Motor performance under OPTIMAL conditions: comparing task-relevant and task-irrelevant autonomy support

Rendimiento motor bajo condiciones OPTIMAL: comparación entre el apoyo a la autonomía relevante y no relevante para la tarea

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Abstract

Introduction: The OPTIMAL Theory proposes that enhanced expectancies for performance, autonomy support, and external focus of attention act as interacting pillars that facilitate motor skill performance. However, evidence for their benefits in sport-specific motor skills remains inconsistent.
Objective: Evaluate the effects of the interactive OPTIMAL pillars on the performance of a volleyball skill by manipulating autonomy over task-relevant and task-irrelevant aspects.
Methodology: Eighteen adolescents with volleyball practice experience performed a volleyball attacking skill aimed at striking the center of a target under three different conditions: (1) an OPTIMAL condition (which includes reception of positive feedback and instruction inducing external focus of attention) plus a task-irrelevant choice (selection of the ball); (2) an OPTIMAL condition plus a task-relevant choice (whether to receive a demonstration of the motor execution); and (3) a control condition. Each participant completed 10 trials per condition across three sessions separated by seven days. The control condition was completed on the first day, and the two OPTIMAL conditions were counterbalanced on days two and three. Performance accuracy on a volleyball attacking skill was assessed using a score ranging from 0 to 3 points. Differences between conditions were analyzed using Bayesian repeated-measures *one-way* ANOVA.
Results and Conclusions: Similar performance weas found in performance accuracy across the different conditions. These findings suggest that, in participants with task experience, implementing the OPTIMAL theory pillars plus task-relevant or task-irrelevant choice did not enhance volleyball attacking skill performance relative to the control condition.

Keywords

Adolescents; Bayesian statistics; motor behavior; sport psychology; volleyball.

Resumen

Introducción: La Teoría OPTIMAL propone tres pilares interactivos que facilitan el desempeño de habilidades motoras. Sin embargo, la evidencia sobre sus beneficios en habilidades motoras especificas del deporte es inconsistente.
Objetivo: Evaluar los efectos de la interacción de los pilares OPTIMAL en el desempeño de una habilidad de voleibol, manipulando la autonomía sobre aspectos relevantes e irrelevantes para la tarea.
Metodología: Dieciocho adolescentes con experiencia en la práctica del voleibol realizaron una prueba de ataque en voleibol con el objetivo de acertar el centro de un blanco bajo tres condiciones: (1) condición OPTIMAL (que incluía la retroalimentación positiva e instrucción induciendo foco externo de atención) más la posibilidad de escoger un aspecto irrelevante de la tarea (elección del balón); (2) condición OPTIMAL más la posibilidad de escoger un aspecto relevante de la tarea (elección sobre la posibilidad de recibir o no una demostración); y (3) condición control. Cada participante realizó 10 intentos por condición en tres sesiones. La condición control ocurrió el primer día, y las dos condiciones OPTIMAL fueron contrabalanceadas los días dos y tres. El desempeño se midió mediante la precisión del ataque (puntaje de 0 a 3). Una prueba ANOVA Bayesiana *one-way* de medidas repetidas fue utilizada para comparar las condiciones.
Resultados y Conclusiones: La precisión del ataque fue similar entre las diferentes condiciones de práctica. Esos resultados sugieren que, en participantes con experiencia en la tarea, la implementación de las condiciones OPTIMAL más las posibilidades de escoger aspectos de la tarea no beneficiaron el desempeño en relación con la condición control.

Palabras clave

Adolescentes; comportamiento motor; estadística Bayesiana; psicología del deporte; voleibol.

