Jiménez Díaz, J., Chaves Castro, K., Morena Castro, M., Portuguez Molina, P. & Morales Scholz, G. (2023). Physical practice, mental practice or both: a systematic review with meta-analysis. *Physical Education and Human Movement*, 5(2), 1-14.

Online ISSN:2659-5699
DOI: 10.24310/jpehm.5.2.2023.17875

Physical practice, mental practice or both: a systematic review with meta-analysis

Práctica física, mental o ambas: una revisión sistemática con meta-análisis

Judith Jiménez-Diaz[1,2], Karla Chaves-Castro[1,2], María Morera-Castro[3], Priscilla Portuguez-Molina[1], Gabriela Morales-Scholz[1,2]

[1]Escuela de Educación Física y Deportes, Universidad de Costa Rica, Costa Rica
[2]Centro de Investigación en Ciencias del Movimiento Humano, Universidad de Costa Rica, Costa Rica
[3]Escuela de Ciencias del Movimiento Humano y Calidad de Vida Universidad Nacional, Heredia, Costa Rica

Detalles del artículo:

Número de palabras: 5.341; Tablas: 2; Figuras: 3; Referencias: 45
Recibido: noviembre 2023; Aceptado: noviembre 2023; Publicado: diciembre 2023
Conflicto de interés: El autor declara que no existen conflictos de interés.
Correspondencia del autor: Judith Jiménez Diaz, judith.jimenez_d@ucr.ac.cr

Abstract

Introduction: Previous research has reached positive conclusions regarding the effects of mental practice on performance and learning of a motor skill. The purpose of this study was to use the aggregate data meta-analytic approach to assess the impact of physical practice (PP), mental practice (MP), and the combination of both on acquisition, retention, and transfer tests in motor skill performance. **Methodology:** Twenty-seven studies published up to 2022 were included by searching six databases. Random effects model using the standardized mean difference effect size (ES) was used to pool results. **Results:** A total of 42 ES, were calculated and separated into pairwise comparisons for acquisition, retention, and transfer phase. In the acquisition phase, it was found that MP was more effective than no practice (ES=0.508; n=25; CI=0.29,0.72), PP was more effective than no practice (ES=1.78; n=15; CI=0.97,2.60), CP was more effective than no practice (ES=1.16; n=12; CI=0.57,1.75), PP was more effective than MP (ES=-1.16; n=23; CI=-1.88,-0.45), PP had similar results as CP (ES=-0.01; n=16; CI=-0.31,0.28), and CP was more effective than MP (ES=0.61; n=12; CI=0.17,1.04). In the retention phase, it was found that MP was more effective than no practice (ES=1.11; n=5; CI=0.44,1.79), PP was more effective than no practice (ES=1.03; n=4; CI=0.08, 1.99), PP was more effective than MP (ES=-1.29; n=9; CI=-3.12,0.54), PP had similar results as CP (ES=0.16; n=8; CI=-0.29,0.63), CP had similar results as MP (ES=-0.06; n=3; CI=-1.22,1.09). In the transfer phase, it was found that MP was more effective than no practice (ES=1.12; n=5; CI=0.01,1.59), PP had similar results as no practice (ES=0.41; n=5; CI=-0.02,0.85), and PP was more effective than MP (ES=0.50; n=6; CI=0.12,0.87). Age, skill level, type of mental practice, total of sessions, and type of skill were considered as possible moderator variables. **Conclusions:** Mental practice does not replace physical practice, however, under some conditions, physical practice can be complemented with mental practice.

Key words: motor imagery, motor execution, motor learning, motor skills, motor performance.

Online ISSN:2659-5699
DOI: 10.24310/jpehm.5.2.2023.17875

Resumen

Introducción. Investigaciones anteriores han llegado a conclusiones positivas respecto a los efectos de la práctica mental sobre el rendimiento y el aprendizaje de una destreza motriz. El propósito de este estudio fue utilizar el enfoque meta-analítico de datos agregados para evaluar el impacto de la práctica física (PP), la práctica mental (MP) y la combinación de ambas en las pruebas de adquisición, retención y transferencia en el rendimiento de habilidades motoras. **Metodología:** Se incluyeron 27 estudios publicados hasta 2022 mediante la búsqueda en seis bases de datos. Se utilizó un modelo de efectos aleatorios utilizando el tamaño del efecto de la diferencia de medias estandarizada (ES) para agrupar los resultados. **Resultados:** Se calculó un total de 42 ES y se separaron en comparaciones por pares para la fase de adquisición, retención y transferencia. En la fase de adquisición, se observó que MP era más eficaz que no practicar (ES=0,508; n=25; CI=0,29,0,72), PP era más eficaz que no practicar (ES=1.78; n=15; CI=0.97,2.60), CP era más eficaz que no practicar (ES=1.16; n=12; CI=0.57,1.75), PP fue más eficaz que MP (ES=-1.16; n=23; CI=-1.88,-0.45), PP obtuvo resultados similares a CP (ES=-0.01; n=16; CI=-0.31,0.28), y CP fue más eficaz que MP (ES=0.61; n=12; CI=0.17,1.04). En la fase de retención, se observó que MP era más eficaz que no practicar (ES=1.11; n=5; CI=0.44,1.79), PP era más eficaz que no practicar (ES=1.03; n=4; CI=0.08, 1.99), la PP fue más eficaz que la MP (ES=-1.29; n=9; CI=-3.12,0.54), la PP tuvo resultados similares a la PC (ES=0.16; n=8; CI=-0.29,0.63), la PC tuvo resultados similares a la MP (ES=-0.06; n=3; CI=-1.22,1.09). En la fase de transferencia, se observó que la MP era más eficaz que la ausencia de práctica (ES=1.12; n=5; CI=0.01,1.59), la PP tenía resultados similares a la ausencia de práctica (ES=0.41; n=5; CI=-0.02,0.85), y la PP era más eficaz que la MP (ES=0.50; n=6; CI=0.12,0.87). La edad, el nivel de habilidad, el tipo de práctica mental, el total de sesiones y el tipo de habilidad se consideraron posibles variables moderadoras. **Conclusiones:** La práctica mental no sustituye a la práctica física, sin embargo, en algunas condiciones, la práctica física puede complementarse con la práctica mental.

