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RESEARCH ARTICLE

Improving Perceptual Decision-Making Skill in Volleyball In-Out Situation Using Cognitive-Motor and Spatial Awareness Calibration Training

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ABSTRACT

Perceptual decision-making plays a vital role in volleyball, especially during in–out situations where players must quickly decide whether a ball will land inside or outside the court boundary. This study compared two active perceptual–cognitive training approaches—cognitive–motor inhibition training (CMIT) and spatial awareness calibration training (SACT)—for improving in–out decision accuracy among junior high school students. Using a quasi-experimental, active-comparison pretest–posttest design, 80 Grade 7 students (aged 12–14 years) from a public secondary school in Valencia City, Bukidnon were assigned to two intact groups of 40, with one group receiving CMIT and the other SACT. Both interventions ran for six weeks, with sessions held twice weekly. Decision accuracy was assessed using an observation-based scoring procedure that recorded correct in–out decisions across 18 fixed trials, expressed as a percentage of correct decisions. Data were analyzed using descriptive statistics, paired-samples t-tests, and analysis of covariance (ANCOVA) at the 0.05 significance level. Both groups scored in the moderate range at pretest and the very high range at posttest, and paired-samples t-tests showed significant pretest-to-posttest gains in decision accuracy for each group. Because the study compared two active interventions without a no-treatment control group, these within-group gains cannot be attributed to the interventions alone. After controlling for pretest scores, ANCOVA showed no significant difference between the two interventions; however, a pronounced ceiling effect—most participants reaching the top category at posttest—restricted score variance and the test's sensitivity to detect a between-group difference, so this result should not be interpreted as evidence that the interventions are equivalent. The findings indicate that both CMIT and SACT were associated with improved in–out decision accuracy, while no firm conclusion can be drawn about their relative effectiveness. The results highlight the value of integrating perceptual–cognitive drills, such as inhibition exercises and spatial awareness training, into school-based volleyball instruction.

KEYWORDS *perceptual decision-making, volleyball training, cognitive–motor inhibition, spatial awareness training, sport decision-making*

Introduction

Perceptual decision-making is a decisive factor in volleyball performance, particularly during in–out situations where players must rapidly judge ball–boundary relationships under time pressure and perceptual ambiguity (Formenti *et al.*, 2020; Suárez *et al.*, 2020). These decisions require visual accuracy and executive control processes, such as attentional regulation, response inhibition, and anticipation, which directly influence the speed and accuracy of judgment in competitive play (Kalén *et al.*, 2021; Zwierko *et al.*, 2022). Despite its importance, perceptual decision-making in in–out situations remains a persistent challenge among developing volleyball players, often resulting in delayed responses, incorrect calls, and suboptimal tactical outcomes (Formenti *et al.*, 2020).

International research consistently shows that elite volleyball players demonstrate superior perceptual–cognitive skills, including efficient visual search strategies, anticipatory cue utilization, and inhibitory control, which allow them to resolve boundary-related decisions more accurately than lower-level players (Fortin-Guichard *et al.*, 2020; Zhu *et al.*, 2024b). Decision-training and perceptual–cognitive interventions implemented in Europe and other regions have yielded significant improvements in anticipation, decision speed, and accuracy, particularly when training conditions closely represent real-game demands (Suárez *et al.*, 2020; Montagne *et al.*, 2024). However, most international studies focus on either cognitive–motor inhibition or perceptual–spatial training in isolation, with limited comparative evidence examining their relative effectiveness for in–out decision-making in volleyball (Reiser *et al.*, 2020; Zhu *et al.*, 2024a).

Within the Philippine context, volleyball instruction at the secondary school level often prioritizes technical execution and physical conditioning, while perceptual decision-making and executive control skills receive limited systematic emphasis (Formenti *et al.*, 2020; Suárez *et al.*, 2020). Although volleyball is widely played in schools and competitions, many student-athletes struggle with perceptual judgments such as boundary awareness, ball trajectory estimation, and rapid decision-making during rallies, reflecting gaps in cognitively informed training approaches (Zhu *et al.*, 2024a; Zwayen, 2022). The scarcity of local empirical studies examining perceptual–cognitive interventions in volleyball further limits evidence-based instructional and coaching practices in the Philippine setting.

In the researcher's experience as a junior high school volleyball coach, in–out decision-making errors are frequently observed during training sessions and competitive matches, particularly among developing players who exhibit delayed reactions, premature commitments, or poor spatial calibration near court boundaries. These issues persist even among athletes with adequate technical skills, suggesting that performance limitations stem from perceptual–cognitive constraints rather than motor execution alone (Formenti *et al.*, 2020; Moreira *et al.*, 2021). Such observations underscore the need for structured training interventions that explicitly target inhibitory control and spatial awareness within ecologically valid volleyball contexts.