Introduction

Understanding the factors that enhance motor performance is a central research question for scholars and practitioners in the field of human movement. Scientific advances in the area of motor learning and motor control have traditionally identified practice, instruction, feedback, and motivation as factors affecting human movement (Schmidt et al., 2018). More recently, the OPTIMAL (Optimizing Performance through Intrinsic Motivation and Attention for Learning) Theory (Wulf & Lewthwaite, 2016), supported on the Self-Determination Theory (SDT; Deci & Ryan, 1985, 2000; Camacho-Carranza et al., 2025; De Francisco et al., 2025; Rodrigues et al., 2026; Zhou et al., 2025), has gained particular prominence as a theoretical framework in this area. This theory proposes that three interacting pillars, namely enhanced expectancies for performance, autonomy support, and external focus of attention create a virtuous cycle that benefits the optimization of motor skill performance and learning. Each of these proposed pillars is supported by empirical evidence revealing benefits motor performance through: (i) enhancing performance expectancies via strategies such as positive feedback (i.e., praise) or social and temporal comparisons following successful attempts (Chiviacowsky, 2020); (ii) providing autonomy support by allowing learners to make decisions regarding their practice (Chiviacowsky, 2022); and, (iii) promoting an external focus of attention, induced through instructions or feedback that direct attention to the effects or outcomes of the movement (Chua et al., 2021; Flôres et al., 2025).

Although the OPTIMAL theory highlights the importance of interactions among its three pillars, most research has investigated each pillar in isolation, consistently revealing benefits for motor performance (e.g., Abdollahipour & Psotta, 2017; Halperin et al., 2017; Ziv & Lidor, 2021). Such consistency has also been observed in few studies investigating interactions among the pillars in the performance of general motor skills such as maximal vertical jumps (Chua, Wulf, & Lewthwaite, 2018), balance control task (Chua, Wulf, & Lewthwaite, 2020), and handgrip strength (Singh et al., 2020). However, when the interacting approach has been used to the investigation of sport-specific motor skills, findings are divergent. Specifically, Abdollahipour, Valtr, and Wulf (2020) revealed that, when comparing OPTIMAL and control conditions in a bowling task, participants in the OPTIMAL condition knocked down more pins than those in a control condition, supporting the additive effects of the pillars proposed in the theory. Conversely, in a similar experimental design, Sertic, Avedesian, and Navalta (2021) found no significant differences in accuracy in a softball throwing. One factor that might account for these discrepant findings is participants' level of task experience. Specifically, participants in the bowling study did not have experience in the task, while in the softball study participants had prior experience with the task. This distinction is particularly important because, in training scenarios practitioners typically seek to manipulate practice conditions to enhance performance in individuals with task experience. To date, evidence does not clearly present performance benefits of OPTIMAL conditions for sport-specific skills in individuals with task experience. Furthermore, an aspect that has not yet been explored in this context concerns the use of different forms of autonomy support, specifically the relevance of the aspect over which the performer is granted autonomy. A crucial question is whether choices that are task-relevant (e.g., feedback schedule, demonstration) or task-irrelevant (e.g., paintings on the wall) differentially affect motor performance. Previous studies investigating these effects on motor learning have revealed mixed findings. More specifically, some research suggest that opportunity to choose is intrinsically rewarding and satisfies the psychological need of autonomy (e.g., Chiviacowsky, Wulf, & Lewthwaite, 2012; Lewthwaite, Chiviacowsky, Drews, & Wulf, 2015), whereas other studies indicate that benefits depend on whether control is granted over task-relevant aspects (Carter, Carlsen, & Ste-Marie, 2014; Carter, Rathwell, & Ste-Marie, 2016; Carter & Ste-Marie, 2017). Given the unconclusive findings and the paucity of evidence on motor performance, further investigation is warranted to examine the effect of task-relevant and task-irrelevant choices on the performance of a sport-specific motor skill.