Palabras claves: imaginería mental, ejecución motriz, aprendizaje motor, destreza motriz, desempeño motor.

INTRODUCTION

Physical practice (PP) throughout overt movements (motor execution) has been the gold standard for learning a motor skill (Kraeutner et al., 2014; Lindsay et al., 2021; Ruffino et al., 2021). However, mental practice (MP) -defined as the rehearsal or repetition of movements using mental imagery, without overt movements (Lee et al., 2019; Matsuo et al., 2020; Nakano, 2012)- has also been used to enhance motor performance (Driskell et al., 1994; Feltz & Landers, 1983; Freitas et al., 2020; Heena et al., 2021; Vasilyev et al., 2021).

Over the years, research has suggested that MP could effectively enhance motor learning and performance in a variety of motor skills, confirming that MP is better than no practice at all (Behrendt et al., 2021; Feltz & Landers, 1983). MP has been demonstrated to facilitate motor learning similar to PP, with different percentages of MP and PP during practice (Allami et al., 2008). On the other hand, it has been shown that MP without previous experience did not enhance learning (Gomes et al., 2014).

Previous meta-analytic studies have concluded that MP programs have a positive effect on sport-specific motor skills (Lindsay et al., 2021) and motor performance (Driskell et al., 1994; Simonsmeier et al., 2021). In addition, several studies found that MP had similar results on performance and learning as PP (Doussoulin & Rehbein, 2011; Stumbrys et al., 2016; Truong et al., 2022). Moreover, additional findings suggest that the combination of MP and PP

Online ISSN:2659-5699
DOI: 10.24310/jpehm.5.2.2023.17875

can enhance performance to a greater extent compared to using PP alone (Allami et al., 2008; Behrendt et al., 2021; Hird et al., 1991; Matsuo et al., 2020; Simonsmeier et al., 2021; Wriessnegger et al., 2008) and MP alone (Lindsay et al., 2021).

The disparity in outcomes observed when evaluating the efficacy of MP, PP, and combined practice (CP) can be attributed to multiple factors. These factors may include the participant's age, skill level, and motor imagery ability, the specific type of MP employed (e.g., visual mental practice -VMP- or kinesthetic mental practice -KMP-), the amount of practice, as well as the nature and complexity of the motor skills being practiced (Gomes et al., 2014; Heena et al., 2021; Munzert et al., 2009; Neuper et al., 2005; Ruffino et al., 2017; Zich et al., 2017). For example, previous meta-analysis reported that MP was moderated by the type of task and duration of the practice (Driskell et al., 1994; Feltz & Landers, 1983), the age of the participants (Behrendt et al., 2021) and the amount of sessions (Simonsmeier et al., 2021).

Therefore, to systematically synthesize scientific evidence on the effect of mental practice on motor performance and learning, this study aimed to use the aggregate data meta-analytic approach to assess the impact of physical practice, mental practice, and the combination of both on acquisition, retention, and transfer tests on motor skill performance, performing pairwise comparisons between types of practice.

METHODS

The present meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematics Review and Meta-Analysis (PRISMA) statement (Liberati et al., 2009; Page et al., 2021). Also, following relevant guides for conducting meta-analysis (Siddaway et al., 2019).

Literature search

Search strategy included EBSCOHost (including Academic Search Complete, Education Research Complete, ERIC, Fuente Academica Premier, MEDLINE with Full Text, PsycARTICLES, SPORTDiscus with Full Text) and Scopus electronic databases, using the following Boolean phrase: ("mental practice" OR imagery) AND ("motor learning" OR "motor performance" OR "skill acquisition" OR "motor skill performance") NOT (automobiles OR cars OR vehicles). A first search was conducted in July 2020, a second and final search was conducted in June, 2023.

Study Eligibility Criteria

Included studies had to comply with the following criteria: (a) participants of all ages, healthy or a health condition (e.g. cerebral palsy) but not rehabilitation (e.g. after stroke or after an accident); (b) compared mental practice, physical practice, combined practice, or no practice (e.g. control group); (c) assess motor skills on performance (acquisition) or learning (retention or transfer); (d) published in a peer-reviewed journal in either English, Spanish, or Portuguese; (e) provided sufficient descriptive statistical data (mean, standard deviation, group size) to calculate Effect Size (ES).

Data Extraction

The extracted data included: study characteristics (year of publication, external validity), sample characteristics (sex, age, skill level, health condition), skill characteristics (cognitive, motor, strength), type of mental practice (Visual or Kinesthetic), and practice characteristics (amount of practice).

Online ISSN:2659-5699
DOI: 10.24310/jpehm.5.2.2023.17875

Risk of Bias

To assess the risk of bias for each study, the revised Cochrane risk-of-bias tool for randomized trials (RoB2) was used; which classifies studies as "low risk", "some concern", or "high risk" in five domains (Sterne et al., 2019).