Although prior studies establish the importance of inhibitory control and spatial awareness in sport performance, several gaps remain. First, few studies directly compare cognitive–motor inhibition–based interventions with spatial awareness–based court-zone calibration training in volleyball (Reiser *et al.*, 2020; Zhu *et al.*, 2024a). Second, much of the existing research relies on laboratory or video-based paradigms, leaving limited evidence on how perceptual–cognitive gains transfer to live in–out judgments during actual play (Zhu *et al.*, 2024a; Wollesen *et al.*, 2020). This study addresses these gaps by experimentally examining and comparing two ecologically grounded interventions within a school-based volleyball context.

In response to these challenges, the present study investigates the effects of two training approaches—cognitive–motor inhibition training and spatial awareness calibration training—on perceptual decision-making skills in in–out situations in volleyball. Cognitive–motor inhibition training is grounded in dual-task and executive-control frameworks and aim to improve response suppression and decision accuracy under concurrent cognitive and motor demands (Wollesen *et al.*, 2020; Moreira *et al.*, 2021). In contrast, court-zone spatial awareness calibration training focuses on enhancing boundary perception, zone recognition, and ball landing distance estimation to improve spatial judgment and positioning (Ivosevic & Stöckel, 2025; Zwayen, 2022; Zhu *et al.*, 2024b).

In this study, perceptual decision-making skill refers to an athlete's ability to accurately judge ball–boundary relations by integrating visual cues such as trajectory, bounce, and court-line reference points (Formenti *et al.*, 2020; Zaman *et al.*, 2020). This skill is supported by visual search efficiency, attentional control, and evidence accumulation processes, enabling players to resolve ambiguous spatial information during fast-paced rallies (Kalén *et al.*, 2021; Fortin-Guichard *et al.*, 2020). Although higher-level athletes also tend to commit to decisions more quickly through more effective perception–action coupling and executive regulation, particularly inhibitory control and selective attention (Makaruk *et al.*, 2020; Chen *et al.*, 2021; Zwierko *et al.*, 2022), the present study focuses specifically on the accuracy dimension of in–out decision-making rather than decision speed. Perceptual decision-making accuracy is a trainable attribute and a valid dependent variable for evaluating intervention effects (Suárez *et al.*, 2020; Zhu *et al.*, 2024a).

This study is anchored on Information Processing Theory (IPT) and Ecological Dynamics Theory (EDT). IPT explains how individuals process information through sequential stages—attention, perception, encoding, storage, and retrieval—guiding decision-making under time and information constraints (Fourie & Schlebusch, 2022; Hüttermann *et al.*, 2019). Attention filters relevant stimuli, while encoding and memory processes determine how efficiently information is stored and retrieved for action (Zhang *et al.*, 2025). In this study, IPT underpins the cognitive–motor inhibition training, where drills such as Stop–Go Sprint Cues, Cognitive Agility Ladder with auditory signals, and Choice Reaction Shuffle require athletes to process stimuli, inhibit or execute responses, and update decisions in real time. These activities operationalize IPT stages by engaging attentional selection and response inhibition, which the present study evaluated specifically through in–out decision accuracy (Sampson *et al.*, 2023).

Conversely, Ecological Dynamics Theory conceptualizes decision-making as an emergent process arising from continuous interactions between the performer and the environment (Inns *et al.*, 2023; Rodrigues *et al.*, 2020). It emphasizes perception–action coupling, nonlinearity, and adaptive learning through exposure to task-relevant constraints and affordances (Araújo *et al.*, 2006; Gottwald *et al.*, 2023). In this study, EDT supports the court-zone spatial awareness calibration training, where drills such as Boundary Trace Awareness, Zone Memory Mapping, and Ball Landing Distance Estimation immerse athletes in representative, information-rich environments. These activities enhance sensitivity to spatial cues, promote adaptive decision-making, and allow perceptual judgment to emerge from real-time interaction with dynamic game conditions. Collectively, EDT explains how engagement with authentic performance contexts strengthens perceptual attunement and improves in–out decision accuracy in volleyball (Uehara *et al.*, 2020).

Moreover, the purpose of this study is to determine the effectiveness of cognitive–motor inhibition training and spatial awareness calibration training in improving the perceptual decision-making skill in in–out situations in volleyball among junior high school student-athletes. Specifically, it seeks to determine the level of perceptual decision-making skills of the two groups before and after the interventions, examine whether there is a significant difference in these skills following the interventions, and identify which of the two training approaches is more effective. In line with these objectives, the study tests the following null hypotheses at the 0.05 level of significance: (Ho_1) there is no significant difference in the perceptual decision-making skills of the two groups before and after the interventions, and (Ho_2) neither of the two interventions is more effective than the other in improving perceptual decision-making skills in in–out volleyball situations.

Further, this study is relevant to the Department of Education (DepEd) as it supports the development of higher-order thinking skills, decision-making, and movement competence emphasized in contemporary physical education frameworks aligned with learner-centered and competency-based instruction (Suárez *et al.*, 2020). By integrating cognitive and perceptual dimensions into volleyball training, the study also contributes to Sustainable Development Goal 4 (Quality Education) by promoting inclusive, evidence-based instructional practices that enhance both cognitive and physical development through sport (Kalén *et al.*, 2021).