Based on the above, the objectives of this study were to (i) evaluate the effects of the interacting OPTIMAL pillars on the performance of a volleyball motor skill compared with a control condition, and (ii) examine whether task-relevant and task-irrelevant choices lead to differences in performance. Given the divergent findings regarding the effects of the interacting OPTIMAL pillars on sport-specific motor skill performance, as well as mixed evidence concerning the effect of autonomy, we hypothesized that (i) if present, performance benefits under OPTIMAL conditions would be small, and (ii) no performance differences would be observed between task-relevant and task-irrelevant choice conditions.

Method

Participants

The G*Power v 3.1.9.7 software (Kiel University, Kiel, Germany) (Faul et al., 2007) was used to determine sample size for one-way ANOVA within factors. The following parameters were used: η^2p = 0.15 (Chua et al., 2018, 2020; Sertic et al., 2021; Singh et al., 2020), error probability α = 0.05, β = 0.95, number of groups = 1, and number of measurements = 3. This calculation resulted in a total sample size of 17 participants. The sample consisted of 18 adolescent volunteers (13 male and 5 female), with a mean age of 13.6 years (SD = 1.57), a height of 1.58 m (SD = 0.09), and a body mass of 53.81 kg (SD = 10.65). The participants were part of a social program in the state of Minas Gerais, Brazil, aimed at teaching different sports, including volleyball. Eligibility required that adolescents had been enrolled in the program for a minimum of six months, with regular attendance at two weekly classes, each lasting two hours. The project was approved by the Research Ethics Committee of the University of Uberlandia (05960818.0.0000.5152), and all legal guardians signed the Informed Consent Form.

Procedure

All participants performed the task under three conditions: (i) a control condition, (ii) an OPTIMAL condition in which participants could choose to receive a video demonstration of the task by an expert (OPTIMAL task-relevant), and (iii) an OPTIMAL condition in which participants could choose the ball used to perform the task (OPTIMAL task-irrelevant). Data collection was conducted on the project's sports court over four sessions, with a seven-day interval between sessions, resulting in a four-week data-collection period.

On the first day of data collection, general information about the study was provided and anthropometric measurements (height and weight) were obtained. On the second day, all participants initially received general instructions about the task and observed a demonstration of the task execution performed by an experimenter with volleyball experience. Immediately thereafter, participants completed one familiarization trial followed by 10 trials under the control condition, with no feedback, attentional focus instructions, or autonomy over task-related aspects.

On the third day, participants completed 10 trials under one of the OPTIMAL conditions. This condition included: (i) instructions promoting an external focus of attention ("you should direct your attention to the center of the target while performing the trials"); (i) positive feedback provided after the 3rd, 6th, and 9th trials (e.g., "Very good! Keep it up!"; "You're doing well"; "Very good! Your attacks are improving!"; "Excellent trials!") (Burkle et al., 2025; Drews et al., 2020; Martinez et al., 2024); and (iii) autonomy support according to the condition. On this day, half of the participants performed the task with autonomy to choose whether to watch a video demonstration by an expert after each trial (task-relevant autonomy), whereas the remaining half were allowed to choose one of 10 available balls to use for each trial (task-irrelevant autonomy).

On the fourth day, participants completed an additional 10 trials under conditions identical to those of the third day, except that autonomy conditions were reversed. Participants who had previously performed the task under the task-relevant choice condition on Day 3 were assigned to the task-irrelevant choice condition on Day 4, and vice versa. Across all the conditions analyzed, the inter-trial interval was 10 seconds.

Task and instruments

The task consisted of a volleyball spike skill adapted from Gabbett and Georgieff (2006). Participants performed attacks with the objective of hitting the center of a target measuring 1.5 m in height and 1 m in width, positioned on a wall 3.5 m in front of them, as illustrated in Figure 1. To perform the attack, each participant tossed the ball (Mikasa VLS300; mass = 0.270 kg; diameter = 0.2133 m) above head level and then struck it with their dominant hand. The target was divided into five 20 cm vertical segments (numbered 1 to 5 from left to right). If participants hit the central 20 cm segment (3), they received three points. Two points were awarded for hitting the two 20 cm segments on either side of the central segment (2 and 4), and one point was awarded for hitting the two outer 20 cm segments of the target (1 and 5). If the ball did not touch the target, 0 points were scored. In situations where the ball touched a dividing line, the higher score was awarded.