Estimation of Effect Size

The primary outcome for this meta-analysis was the standardized mean difference calculated from means and standard deviations reported at acquisition, retention, or transfer. We analyzed pairwise comparisons between types of practice (MP vs. PP; MP vs. CP; PP vs. CP) and, when possible, all types of practice with a control group (no practice). The random-effects model (REML) was used to pool overall ES (Borenstein et al., 2009).

Heterogeneity, sensitivity and Small-Study Effects

Heterogeneity was assessed using Cochran´s Q test (Borenstein et al., 2009). Inconsistency was quantified using the I2 statistic, with values less than 25% indicating very low inconsistency, between 25% and 50% denoting low inconsistency, from 50% to less than 75% signifying moderate inconsistency, and 75% or higher indicating substantial inconsistency (Borenstein et al., 2009, 2017). Small-study effects was assessed with a funnel plot and Egger´s regression test (Sedgwick & Marston, 2015). Sensitivity analyses were carried out by the Leave-one-out analysis.

RESULTS

Study Selection

A flowchart depicting the study selection process is shown in Figure 1. Twenty-seven studies involving 1494 participants between 13 and 31 years of age match the eligibility criteria. Table 1 shows descriptive information about the included studies. A total of 42 ES were calculated and separated into pairwise comparisons for acquisition, retention, and transfer.

Most of the studies reported healthy participants of both sexes -female and male-, novice and expert -but with no prior experience in the motor skill assessed in the study-, and the majority of the studies (69%) were performed in a laboratory environment.

Risk of Bias Assessment

Using the Rob2 scale, 13 of 27 studies, representing 48.15% reported low risk, 37.04% of the studies report some concern (10 of 27), and four of 27 studies, representing 14.81% reported high risk (Figure 2).

Estimation of Effect Size

Acquisition phase. A total of 25 studies met the inclusion criteria, involving 1419 participants that compared motor performance as a function of MP, PP, CP, or no practice. It was found that MP, PP, and CP were more effective than no practice; PP was more effective than MP; PP had similar results as CP; and CP was more effective than MP (see Table 2). In total, six pairwise comparison meta-analyses were calculated.

Retention phase. A total of 11 studies met the inclusion criteria, involving 634 participants that compared motor learning in retention tests as a function of MP, PP, CP, or no practice. It was found that PP had similar results as MP and CP. Not enough data to compare no practice with CP, MP, and PP; and CP with MP (see Table 2). In total, two pairwise

Online ISSN:2659-5699
DOI: 10.24310/jpehm.5.2.2023.17875

comparison meta-analyses were calculated.

Transfer phase. A total of 3 studies met the inclusion criteria, involving 155 participants that compared motor learning in transfer tests as a function of MP, PP, CP, or no practice. It was found that PP was more effective than MP (see Table 2). There was not enough data for the other pairwise comparisons. In total, one pairwise comparison meta-analysis was calculated.