This study seeks to determine the perceptual decision-making skills of two groups of volleyball players before and after the interventions, examine whether significant differences exist between the groups, and identify which intervention is more effective in improving in–out decision-making skills. Guided by contemporary perceptual–cognitive and motor-learning literature, this study will provide empirical evidence that strengthens the interpretation of results and contributes meaningfully to coaching practice, physical education instruction, and future research on volleyball decision-making.

Methods

This study used a quasi-experimental, active-comparison pretest–posttest design, in which two active interventions were compared head-to-head rather than against a no-treatment control—an approach used in educational and sport science research when random assignment to a non-intervention condition is impractical or ethically constrained (Campbell & Stanley, 1963; Mohajan, 2020; Shadish *et al.*, 2002). The study included 80 junior high school students, with 40 assigned to each intervention group. The students were enrolled in Grade 7, aged 12 to 14 years, from a public secondary school in Valencia City, Bukidnon. Both male and female students were included, comprising members of the school volleyball team and students enrolled in regular Physical Education classes.

An intact-group sampling technique was used, in which existing classes or training groups were assigned to one of the two intervention conditions. This sampling approach was selected to preserve the natural instructional structure of the school and to ensure the feasibility of implementation. Caution was exercised for participants with injuries, medical conditions, or limitations that may compromise their safety. Their health and well-being were prioritized, which means that their non-participation is justified

The primary research instrument was an observation-based perceptual decision-making rubric designed to assess decision accuracy in in–out situations in volleyball, a method widely used in sport science to capture perceptual–cognitive performance under representative task conditions (Fortin-Guichard *et al.*, 2020; Inns *et al.*, 2023). Observation-based instruments are considered appropriate for evaluating decision-making in dynamic sports environments because they allow performance to be assessed in context-specific situations that closely resemble actual gameplay (Araújo *et al.*, 2006; Zhu *et al.*, 2024a). In this study, the rubric was applied during controlled volleyball play scenarios in which balls are deliberately directed near court boundaries to elicit real-time perceptual decisions, consistent with recommendations for maintaining ecological validity in perceptual–cognitive assessment (Araújo *et al.*, 2006; Inns *et al.*, 2023).

Performance was evaluated by a trained rater with expertise in Physical Education and volleyball, following established guidelines that emphasize rater training and calibration to enhance scoring consistency and reduce observer bias. Prior to data collection, the rater underwent orientation and practice scoring sessions to standardize interpretation of the rubric criteria, a procedure shown to improve reliability in observational sport assessments. The rubric focused exclusively on decision accuracy, operationally defined as the player's ability to correctly decide whether to receive a ball that lands in or refrain from receiving a ball that lands out, aligning with criterion-based definitions of perceptual decision-making in invasion and net sports (Fortin-Guichard *et al.*, 2020; Zhu *et al.*, 2024a). Scoring followed a criterion-referenced evaluation, in which performance is judged against predefined accuracy standards rather than peer comparison, a method recommended for skill assessment in educational and performance-based research to ensure the objectivity and interpretability of scores.

The observation-based perceptual decision-making scoring procedure was adapted from a previously developed perceptual decision-making test for a boundary-judgment sport (Rodriguez, 2023) and underwent face validity procedures prior to its implementation. Face validation was conducted with a panel of experts from the Lourdes College Graduate School. The validators evaluated the test's mechanics and scoring procedure with respect to the clarity of indicators, relevance to perceptual decision-making in in–out volleyball situations, appropriateness of the scoring criteria, and alignment with the study's objectives. Their comments and recommendations were incorporated to refine the procedure, ensuring that the instrument adequately represents the construct it intends to measure.

To establish the reliability of the scoring procedure, internal consistency was examined through a pilot implementation prior to the main data collection, in which a single trained rater scored a sample of in–out decision scenarios. Because all observations in the main study were conducted by one trained rater, scoring dependability was supported through structured calibration of that rater rather than through inter-rater agreement.

In terms of reliability, the test was administered in three (3) sets with six (6) trials per set, for a total of eighteen (18) trials. Based on this 18-trial administration, the Cronbach's Alpha reliability coefficient was $\alpha = 0.799$ (SE = 0.083; 95% CI: 0.637 to 0.961), indicating acceptable to good reliability by commonly used standards in behavioral and performance measurement contexts (Kahveci, 2024).

Each participant completed a fixed total of 18 in–out trials, distributed across the three court boundaries—six along the left sideline, six along the right sideline, and six along the end line—with three balls directed to land in-bounds and three out-of-bounds at each boundary. Each correct decision (receiving a ball that lands in, or refraining from a ball that lands out) was awarded one (1) point and each incorrect decision zero (0) points. Each participant's raw score (0 to 18) was then converted to a percentage of correct decisions (correct ÷ 18 × 100) to standardize interpretation across participants. The scoring is as follows:

Observation Indicator	Operational Description	Score
Correct "IN" Decision	Player receives or plays the ball when it lands inside the boundary line	1
Correct "OUT" Decision	Player does not receive or intentionally lets go of the ball when it lands outside the boundary line	1
Incorrect "IN" Decision (False Positive)	Player receives/plays a ball that lands outside the boundary line	0
Incorrect "OUT" Decision (False Negative)	Player does not receive a ball that lands inside the boundary line	0