Figure 1. Representation of the volleyball spike skill within the data-collection setup.

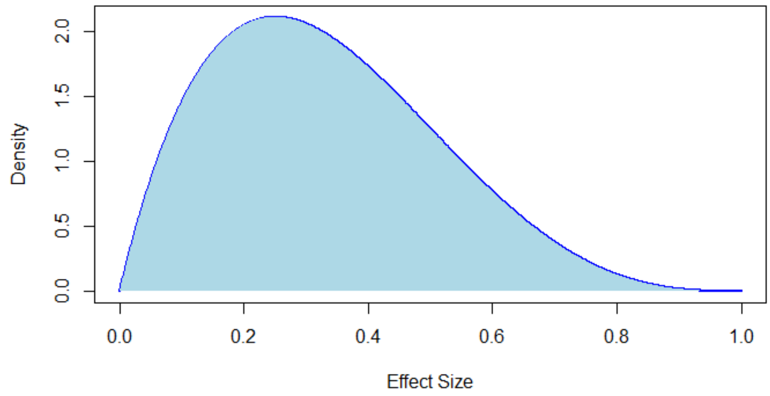
Data analysis

A limitation of frequentist statistics approach is its inability to quantify evidence for the null hypothesis (H_0), instead it restricts researchers to reject or fail to reject the alternative hypothesis (H_1) (Rouder et al., 2009). This problem can be alleviated by adopting a Bayesian approach in which the level of evidence favoring H_0 and H_1 can be quantified (van de Schoot et al., 2015). This approach returns a Bayes Factor, a continuous measure of evidence—ranging from anecdotal to extreme—in favor of one hypothesis over the other. A "moderate" level of evidence is generally considered a good level of support (see the different categories proposed by Wagenmakers et al. (2018) in Table 1. Thus, we decided to use Bayesian repeated measures *one-way* Anova using the JASP software (JASP Team, 2024). For analysis, the H_1 was defined as the presence of a difference in performance among the three conditions. The prior distribution for the Bayesian Anova was specified as Beta (2, 4) distribution (Figure 2). This choice was made to reflect prior knowledge supported on effect sizes reported in previous studies (Abdollahipour et al., 2020; Carter & Ste-Marie, 2017; Lewthwaite et al., 2015; Sertic et al., 2021). The Beta (2, 4) distribution is left-skewed, indicating a belief that values closer to 0 are more probable than values near 1. In practical terms, this means that the model was priorly biased towards lower effect sizes, but it still allowed medium and high effects.

Table 1. Categories for interpreting the Bayes factor (Jeffreys, 1961; Wagenmakers et al., 2018)

Bayes factor	Evidence category
> 100	Extreme evidence for H_1
30 - 100	Very strong evidence for H_1
10 - 30	Strong evidence for H_1
3 - 10	Moderate evidence for H_1
1 - 3	Anecdotal evidence for H_1
1	No evidence
1/3 - 1	Anecdotal evidence for H_0
1/10 - 1/3	Moderate evidence for H_0
1/30 - 1/10	Strong evidence for H_0
1/100 - 1/30	Very strong evidence for H_0

Figure 2. Distribution of prior (*Beta* = 2, 4) employed in the Bayesian *One-way* Anova.