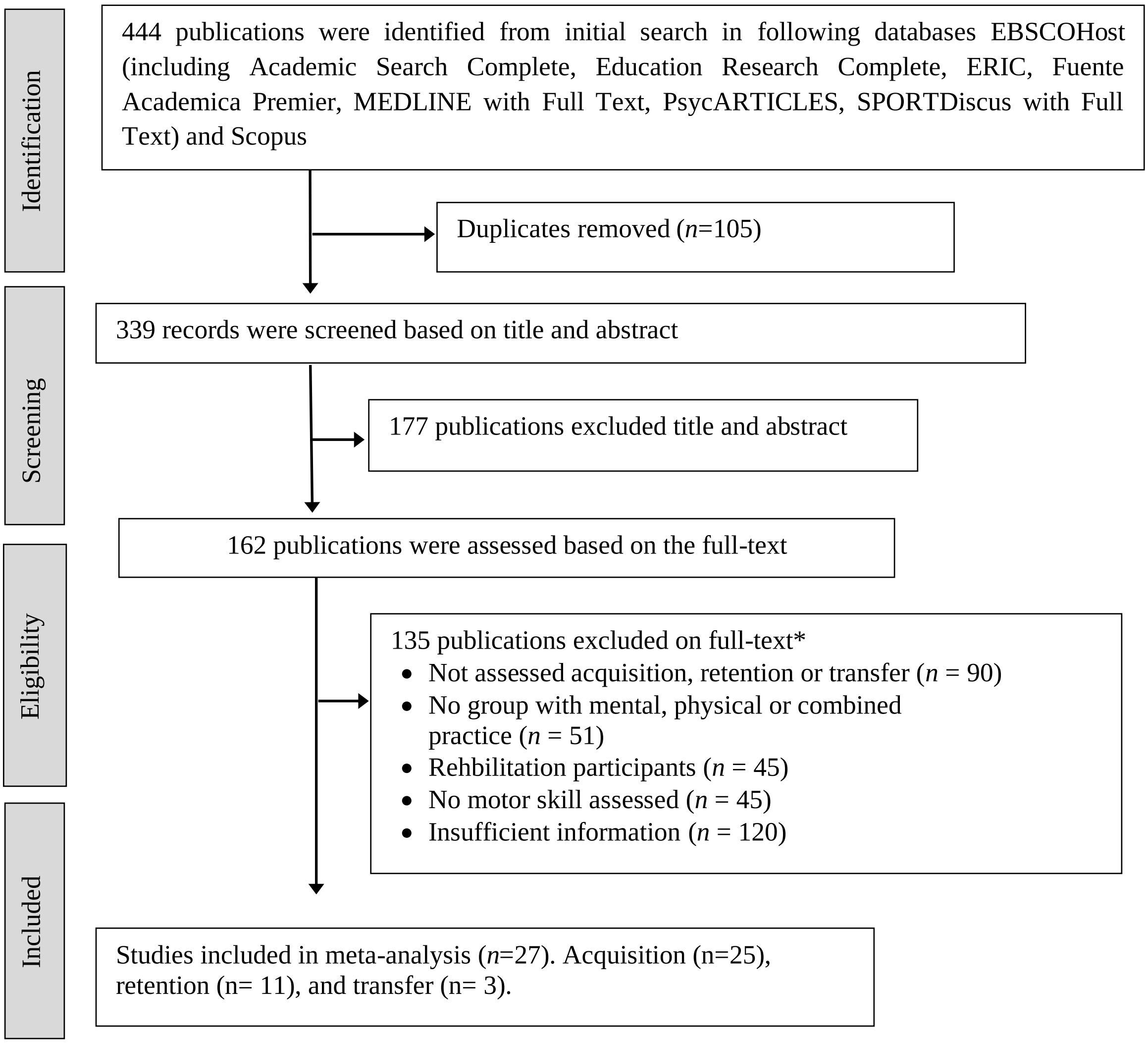

Figure 1. Flowchart of the studies' selection
Note: *Some studies excluded for more than one reason.

Online ISSN:2659-5699
DOI: 10.24310/jpehm.5.2.2023.17875

Table 1. Main characteristics of included studies

Reference	Sample characteristics	Skill characteristics	Type of practice	Practice characteristics
Abraham et al. (2017)	Amateur and advanced female dancers (*n* = 24) Age_{MP} = 13.5 ± 0.49 Age_{CG} = 13.63 ± 0.52	Motor skill	MP; CG	22 minutes / session, 2 sessions / week, 6 weeks
Allami et al. (2008)	Age = 28.5 *n* = 25	Motor skill	MP; 25%MP + PP; 50%MP + PP; 75%MP + PP, 75%MP(VR) + PP	1 session (240 attempts)
Azimkhani et al. (2013)	Men (*n* = 64) Age = 19 ± 1.41	Motor skill	CG; PP; MP; MP + PP	1 session (20 attempts)
Bek et al. (2016)	Novice men and women (*n* = 50) Age = 19.5 ± 0.98	Cognitive skill	CG; MP; OP	1 session (60 attempts)
Contreras-Hernández et al. (2020)	Expert men (*n* = 11) Age = 21.18 ± 2.16	Motor skill	PP; PP + MP	1 session (40 attempts)
Debarnot et al. (2011)	Men and women (*n* = 24) Age = 28	Cognitive skill	CG; PP; MP	1 session (8 minutes)
Doussoulin y Rehbein (2011)	Men and women (*n* = 64) Age = 9.5	Motor skill	PP; MP; OP	10 attempts / 6 sessions, 1 session per week
Freitas et al. (2020)	Men and women (*n* = 48) Age = 21.8 ± 2.2	Motor skill	PP; MP	1 session (12 attempts)
Hird et al. (1991)	Men, and women (*n* = 36) University students	Motor skill Cognitive skill	CG; PP; MP; 25%MP + PP; 50%MP + PP; 75%MP + PP	8 attempts / 7 sessions 4 attempts / 7 sessions
Ingram et al. (2016)	Novice men and women (*n* = 30) Age_{PP} = 21.6 ± 7.1 Age_{MP} = 23.6 ± 5.3	Cognitive skill	PP; MP	1 session (1000 attempts)
Kawasaki et al. (2019)	Men and women (*n* = 36) Age = 21.2 ± 0.7	Motor skill	CG; MP	1 session (2 minutes)
Kelsey (1961)	University Men (*n* = 36)	Strength	CG; PP; MP	5 minutes / session, 5 sessions / week, 4 weeks
Kraeutner et al. (2015)	Men and women (*n* = 42) Age = 22.1 ± 5.3	Cognitive skill	PP; MP	1 session (1000 attempts)
Kremer et al. (2011)	Novice and expert men and women (*n* = 60) Age= 26.8 ± 9.6	Motor skill	CG; MP	1 session (50 attempts)
Lee (1990) (Exp. 1)	Men (*n* = 52) Age = 20	Strength	CG; MP; MP(NR)	1 session (30 seconds)
Lee (1990) (Exp. 2)	Men (*n* = 142) Age = 21	Strength	CG; MP; MP(NR)	1 session (30 seconds)