Scores were interpreted using a criterion-referenced framework, wherein performance was evaluated against an accuracy standards rather than relative to other players. Below is the interpretation of scores:

Score Range (% Correct Decisions)	Interpretation
80.1–100	Very High
60.1–80	High
40.1–60	Moderate
20.1–40	Low
0–20	Very Low

Additionally, the rater was positioned in a location that provides a clear and unobstructed view of the court boundary lines to ensure accurate judgment of ball landing positions. All in–out decisions were evaluated using official volleyball rules, wherein a ball that touches any part of the boundary line is considered in. Prior to data collection, the rater was oriented and underwent calibration sessions to standardize scoring interpretation, align judgment criteria, and ensure consistency and reliability throughout the observation process.

Before data collection, the study secured ethical approval from the Lourdes College Graduate School Research Ethics Committee, complying with standards for research involving humans. The review included protocols, instruments, consent forms, data plans, and risk–benefit assessments. Following approval, authorization was obtained from the school principal and DepEd officials. Orientation sessions for administrators, teachers, parents, and students explained objectives, procedures, risks, benefits, and participants' rights, including voluntary participation and withdrawal. Assent from students and consent from parents were obtained. The study adhered to Belmont Report principles—Respect for Persons, Beneficence, and Justice—ensuring informed, voluntary participation, minimal risk activities, and fair inclusion. Confidentiality was protected: participants' codes replaced names, records stored securely, and data used solely for research. Data collection started with a pretest, followed by a six-week intervention, then a posttest. Participants received no incentives, and their performance did not impact grades. Findings were shared with participants and authorities as per ethical standards.

The intervention programs lasted six weeks with twice-weekly sessions of 30-45 minutes. Participants continued their usual volleyball training, but the structured cognitive–motor and spatial calibration drills were only during intervention sessions to avoid overlap. Each session started with a 5–10 minute warm-up (light jogging, mobility exercises, stretching) to prepare the neuromuscular system and reduce injury risk. Sessions ended with a 5–8 minute cool-down (low-intensity movements, breathing exercises, static stretching). The cognitive–motor group focused on response inhibition, decision suppression, and rapid response tasks, progressively increasing difficulty with faster cues, shorter response times, and conflicting stimuli. The spatial calibration group worked on court boundary awareness, spatial orientation, and ball-trajectory judgment, increasing ball speed, angles, and active zones over time. Progression was gradual across six weeks, with initial familiarization, then increased complexity and game-like conditions. The researcher monitored responses to keep tasks challenging yet safe. All sessions were led by the researcher or trained assistant following a manual, with attendance and deviations recorded. Participants got uniform instructions and limited verbal feedback to avoid coaching cues. Rest and hydration breaks were standardized. The posttest followed the intervention under similar conditions to the pretest, ensuring observed changes are due to the interventions while safeguarding safety, ethics, and rigor.

The data were analyzed using descriptive and inferential statistics to examine changes in in–out decision accuracy for the cognitive–motor inhibition training and spatial awareness calibration training groups. Descriptive statistics summarized pretest and posttest performance and the baseline characteristics of each group, including its sex and playing-experience composition. Paired-samples t-tests compared pretest and posttest scores within each group, with the normality of the difference scores assessed using the Shapiro–Wilk test and Q–Q plots. To compare the two interventions, an analysis of covariance (ANCOVA) was conducted with posttest score as the dependent variable and pretest score as the sole covariate; sex and playing experience were recorded but, because exploratory checks indicated they were not needed to adjust the group comparison, they were not retained in the final model. The ANCOVA assumptions of normality of residuals and homogeneity of variances were examined, as reported in the Results. Significance was set at α = 0.05, and effect sizes were reported.

Results

Table 1 presents the frequency, percentage, mean, and standard deviation of participants' perceptual decision-making skill during in–out situations in volleyball before and after the interventions.

Table 1. *Frequency, Percentage, Mean, and Standard Deviation Distribution of the Participants' Perceptual Decision-making Skill During in–out Situations in Volleyball Before and After the Interventions*

Range	Interpretation	Cognitive–Motor Inhibition Training				Spatial Awareness Calibration Training			
		Pretest		Posttest		Pretest		Posttest	
		f	%	f	%	f	%	f	%
80.1 - 100	Very High	0	0	37	93	0	0	37	93
60.1 - 80	High	12	30	3	8	2	5	3	8
40.1 - 60	Moderate	24	60	0	0	29	73	0	0
20.1 - 40	Low	4	10	0	0	9	23	0	0
1 - 20	Very Low	0	0	0	0	0	0	0	0
Total		40	100	40	100	40	100	40	100
Mean		55.1		91.8		48.3		91.3	
Interpretation		Moderate		Very High		Moderate		Very High	
SD		11.47		6.49		8.44		6.86	

For the cognitive–motor inhibition training group, the pretest mean score was 55.1 (SD = 11.47), placing it in the moderate range of perceptual decision-making skills. In the posttest, the mean score rose to 91.8 (SD = 6.49), indicating a very high level. Regarding score distribution during the pretest, most participants, 24 (60%), fell into the moderate range (40.1–60). Meanwhile, 12 participants (30%) were in the high range (60.1–80), and 4 participants (10%) were in the low range (20.1–40). No participants were classified as very high or very low. In the posttest, the majority of participants, 37 (93%), achieved the very high range (80.1–100), while 3 participants (8%) were in the high range (60.1–80). No participants were in the moderate, low, or very low categories.

