption during small-sided games accompanied by verbal encouragement, indicating intensified cardiorespiratory engagement. Puce et al. [9] demonstrated that AMCattenuated indices of muscle fatigue during swimming performance, suggesting that motivational interventions influence peripheral neuromuscular function as well as central psychological processes. Amagliani et al. [24] reported increased maximal effort and force production following motivational cueing, supporting the hypothesis that external feedback modulates central motor command outputs and reduces inhibitory signals limiting peak performance. These findings, without direct physiological measurement in the present study, suggest that AMC may operate through integrated psychophysiological pathways involving enhanced arousal, reduced perceptual fatigue, attentional redirection, and augmented motor unit recruitment; causal attribution requires concurrent physiological monitoring in future investigations.

The observed hand dominance effects, in which dominant-hand performance consistently exceeded non-dominant-hand performance ($F(1,36) = 75.22$, $p < 0.001$, $\eta p^2 = 0.676$), reflect established principles of motor lateralization and hemispheric specialization. Neuroanatomical asymmetries in corticospinal tract organization confer superior motor control on the dominant hemisphere and the contralateral limb [25]. The dominant hand is controlled by the opposite cerebral hemisphere, which explains why right-handed individuals typically exhibit left-hemisphere dominance for hand motor skills, whereas left-handed individuals demonstrate right-hemisphere dominance for such tasks. Motor skills and language constitute among the most lateralized functions in humans, with one hemisphere exerting disproportionate influence over movement execution or speech production, designated as the "dominant hemisphere" [26]. The left hemisphere is predominantly associated with language processing, and damage to this region frequently results in language disorders. Ambidextrous individuals exhibit relatively symmetrical hemispheric organization, permitting equivalent proficiency with both hands. Notably, the AMC provision yielded proportionally equivalent performance enhancements across both hands, indicating that motivational cueing operates through generalized arousal and effort-augmentation mechanisms rather than preferentially facilitating dominant-limb neural pathways [27].

Super solo-style comparisons revealed a consistent superiority of two-handed forehand performance relative to two-handed backhand execution across both experimental conditions. Biomechanical analysis suggests that forehand strokes typically permit greater kinetic chain recruitment and more favorable joint angle configurations for force transfer [19]. The requirement to reverse ball rotation with each stroke in super solo imposes substantial coordinative demands, potentially accentuating biomechanical advantages inherent to forehand mechanics. The absence of a significant AMC × style interaction indicates that AMC augmented gross effort expenditure uniformly rather than selectively facilitating specific movement mechanics. This finding supports a generalized arousal account of AMC action rather than a pattern-specific attentional mechanism.

Several methodological strengths enhance confidence in reported findings. The counterbalanced crossover design effectively controlled for order effects and individual difference confounds. The 72-hour washout interval prevented carryover effects associated with residual fatigue [21]. Standardization of AMC delivery through systematic instructor training and audio verification minimized variability in interventions. Sample size determination via a priori power analysis ensured adequate statistical power (95%), with 76 participants exceeding minimum requirements.

Despite these strengths, limitations warrant acknowledgment. The lack of control over instructor gender constitutes a potential confound, as student responsiveness to encouragement may vary with instructor demographic characteristics. Future investigations should systematically evaluate gender-specific effects of motivational cueing. The sequential testing protocol required waiting periods for participants who were not actively engaged in performance trials. Prolonged waiting potentially induced anxiety or reduced motivation, introducing confounding variance. Optimizing testing procedures to minimize waiting effects would strengthen methodological rigor. The study population comprised university-level sports science students with intermediate proficiency in speedball, potentially limiting generalizability to elite athletes or novice populations. The performance assessment focused exclusively on quantitative stroke frequency, without evaluating qualitative dimensions such as accuracy or movement efficiency. The single-session crossover design precludes drawing conclusions about long-term adaptation or potential habituation effects from repeated exposure to AMC. A further limitation is the exclusive reliance on stroke frequency as the performance criterion. Accuracy, stroke quality, and within-bout fatigue trajectories were not assessed, restricting interpretation to quantitative output. Future studies should incorporate technique-quality indices and intra-bout time-series analyses to characterize AMC effects more completely.

Future research should examine the durability of AMC-mediated enhancements and the mechanisms underlying adaptation with chronic exposure. Investigations combining motivational cueing with concurrent physiological monitoring (electromyography, metabolic assessment, cortical activation patterns) would elucidate mechanistic pathways [28, 29]. The integration of AMC protocols into periodized training programs warrants systematic evaluation to determine optimal timing and frequency. Extension to clinical populations would broaden applicability.

4.1. Practical Recommendations

Educators, coaches, and sport practitioners should integrate auditory motivational cueing into technical skill training protocols to enhance performance outcomes. The present findings indicate that standardized motivational phrases delivered approximately every 10 seconds throughout performance bouts yield significant improvements across diverse movement patterns and hand dominance conditions. Optimal implementation requires instructor training to ensure consistent delivery devoid of non-verbal confounds. Personalization participants' names appears beneficial, although a systematic investigation of individualized versus generic cueing strategies remains necessary. The AMC application appears particularly valuable during high-intensity training sessions or when fatigue accumulation threatens performance quality. Practitioners should recognize that motivational cueing provides generalized performance enhancement rather than selectively improving specific technical elements, suggesting utility as a complementary strategy alongside targeted technical instruction.

5. Conclusions

This investigation demonstrates that AMC acutely increases speedball super solo stroke frequency across multiple movement patterns and hand dominance conditions, with medium-to-large effect sizes. Effect magnitudes ranging from medium to large indicate substantial practical significance, in addition to statistical significance. Performance improvements appear to be mediated by integrated psychophysiological mechanisms, including enhanced intrinsic motivation, increased effort investment, optimized attentional focus, reduced perceptual fatigue, and sustained arousal. The robustness of findings across counterbalanced experimental groups substantiates AMC as a reliable performance-enhancing intervention applicable to both dominant- and non-dominant-hand conditions. These findings are limited to acute stroke-frequency output in a university-level student sample. Future research should examine long-term adaptation, mechanistic pathways through concurrent physiological monitoring, individualized cueing strategies, and performance quality indices beyond stroke count.

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