Online ISSN:2659-5699
DOI: 10.24310/jpehm.5.2.2023.17875

Reference	Sample characteristics	Skill characteristics	Type of practice	Practice characteristics
Mousa Ay et al. (2013)	University students (*n* = 24) Age = 19 ± 0.5	Motor skill	PP; PP + MP	60 minutes / session, 2 sessions / week, 4 weeks
Mulder et al. (2004) (Exp. 1)	Men and women (*n* = 37) Age = 19-35	Motor skill	CG; PP; MP	100 attempts / 2 sessions
Mulder et al. (2004) (Exp. 2)	Men and women (*n* = 40) Age = 19-35	Motor skill	CG; PP; MP	100 attempts / 2 sessions
Norouzi et al. (2004)	Novice men (*n* = 45) Age = 14.65 ± 1.34	Motor skill	PP; PP + MP	12 attempts/ session 2 sessions / week, 4 weeks
Oxendine (1969) (Exp. 1)	Men (*n* = 80) Age = 12.4 ± 6.35	Motor skill	PP; 25%MP + PP; 50%MP + PP; 75%MP + PP	7 sessions (8 attempts)
Oxendine (1969) (Exp. 2)	Men (*n* = 72) Age= 12.7 ± 5.27	Motor skill	PP; 25%MP + PP; 50%MP + PP; 75%MP + PP	7 sessions (12 attempts)
Oxendine (1969) (Exp. 3)	Men (*n* = 12) Age= 12.7 ± 4.59	Motor skill	PP; 25%MP + PP; 50%MP + PP; 75%MP + PP	7 sessions (12 attempts)
Robin et al. (2007)	Expert tennis players (*n* = 30) Age = 19 ± 2.5	Motor skill	CG; MP + PP	60 attempts / 15 sessions
Sharif et al. (2015)	Men with mental paralysis (*n* = 29) Age = 18.51 ± 5.03	Motor skill	CG; PP; MP	30 attempts / 5 sessions
Stumbrys et al. (2016)	Men and women (*n* = 64) Age = 31.3 ± 7.3	Cognitive skill	CG; PP; MP; MP(LD)	1 session
Taktek et al. (2008)	School students (*n* = 96) Age = 8 to 10	Motor skill	CG; MP(K) + PP; MM(V) + PP; MP(V); MP(K); PP	1 session (20 attempts)
Truong et al. (2022)	Adults (*n* = 46)	Cognitive skill	PP; MP	1 session (44 attempts)
Urcuyo Ovares et al. (2020)	Men and women University students (*n* = 27) Age = 20.96 ± 4.47	Motor skill	PP; MP; MP + PP	1 session (10 attempts)
Wichman et al. (1983)	High school students (*n* = 35)	Motor skill	CG; MP	1 session (6 minutes)
Ziegler (1987)	Women (*n* = 92) University students	Motor skill	CG; PP; MP; MP(A); MP + PP	20 attempts/ session, 3 sessions /week; 3 weeks

Nota. Age in years and standard deviation, *n* = sample size, Exp. = Experiment, MP = mental practice, PP = physical practice, CG = control group, VR = visual rotation in the practice, PO = practice by observation, LD = lucid dreams. V = visual, K = kinesthetic. NR = MP is not related to the skill, A = MP with active movements.

Online ISSN:2659-5699
DOI: 10.24310/jpehm.5.2.2023.17875

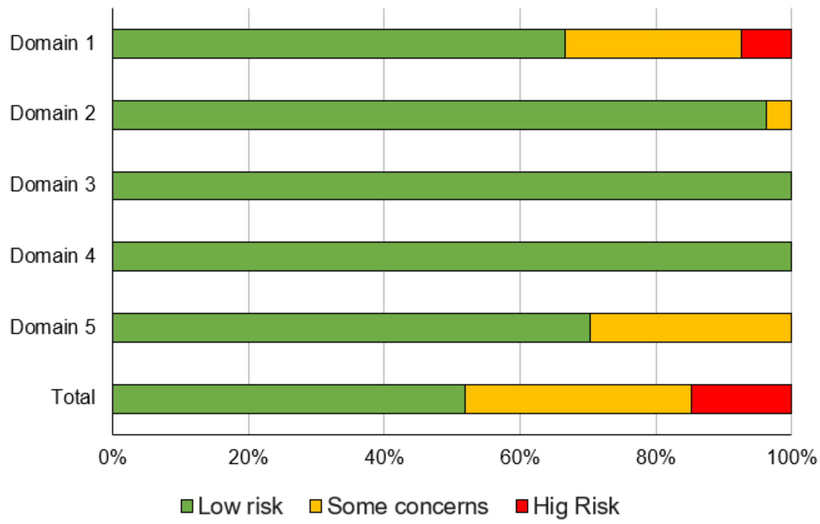

Figure 2. Risk of bias assessment for Rob2

Small-Study Effects

For all comparisons analyzed, Funnel plot and Egger's regression test was assessed. Asymmetry was confirmed for PP vs. CP (p=0.25) and CP vs. MP (p=0.11) in acquisition; PP vs. CP (p=0.23) in retention comparisons. While the other comparisons reported no asymmetry (p's < 0.05; Supplementary file 1).

Sensitivity analysis

For the six significant comparisons, sensitivity analyses (Leave-one-out) showed that the overall ES doesn't change its results after removing one individual ES each time (Supplementary file 2).

Table 2. Overall ES for each pairwise comparison in acquisition, retention, and transfer phase.

Phase	Pairwise	ES	N	CI	Q	I^2%
Acquisition	MP>no P	0.50	25	0.29, 0.72	42	40%
	PP>no P	1.78	15	0.97, 2.60	76	89%
	CP>no P	1.16	12	0.57, 1.75	41	74%
	PP>MP	-1.16	23	-1.88, -0.45	159	92%
	PP=CP	-0.01	16	-0.31, 0.28	26	42%
	CP>MP	0.61	12	0.17, 1.04	24	53%
Retention	PP=MP	-1.29	9	-3.12, 0.54	89	97%
	PP=CP	0.16	8	-0.29, 0.63	19	65%
Transfer	PP>MP	0.50	6	0.12, 0.87	2	0%

Note: MP = Mental practice, PP = Physical practice, CP = Combined practice, No P = no practice.