For the spatial awareness calibration training group, the pretest mean score was 48.3 (SD = 8.44), indicating a moderate level. In the posttest, the mean score increased to 91.3 (SD = 6.86), which falls into the very high level of perceptual decision-making skill. Regarding distribution, the pretest results show that 29 participants (73%) were in the moderate range, 9 participants (23%) were classified as low, and 2 participants (5%) as high, with none in the very high or very low categories. In the posttest, 37 participants (93%) were in the very high category, 3 participants (8%) in the high category, and no participants in the moderate, low, or very low categories.

Moreover, the difference in perceptual decision-making skills in in–out situations between the two groups before and after the interventions was investigated, initially claiming no significant difference between the two test points. Prior to conducting the paired-samples t-test, the normality assumption for the difference scores was examined using the Shapiro–Wilk test and Q–Q plots. Results showed that the difference scores for the cognitive–motor inhibition training group did not deviate significantly from normality (W = 0.960, p =

.174), and the same was observed for the spatial awareness calibration training group (W = 0.978, p = .597). Since the obtained p-values were greater than the 0.05 level of significance, the null hypothesis of normality was retained for both groups. Moreover, the Q–Q plots showed that the points were generally aligned with the diagonal reference line, indicating approximate normal distribution of the paired differences. Therefore, the assumption of normality was satisfied, justifying the use of the paired-samples t-test to analyze the pre-test and post-test scores. Table 2 presents the report of the paired-sample t-test analysis.

Table 2. *Paired Samples t-test for Pre-Test and Post-Test Scores in cognitive–motor inhibition training and Court-Zone Spatial Awareness Calibration Training*

Group	Test	M	Interpretation	SD	t	p	Cohen's d
cognitive–motor inhibition training (n = 40)	Pre-test	55.08	Moderate	11.47	-19.42*	<0.001	- 3.07
	Post-test	91.83	Very High	6.49			
spatial awareness calibration training (n = 40)	Pre-test	48.33	Moderate	8.44	-22.55*	<0.001	- 3.57
	Post-test	91.25	Very High	6.86			

**Significant at 0.05 two-tailed alpha level. M = mean, SD = standard deviation, t = t statistic, p = probability value, Cohen's d = effect size*

Table 2 shows the results of the paired-samples t-test comparing pre- and post-test perceptual decision-making scores during in–out situations in volleyball for two groups. For the cognitive–motor inhibition training group (n = 40), the pre-test mean score was 55.08 (SD = 11.47), considered moderate, while the post-test mean increased to 91.83 (SD = 6.49), considered very high. The t-test revealed a significant difference between pre-test and post-test scores, t(39) = −19.42, p < .001. The effect size, Cohen's d = −3.07, indicates a very large change, reflecting a substantial improvement in perceptual decision-making between the two testing periods.

Similarly, for the spatial awareness calibration training group (n = 40), the pre-test mean was 48.33 (SD = 8.44), considered moderate, and the post-test mean increased to 91.25 (SD = 6.86), considered very high. The t-test also showed a significant difference, t(39) = −22.55, p < .001. The effect size (Cohen's d = −3.57) likewise indicates a very large change between the testing periods.

The null hypothesis stated that the perceptual decision-making skills during in–out situations of the two groups do not differ significantly before and after the interventions. Since the p-values for both groups are less than the 0.05 significance level, the null hypothesis is rejected. This indicates that the pretest and posttest in–out decision-accuracy scores of both the cognitive–motor inhibition training group and the spatial awareness calibration training group differ significantly. Because the active-comparison design did not include a no-treatment control group, however, these within-group gains reflect change over the intervention period rather than improvement attributable to the interventions alone.

Finally, the effectiveness of the two interventions was compared, with the null hypothesis that neither intervention was more effective than the other at improving perceptual decision-making skills during in-out situations in volleyball. Before conducting ANCOVA, assumptions were checked for validity, including normality of residuals and homogeneity of variances. Q–Q plots showed residuals followed the diagonal line, indicating normality. Levene's Test for Equality of Variances results (F(1,78)=0.284, p=.596) showed variances were equal between groups. These checks confirm that ANCOVA assumptions were satisfied, justifying the comparison of posttest scores while controlling for pretest scores. Results are shown in Table 3.

Table 3. ANCOVA *Summary Table for Posttest Scores with Pretest Scores as Covariate*

GROUPS	Adjusted Mean	Interpretation	F(1,77)	p	Partial η^2
Cognitive–Motor Inhibition Training	91.80	Very High	0.106	0.745	0.001
Spatial Awareness Calibration Training	91.28	Very High			

Adjusted Mean = estimated marginal mean controlling for the pretest covariate; F = F statistic; p = probability value; partial η^2 = effect size.