Results

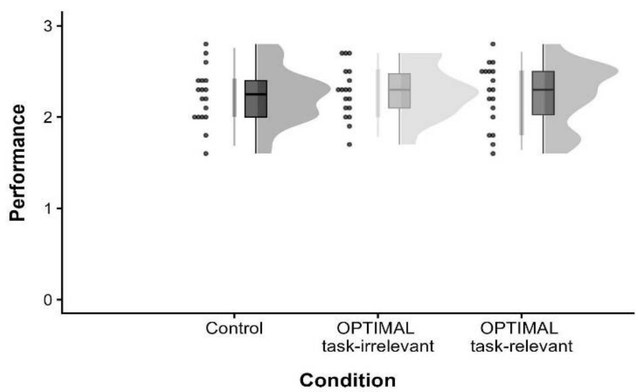
Table 2 represents absolute and relative frequencies of scores achieved by participants in each experimental condition. Descriptive results revealed that, regardless of condition, 17% of the trials resulted in low scores (zero and one). Consequently, in more than 83% of the trials, participants achieved high scores (two or three).

Table 2. Absolute and relative (%) frequencies of scores across all trials in each experimental condition.

Condition	Score = 0 (%)	Score = 1 (%)	Score = 2 (%)	Score = 3 (%)
Control	3 (1.67)	23 (12.78)	84 (46.67)	70 (38.89)
OPTIMAL task-irrelevant	3 (1.67)	26 (14.44)	70 (38.89)	81 (45)
OPTIMAL task-relevant	9 (5)	17 (9.44)	75 (41.67)	79 (43.89)

Results revealed similar mean performance across the different testing conditions (OPTIMAL task-irrelevant: 2.27 ± 0.28; OPTIMAL task-relevant: 2.27 ± 0.35; Control: 2.23 ± 0.31) (Figure 3). A repeated measures Bayesian *one-way* ANOVA indicated moderate evidence against an effect of condition, with a Bayes Factor of *BF* = 0.17. This suggests that the observed data were approximately 5.88 times (1/0.17) more likely under H_0 than under H_1, providing moderate evidence in favor of no performance differences between conditions.

Figure 3. Participants performance under each of the three experimental conditions.



Discussion

The aim of the present study was to evaluate the effects of the interactive pillars proposed in the OPTIMAL Theory (Wulf & Lewthwaite, 2016), autonomy support, enhanced expectancies, and an external focus of attention, on the performance of a volleyball motor skill, and to examine whether task-relevant and task-irrelevant choices lead to differences in performance. The results did not support differences in volleyball spike performance between experimental conditions.

Notably, the results did not support the difference between OPTIMAL and control conditions. This finding contrasts with previous investigations that have reported positive effects of the OPTIMAL pillars on motor performance (Abdollahipour, Valtr, & Wulf, 2020). That study, using a bowling task, revealed higher performance in the OPTIMAL condition compared with a control condition. This divergence from the present findings may be explained by differences in participants' task experience. In the current study, participants had prior experience with the task, whereas participants in the bowling study had no experience. It is therefore possible that OPTIMAL conditions enhance performance in sport tasks when individuals lack task experience, but that this benefit is neutralized when individuals have experience. This interpretation is supported by Sertic et al. (2021), who found no significant differences in softball throwing accuracy between OPTIMAL and control conditions in individuals with softball experience. An additional explanation those authors proposed for the absence of group difference is the low level of task difficulty. That explanation aligns with the present findings, as descriptive results revealed that, across groups, participants achieved high performance scores (scores of two or three) in more than 80% of the trials. Such results indicate that high performance was easily achieved in this task. Taken together, these evidence and explanations suggest that task experience and task difficulty are interrelated factors that play an important role in shaping performance under OPTIMAL conditions. Accordingly, future research should investigate the effects of OPTIMAL conditions in sport tasks comparing participants with and without task experience, as well as tasks with varying levels of difficulty, to further elucidate the influence of OPTIMAL conditions on sport-specific motor skill performance.