Online ISSN:2659-5699
DOI: 10.24310/jpehm.5.2.2023.17875

Moderator Variables Analysis

Age and skill level of the participants, type of MP, amount of practice, and skill characteristic were selected a priori as possible factors that may influence the effect of type of practice. Nonetheless, for all pairwise comparisons, the skill level of the participants could not be analyzed due to lack of information; skill characteristics could not be analyzed considering most of the skills were motor skills -few studies analyzed cognitive skills-; therefore, there was not enough data in all categories for subgroups analysis (n > 7). Moreover, most of the studies used a KMP, therefore there was not enough sample size for VMP. Moderator variable analyses were performed for pairwise comparisons that include PC, PP, and MP that had significant ES results.

We analyzed possible moderator variables for the significant comparisons (PP vs. MP and CP vs. MP) during the acquisition phase. For the pairwise comparison between PP vs. MP; no significant results were found for age (p=0.756, n= 13) nor amount of practice (p=0.913, n=23; assessed by total of sessions). These findings suggest that PP outperformed MP in individuals aged between 9 and 28 years old. Additionally, PP yielded superior results compared to MP when the number of practice sessions ranged from one to 20. For the pairwise comparison between CP vs. MP; a significant result was found for the amount of practice (p=0.007, n=12) assessed by total of sessions (Figure 3); these suggest that CP had better results than MP for one practice session, but similar results in performance can be found between CP and MP with more sessions (i.e. nine sessions). No significant comparisons were found to perform moderator variable analysis at retention phase. No moderator variables analyses were performed due to the small amount of ES in this phase and low I-square percentage at the transfer phase.

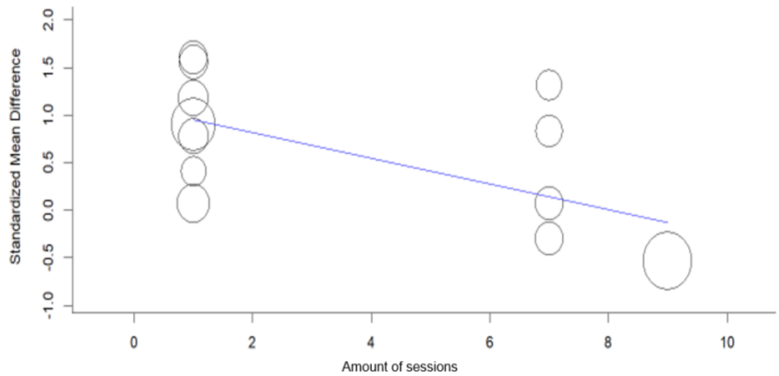

Figure 3. Meta-regression for amount of practice at acquisition phase for comparison between CP vs. MP.

DISCUSSION

To systematically synthesize scientific findings regarding the impact of mental practice on motor performance and learning, we conducted out a meta-analytic review. This review aimed to compare pairwise motor skill performance across various types of practice in acquisition, retention, and transfer tests. Six pairwise comparisons were examined in acquisition phase, two in retention phase, and one in transfer phase.

In summary, our analyses indicate that motor skill performance is notably enhanced when individuals engage in MP, PP, or CP compared to having no practice at all. Furthermore, PP and CP yield superior results compared to MP alone, and there is a similarity in outcomes

Online ISSN:2659-5699
DOI: 10.24310/jpehm.5.2.2023.17875

between PP and CP, on acquisition test. In terms of learning assessment, during the retention phase, PP demonstrated similar results to both MP and CP, suggesting comparable retention of learned skills. However, in the transfer test, PP exhibited better performance than MP when practiced alone. As anticipated, and in line with the majority of prior studies, the findings of our research affirm that MP, PP, or CP significantly enhance motor skill performance when compared to no practice at all during the acquisition phase (Allami et al., 2008; Debarnot et al., 2011; Feltz & Landers, 1983; Freitas et al., 2020; Hird et al., 1991; Lindsay et al., 2021; Mulder et al., 2004; Sharif et al., 2015; Taktek et al., 2008). Furthermore, our study provides support for the evidence that CP yields more substantial performance benefits than MP alone (Heena et al., 2021; Hird et al., 1991; Taktek et al., 2008); PP outperforms MP (Freitas et al., 2020;

Ingram et al., 2016; Mulder et al., 2004; Ruffino et al., 2021; Sharif et al., 2015; Truong et al., 2022), and PP demonstrates similar performance outcomes to CP (Lindsay et al., 2021). However, contrary to some earlier research that suggested CP was superior to PP (Behrendt et al., 2021; Simonsmeier et al., 2021), our findings indicate that CP and PP exhibit comparable performance results. These conflicting results may arise from methodological distinctions in our meta-analysis, such as inclusion criteria, outcome measures, and research approaches, or variations in the methodologies employed in the studies included, such as MI programming.

Drawing upon prior research, we undertook an investigation into various potential moderator variables that could influence the impact of practice type on motor skill performance and learning. It's worth noting that due to limited sample sizes in certain categories, not all coded factors were subjected to analysis. Our research revealed that the number of practice sessions serves as a moderator variable when comparing CP and MP. These findings align with previous studies that have suggested the benefits of MP are contingent on specific dosage levels (Driskell et al., 1994; Hinshaw, 1991; Simonsmeier et al., 2021).