Table 3 shows the ANCOVA results comparing posttest perceptual decision-making scores in volleyball in-out situations between the cognitive–motor inhibition training group and the court-zone spatial awareness calibration training group, controlling for pretest scores. The descriptive results reveal that the cognitive–motor inhibition training group had a pretest mean of 55.08 (SD = 11.47), categorized as moderate, and a posttest mean of 91.83 (SD = 6.49), categorized as very high. Similarly, the court-zone spatial awareness calibration training group had a pretest mean of 48.33 (SD = 8.44), also categorized as moderate, and a posttest mean of 91.25 (SD = 6.86), categorized as very high. After adjusting for pretest scores as a covariate, the ANCOVA analysis found no significant difference in posttest perceptual decision-making scores between the two groups, $F(1,77) = 0.106$, $p = 0.745$. The partial eta squared ($\eta^2 = 0.001$) indicates a negligible effect size, meaning the intervention type explained only a very small portion of the variance in the scores.

The null hypothesis stated that neither intervention is more effective at improving perceptual decision-making skills during in–out situations in volleyball. Since the p-value (0.745) is greater than the significance level of 0.05, the null hypothesis is not rejected, indicating no statistically significant difference between the cognitive–motor inhibition training and court-zone spatial awareness calibration training interventions in their adjusted posttest in–out decision-accuracy scores. This non-significant result should be interpreted with caution: because most participants in both groups reached the very high category at posttest, the resulting ceiling effect restricted score variance and reduced the analysis's sensitivity to detect a between-group difference. The absence of a significant difference therefore does not establish that the two interventions are equivalent, particularly as no equivalence test was conducted.

Discussion

The results of the study show that the mean scores and interpretations indicate different performance levels between the pretest and posttest. In the pretest, most were moderate, with some high or low, showing varied accuracy. Posttest results show most are in the very high category, with lower variability, as indicated by smaller standard deviations.

The moderate pretest level likely reflects the diverse backgrounds and initial familiarity of the Grade 7 students, who included volleyball players and PE students with varying experience levels. Their initial in–out decision accuracy was moderate because perceptual–cognitive skills like boundary awareness and quick decision-making are still developing in young, novice athletes. Additionally, this was their first exposure to the study's observation-based rubric and decision scenarios, which are different from typical gameplay and affect initial performance.

The literature indicates that perceptual decision-making in volleyball depends on attentional control, cue utilization, and executive processes that are typically more developed in more experienced performers (Formenti *et al.*, 2020; Fortin-Guichard *et al.*, 2020; Zhu *et al.*, 2024a). In addition, the pretest required participants to perform in a structured, observation-based setting involving controlled in–out scenarios, which may have introduced demands that differed from typical gameplay and thus contributed to moderate initial scores (Zaman *et al.*, 2020; Kalén *et al.*, 2021).

Moreover, the high posttest score may be due to increased familiarity with the assessment format and repeated exposure to decision scenarios during the study. Over six weeks, participants continued volleyball practice and Physical Education activities, as well as intervention sessions. Regular volleyball practice exposes students to repeated judgments of ball trajectories, boundary decisions, and perceptual cues, which can improve their comfort and responsiveness during the posttest. Additionally, the standardized observation and scoring criteria in both tests likely enhance understanding of decision conditions. Consistent evaluation by calibrated raters and clear boundary rules (e.g., balls touching the line are "in") provide a stable task framework. As students grow accustomed to these conditions and scenarios, their responses may become more consistent and accurate within the scoring framework.

The literature supports the view that repeated exposure to representative volleyball situations strengthens cue pickup, anticipatory processing, and visuospatial judgment, which are essential to accurate in–out decisions (Suárez *et al.*, 2020; Zhang *et al.*, 2025; Zhu *et al.*, 2024a). Moreover, the use of a calibrated rater, standardized scoring criteria, and clearly defined official boundary rules likely provided a stable assessment environment that supported more consistent responses during the posttest (Makaruk *et al.*, 2020; Li *et al.*, 2024). Thus, the very high posttest level may be interpreted as reflecting participants' later-stage performance within a more familiar and standardized perceptual decision-making context.

Moreover, this study reveals that participants' perceptual decision-making skills during in–out situations in volleyball significantly changed from pre-test to post-test in both groups. The paired samples t-test indicated statistically significant differences in scores between the cognitive–motor inhibition training group and the spatial awareness calibration training group, demonstrating that these interventions effectively enhance perceptual decision-making skills in in–out volleyball situations. Consequently, the null hypothesis—that there is no significant difference in perceptual decision-making skills before and after the interventions—is rejected.

The difference between the pre-test and post-test perceptual decision-making scores may be understood in relation to the participants' developmental stage, exposure to volleyball environments, and familiarity with perceptual decision tasks. The participants were Grade 7 students aged 12–14, a period during which perceptual–cognitive abilities such as attentional control, visual cue recognition, and rapid stimulus categorization continue to develop through participation in sport. Studies indicate that perceptual decision-making in volleyball improves as athletes gain more opportunities to process ball trajectory, spatial cues, and boundary information during gameplay (Formenti *et al.*, 2020; Fortin-Guichard *et al.*, 2020).