A third explanation for the similar performance across conditions relates to intrinsic motivation, defined as engaging in an activity for the inherent satisfaction and pleasure it provided, as outlined in the SDT (Deci & Ryan, 1985, 2000). According to this theory, intrinsic motivation is a powerful driver of performance and learning. In this context, performing a volleyball spike may already hold strong intrinsic appeal for adolescents, eliciting engagement and activating reward-related systems (e.g., dopamine; Schultz, 2010, 2013), thus equally benefiting performance across conditions. In this scenario, adding external-focus instructions and autonomy support may have encountered a "ceiling effect" or "saturation effect". That is, their incremental benefits observed in other studies may have been insufficient in this study because motivation and performance were already optimized by the inherent motivational nature of the activity. This interpretation aligns with evidence showing that when a task is already intrinsically rewarding, adding external incentives or motivational manipulations often fail to yield additional improvements. Supporting this view, Drews et al. (2020) reported that children practicing a pedalo task reported high levels of enjoyment across conditions, regardless of whether positive feedback was provided, resulting in similar performance and learning outcomes. Similarly, the familiarity and inherent pleasure associated with regular volleyball practice may have created a strong motivational baseline in the present study, rendering OPTIMAL conditions redundant in terms of immediate performance effects.

Another important finding was the lack of performance difference between the OPTIMAL task-relevant and task-irrelevant autonomy groups. This finding can be explained by the role of autonomy support within OPTIMAL Theory (Wulf & Lewthwaite, 2016), which is grounded in SDT (Deci & Ryan, 1985, 2000). These theoretical frameworks posit autonomy as an innate psychological need that is satisfied by the perception of having the opportunity to actively participate in determining one's own actions (Aarts et al., 2009; Chambon & Haggard, 2012). Consequently, the beneficial effects of autonomy are thought to depend on the opportunity of choice itself, rather than on the relevance of that choice to the task. In this study, the mere presence of the choice, and the consequent enhancement of perceived control, may therefore account for the absence of performance differences in motor performance between the task-relevant and task-irrelevant conditions. These findings are supported by evidence revealing that choosing the order of exercises enhanced balance performance (Wulf & Adams, 2014). The benefits associated with autonomy support have been linked to activation of the brain's reward system, including dopamine release triggered by the possibility to choose (Schultz, 2010, 2013; Leotti & Delgado, 2011; Murayama et al., 2015), as well as to increased intrinsic motivation (Ryan, & Deci, 2020). Accordingly, in the context of the present study, both relevant and irrelevant autonomy conditions likely operated through a common psychological mechanism: the promotion of an optimized motivational state driven by a heightened sense of control. This shared mechanism may have leveled performance across autonomy conditions.

This study advances previous evidence on the OPTIMAL theory by explaining that motor performance is shaped by the interactive nature of its core pillars and by the influence of moderating variables. We propose that task difficulty and task experience function as such moderators, playing a relevant role in how the pillars interact. In that context, we acknowledge that the deliberate decision to recruit participants with volleyball experience may have influenced our results by reducing task difficulty and potentially increasing motivation. Future studies should therefore examine these factors more explicitly, for example, by testing participants without task experience, and explore different ways of combining the theory's principles. Additionally, the inclusion of supplementary measures, such as motivational and affective assessments between trials, may help clarify the mechanisms underlying the OPTIMAL theory.

Based on our findings, as well as previous studies showing that OPTIMAL conditions can lead to performance equal to or higher than control conditions, we suggest that practitioners can benefit motor performance on learners without task experience by targeting the core pillars of the OPTIMAL theory. This can be achieved by enhancing their performance expectancies through positive feedback, supporting autonomy by allowing performers to make decisions about aspects of their practice, and promoting an external focus of attention through instructions or feedback that direct attention toward the intended movement effect rather than the body.

Conclusions

The findings of this study suggest that implementing the OPTIMAL Theory pillars plus task plus task-relevant or task-irrelevant choices did not enhance volleyball attacking skill performance relative to the control condition in participants with prior task experience. These results, along with the proposed explanations, contribute to a more nuanced understanding of the benefits of OPTIMAL conditions to motor performance. Additionally, the study offers important insights into the role of potential moderating factors on motor performance.

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