Furthermore, it's worth noting that a substantial portion of the existing literature predominantly focuses on assessing the impact of MP on performance, and there has been comparatively less research that delves into the examination of MP's influence on learning through retention or transfer tests. Regarding learning assessment, our investigation uncovered that during the retention phase, MP and PP yielded similar results, as did the CP approach. However, in the transfer test, PP demonstrated superior performance compared to MP when practiced alone. This contrasts with some previous research findings that indicated similar outcomes for PP and MP in both retention and transfer tests (Sharif et al., 2015) and highlighted the effectiveness of MP over no practice (Kawasaki et al., 2019). In summary, the available evidence collectively suggests that, for both motor skill performance and learning, both PP and CP approach tend to yield superior results compared to MP practiced alone.It has been suggested that MP and PP share similar neural mechanisms in the cognitive process, as evidenced by comparable brain activity during their execution (Jackson et al., 2003; Lee et al., 2019; Matsuo et al., 2020; Nakano, 2012). Specifically, MP has been shown to elicit brain activity in areas such as the primary motor area, premotor area, supplementary motor area, frontal area, parietal area, thalamus, and cerebellum, mirroring the patterns seen during PP (Broniec, 2016; Jackson et al., 2003; Lee et al., 2019; Wang et al., 2014; Zich et al., 2017). Nonetheless, some variations in brain activation have been noted in prior research, where different brain regions are engaged during MP (Di Nota et al., 2016; Macuga & Frey, 2012).

This review possesses several notable strengths. Our meta-analysis comprehensively examined the impact of different practice types on motor performance and learning, covering most possible pairwise comparisons between MP, PP, CP, and no practice. We imposed no year limits and conducted searches in three languages, broadening the scope of included studies and

Online ISSN:2659-5699
DOI: 10.24310/jpehm.5.2.2023.17875

enhancing the reliability of our findings. Additionally, the consideration of numerous moderating variables aids practitioners in gaining insights into the generalizability of practice types for motor performance. Our risk of bias assessment found the majority of studies to have low risk, with only 14.81% exhibiting high risk, and sensitivity analyses confirmed the robustness of our results to potential bias. While caution is warranted due to the small sample size, the limited number of high-risk bias studies bolsters our confidence in the overall quality of the research. However, limitations of this meta-analysis included a small sample size for retention and transfer phase analysis and the inability to execute the moderator variable assessment as originally planned due to the exclusion of many studies that did not meet eligibility criteria. This might explain the small study effects observed and the lack of capacity to include representative studies. Furthermore, some studies were excluded due to insufficient statistical information, highlighting the need for researchers and journals to include descriptive data in their papers for future meta-analyses.

Learning through physical practice continues to be the gold standard for improving motor skill performance, and it is acknowledged that MP cannot entirely replace PP (Allami et al., 2008; Fairbrother, 2010; Kraeutner et al., 2016). However, our study underscores that MP can serve as a valuable alternative when PP is unavailable or as a complement to PP. Additionally, MP can be particularly useful in scenarios involving space constraints, limited materials, restricted facility access, or factors like injuries and fatigue (Fairbrother, 2010). Thus, a balance between MP and PP when planning practice sessions, incorporating CP where appropriate should be considered.

Finally, in light of the many facets of MP that remain unexplored, future research should prioritize several key directions. First and foremost, investigations should delve into the effects of varying combinations of MP and PP (Heena et al., 2021). Recognizing that MP alone may not be the most optimal choice in the majority of circumstances, understanding the nuances of CP can provide valuable insights.

Furthermore, there is a pressing need for additional research to thoroughly evaluate the impact of MP on learning, encompassing retention and transfer assessments. These assessments can shed light on how MP contributes not only to immediate performance but also in learning and application of motor skills. Lastly, given the substantial body of research surrounding the cognitive processes and brain activity associated with motor imagery and motor execution, there is a compelling case for conducting a systematic review. Such a review could provide a comprehensive understanding of the neural mechanisms at play during MP, bridging the gap between theory and empirical evidence in this intriguing area of study.

In summary, this study has synthesized and quantified scientific evidence concerning the influence of MP on motor performance and learning. It is crucial to recognize that MP cannot entirely supplant PP. However, the findings from this comprehensive meta-analysis indicate that maintaining a well-calibrated equilibrium between PP and MP can have a positive impact on participants' performance levels, similar to what is achieved with PP alone. This balanced approach serves as a valuable tool to mitigate the risks associated with excessive physical practice, such as physical fatigue, burnout, and injuries. Moreover, it offers a practical solution for situations where PP is constrained by factors like limited access to facilities or materials. By striking this equilibrium between MP and PP, motor skill development can be optimized and performance outcomes enhanced.

Online ISSN:2659-5699
DOI: 10.24310/jpehm.5.2.2023.17875

REFERENCES

Allami, N., Paulignan, Y., Brovelli, A., & Boussaoud, D. (2008). Visuo-motor learning with combination of different rates of motor imagery and physical practice. Experimental Brain Research, 184(1), Article 1. https://doi.org/10.1007/s00221-007-1086-x

Behrendt, F., Zumbrunnen, V., Brem, L., Suica, Z., Gäumann, S., Ziller, C., Gerth, U., & Schuster-Amft, C. (2021). Effect of motor imagery training on motor learning in children and adolescents: A systematic review and meta-Analysis. International Journal of Environmental Research and Public Health, 18(18), 9467. https://doi.org/10.3390/ijerph18189467

Borenstein, M., Hedges, L. V., Higgins, J. P., & Rothstein, H. R. (2009). Introduction to meta-analysis. John Wiley & Sons. https://doi.org/10.1002/9780470743386

Borenstein, M., Higgins, J. P. T., Hedges, L. V., & Rothstein, H. R. (2017). Basics of meta-analysis: I 2 is not an absolute measure of heterogeneity: I 2 is not an absolute measure of heterogeneity. Research Synthesis Methods, 8(1), Article 1. https://doi.org/10.1002/jrsm.1230