Another factor that may explain the pattern of results is the nature of perceptual decision tasks, which often stabilize once performers become familiar with the task context and response requirements. During the pre-test, participants encountered the structured observation-based in–out decision scenarios for the first time. At this stage, variability in attention, cue interpretation, and adjustment to the instructions may have influenced performance. Research suggests that repeated engagement with similar perceptual tasks enables performers to refine their interpretation of sensory information and the organization of their responses (Zaman *et al.*, 2020; Kalén *et al.*, 2021).

Moreover, the characteristics of volleyball as an open-skill sport also provide context for the results. In open-skill environments, athletes continuously process changing environmental information such as ball speed, landing location, and court positioning. Literature indicates that participation in such environments supports the development of perceptual–cognitive abilities, including anticipation, spatial awareness, and decision accuracy (Suárez *et al.*, 2020; Zhu *et al.*, 2024a). Throughout the six-week study period, participants remained engaged in volleyball and Physical Education activities, providing repeated exposure to situations requiring boundary judgments and rapid perceptual responses. Such exposure may strengthen visuospatial working memory and perception–action coupling, which are essential for accurate in–out decisions (Zhang *et al.*, 2025).

The results can also be interpreted through the lens of Information Processing Theory (IPT), which explains how individuals process and respond to task-relevant stimuli through stages of attention, perception, encoding, and response selection (Fourie & Schlebusch, 2022; Hüttermann *et al.*, 2019). During the pretest, participants were still adjusting to the perceptual demands of identifying ball trajectory and boundary cues within a structured evaluation setting. As students repeatedly encountered similar perceptual stimuli during the study period, their ability to encode and retrieve relevant information may have become more efficient, leading to more consistent responses on the posttest.

Similarly, Ecological Dynamics Theory (EDT) provides an environmental perspective for understanding the results. This theory emphasizes that perceptual decision-making emerges from continuous interaction between the performer and the surrounding environment (Inns *et al.*, 2023; Rodrigues *et al.*, 2020). In volleyball, in–out judgments require athletes to interpret environmental affordances such as ball trajectory, court boundaries, and spatial positioning. Repeated exposure to representative volleyball situations may enhance athletes' attunement to these cues, supporting more effective perception–action coupling (Araújo *et al.*, 2006; Gottwald *et al.*, 2023). From this perspective, the posttest results may reflect participants' increased sensitivity to spatial and trajectory information within the volleyball environment.

The consistency of the assessment procedures may also have contributed to the observed pattern of results. The use of a criterion-referenced rubric, calibrated rater training, and standardized boundary rules ensured stable evaluation conditions across both testing periods. Research suggests that when athletes perform within well-defined task constraints and consistent procedures, their responses tend to become more reliable as they become familiar with the assessment environment (Makaruk *et al.*, 2020; Li *et al.*, 2024).

As for comparing the effectiveness of the two interventions, the results indicate that neither cognitive–motor inhibition training nor spatial awareness calibration training was statistically more effective than the other in improving perceptual decision-making skills during in–out situations in volleyball. After controlling for pretest scores, the ANCOVA revealed no significant difference between the two intervention groups, leading to the non-rejection of the null hypothesis. This means that both interventions produced comparable posttest perceptual decision-making outcomes among the participants.

The results indicate that both groups exhibited similar perceptual decision-making performance on the posttest, after accounting for their initial pretest differences. In other words, when baseline scores were statistically controlled, the type of intervention did not significantly differ in perceptual decision-making accuracy between the two groups. This finding suggests that participants in both intervention conditions reached comparable levels of perceptual decision-making performance during in–out volleyball situations by the end of the study. The minimal effect size further implies that the difference between the two interventions in their influence on posttest scores was negligible, indicating that the two training approaches yielded similar results for the skill measured under the study conditions.

The similar posttest mean scores for the cognitive–motor inhibition training and for the court-zone spatial awareness calibration training suggest both groups had high perceptual decision-making accuracy, with little difference detected. The ceiling effect, where most participants scored in the very high category, limited variability and the ability to detect differences. Both groups started with comparable, moderate baseline scores, which may explain the similar high posttest results and the lack of a significant difference in the ANCOVA analysis.

The study's finding that neither intervention was statistically more effective can be interpreted in light of the underlying theories and the literature. According to Information Processing Theory (IPT), perceptual decision-making involves stages such as attention, perception, encoding, and response selection when processing stimuli (Fourie & Schlebusch, 2022; Hüttermann *et al.*, 2019). Although the interventions differed in approach, both required participants to focus on cues, interpret spatial information, and make quick decisions, engaging similar cognitive processes. Similarly, Ecological Dynamics Theory (EDT) views skill development as emerging from continuous interaction between performer and environment (Inns *et al.*, 2023; Rodrigues *et al.*, 2020). In volleyball, accurate in–out decisions rely on interpreting environmental cues such as ball trajectory and position. Both interventions exposed participants to such cues, which may have enhanced perception–action coupling and decision accuracy and contributed to the similar posttest results, although the ceiling effect noted above means this similarity cannot be taken as firm evidence of equivalent effectiveness.

Literature also indicates that inhibitory control and spatial awareness are vital for perceptual decisions. Cognitive–motor training improves executive control (Moreira *et al.*, 2021; Wollesen *et al.*, 2020), while spatial and perceptual–cognitive training enhances cue recognition, anticipation, and positioning (Formenti *et al.*, 2020; Suárez *et al.*, 2020; Zhu *et al.*, 2024a). Since both skills relate to boundary judgments, both interventions likely supported perceptual decision-making through different but relevant pathways.

Several limitations should be considered when interpreting these findings. First, the study used an active-comparison design in which two interventions were compared without a no-treatment or business-as-usual control group; because participants also continued their regular volleyball and Physical Education activities throughout the six weeks, the within-group improvements cannot be isolated from practice, maturation, or growing familiarity with the assessment. Second, a pronounced ceiling effect at posttest—most participants reaching the very high category in both groups—restricted score variance and limited the sensitivity of the ANCOVA, so the non-significant between-group result cannot be taken as evidence that the two interventions are equivalent. Third, the outcome captured decision accuracy only; it did not directly measure decision speed, reaction time, or response inhibition, so the findings should be read as evidence about accuracy rather than the full range of perceptual–cognitive processes invoked in the framework. Fourth, scoring in the main study was performed by a single trained rater, so although calibration procedures were used, inter-rater reliability could not be established. Finally, the participants were drawn from a single grade level at one public secondary school and combined varsity and Physical Education students, which limits the generalizability of the results. Future research should incorporate a control group, use a more difficult or graded measure that reduces ceiling effects, include timing-based indices alongside accuracy, and test the interventions across multiple schools and age groups.

Conclusion

The purpose of this study—to determine the effectiveness of cognitive–motor inhibition training and spatial awareness calibration training in improving perceptual decision-making skill during in–out situations in volleyball among junior high school students—was addressed using an active-comparison design. The findings showed that both groups demonstrated substantial improvements in in–out decision accuracy from pretest to posttest. Because the design compared two active interventions without a no-treatment control, these gains are best described as changes associated with the intervention period rather than effects attributable to the interventions alone. The comparative analysis revealed no statistically significant difference between the two interventions; given the ceiling effect observed at posttest, this comparison is best regarded as inconclusive rather than as confirmation that the two approaches are equally effective.

The findings also provide empirical support for the study's theoretical framework, particularly Information Processing Theory (IPT) and Ecological Dynamics Theory (EDT). From the perspective of IPT, the improvements observed among the participants suggest that repeated engagement with perceptual decision tasks may enhance the cognitive processes of attention, perception, encoding, and response selection that underpin accurate decision-making in sport contexts. Meanwhile, EDT helps explain how perceptual decision-making emerges through the interaction between the performer and the environment, as both interventions exposed participants to task-relevant cues such as ball trajectory, spatial positioning, and court boundaries. Together, these frameworks support the view that perceptual decision-making in sport is a trainable ability that develops through structured practice involving cognitive engagement and representative performance environments.

The results of this study also carry important educational implications, particularly for physical education instruction and volleyball coaching in school settings. The findings suggest that incorporating perceptual–cognitive training strategies—such as response inhibition drills and spatial awareness calibration activities—may enhance learners' ability to make accurate and timely decisions during game situations. Integrating such training approaches into school-based volleyball programs may help move instruction beyond purely technical skill development toward a more comprehensive approach that also cultivates perceptual judgment, attentional control, and game intelligence. Consequently, physical education teachers and coaches may consider incorporating cognitively enriched training activities into regular volleyball instruction to support the holistic development of student-athletes.

Based on the study's findings, it is recommended that coaches and PE teachers incorporate cognitive–motor inhibition and spatial awareness training into volleyball sessions to improve students' perceptual decision-making during in–out situations. School-based programs may include perceptual–cognitive drills, such as response inhibition and spatial awareness exercises, to enhance decision accuracy. Curriculum planners and administrators might support strategies combining cognitive, perceptual, and motor elements for comprehensive learning. Future research should assess the long-term effects of these interventions across different age groups and competition levels, and explore additional methods like video-based decision training, virtual simulations, or technology-assisted drills to further improve decision-making skills in volleyball and other sports. Broader variables such as reaction time, anticipation, or tactical decision-making could also be examined to deepen understanding of perceptual–cognitive development.

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AI Declaration: *This study used artificial intelligence tools to support manuscript preparation. Consensus.app and scite.ai were used to identify and verify peer-reviewed literature; ChatGPT was used to improve coherence and academic phrasing; and Grammarly was used for grammar and style. All AI-surfaced sources were independently validated against primary sources, and all scholarly content, analysis, and interpretation are the author's own.*

Data Availability Statement: *The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request. Requests for access will be evaluated in accordance with ethical guidelines and data privacy policies.*