Broniec, A. (2016). Analysis of EEG signal by flicker-noise spectroscopy: Identification of right-/left-hand movement imagination. Medical & Biological Engineering & Computing, 54(12), 1935-1947. https://doi.org/10.1007/s11517-016-1491-z

Debarnot, U., Clerget, E., & Olivier, E. (2011). Role of the primary motor cortex in the early boost in performance following mental imagery training. PLoS ONE, 6(10), Article 10. https://doi.org/10.1371/journal.pone.0026717

Di Nota, P. M., Levkov, G., Bar, R., & DeSouza, J. F. X. (2016). Lateral occipitotemporal cortex (LOTC) activity is greatest while viewing dance compared to visualization and movement: Learning and expertise effects. Experimental Brain Research, 234(7), 2007-2023. https://doi.org/10.1007/s00221-016-4607-7

Doussoulin, A., & Rehbein, L. (2011). Motor imagery as a tool for motor skill training in children. Motricidade, 7(3). https://doi.org/10.6063/motricidade.7(3).131

Driskell, J. E., Copper, C., & Moran, A. (1994). Does mental practice enhance performance? Journal of Applied Psychology, 79(4), Article 4. https://doi.org/10.1037/0021-9010.79.4.481

Fairbrother, J. T. (2010). Fundamentals of Motor Behavior. Human Kinetics. https://doi.org/10.5040/9781492597346

Feltz, D. L., & Landers, D. M. (1983). The effects of mental practice on motor skill learning and performance: A meta-analysis. Journal of sport psychology, 5(1), Article 1. https://doi.org/10.1123/jsp.5.1.25

Freitas, E., Saimpont, A., Blache, Y., & Debarnot, U. (2020). Acquisition and consolidation of sequential footstep movements with physical and motor imagery practice. Scandinavian Journal of Medicine & Science in Sports, 30(12), 2477-2484. SPORTDiscus with Full Text.

Gomes, T. V. B., Ugrinowitsch, H., Marinho, N., Shea, J. B., Raisbeck, L. D., & Benda, R. N. (2014). Effects of mental practice in novice learners in a serial positioning skill acquisition. Perceptual and Motor Skills, 119(2), Article 2. https://doi.org/10.2466/23.PMS.119c20z4

Heena, N., Zia, N. U., Sehgal, S., Anwer, S., Alghadir, A., & Li, H. (2021). Effects of task complexity or rate of motor imagery on motor learning in healthy young adults. Brain & Behavior, 11(11), Article 11. https://doi.org/10.1002/brb3.2122

Hinshaw, K. E. (1991). The effects of mental practice on motor skill performance: Critical evaluation and meta-analysis. Imagintation, cognition and personality, 11(1). https://doi.org/doi.org/10.2190/X9BA-KJ68-07AN-QMJ8

Hird, J. S., Landers, D. M., Thomas, J. R., & Horan, J. J. (1991). Physical practice is superior to mental practice in enhancing cognitive and motor task performance. Journal of Sport and Exercise Psychology, 13(3), Article 3. https://doi.org/10.1123/jsep.13.3.281

Ingram, T. G. J., Kraeutner, S. N., Solomon, J. P., Westwood, D. A., & Boe, S. G. (2016). Skill acquisition via motor imagery relies on both motor and perceptual learning. Behavioral Neuroscience, 130(2), 252-260. https://doi.org/10.1037/bne0000126

Jackson, P. L., Lafleur, M. F., Malouin, F., Richards, C. L., & Doyon, J. (2003). Functional cerebral reorganization following motor sequence learning through mental practice with motor imagery. Neuroimage, 20(2), Article 2. https://doi.org/10.1016/S1053-8119(03)00369-0

Kawasaki, T., Kono, M., & Tozawa, R. (2019). Efficacy of verbally describing one's own body movement in motor skill acquisition. Brain Sciences, 9(12), Article 12. https://doi.org/10.3390/brainsci9120356

Online ISSN:2659-5699
DOI: 10.24310/jpehm.5.2.2023.17875

Kraeutner, S. N., Gionfriddo, A., Bardouille, T., & Boe, S. (2014). Motor imagery-based brain activity parallels that of motor execution: Evidence from magnetic source imaging of cortical oscillations. Brain Research, 1588, 81-91. https://doi.org/10.1016/j.brainres.2014.09.001

Kraeutner, S. N., MacKenzie, L. A., Westwood, D. A., & Boe, S. G. (2016). Characterizing skill acquisition through motor imagery with no prior physical practice. Journal of Experimental Psychology: Human Perception and Performance, 42(2), Article 2. https://doi.org/10.1037/xhp0000148

Lee, W. H., Kim, E., Seo, H. G., Oh, B.-M., Nam, H. S., Kim, Y. J., Lee, H. H., Kang, M.-G., Kim, S., & Bang, M. S. (2019). Target-oriented motor imagery for grasping action: Different characteristics of brain activation between kinesthetic and visual imagery. Scientific Reports, 9(1), 12770. https://doi.org/10.1038/s41598-019-49254-2

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P. A., Clarke, M., Devereaux, P. J., Kleijnen, J., & Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: Explanation and elaboration. British Medical Journal, 339, b2700. https://doi.org/10.1136/bmj.b2700

Lindsay, R. S., Larkin, P., Kittel, A., & Spittle, M. (2021). Mental imagery training programs for developing sport-specific motor skills: A systematic review and meta-analysis. Physical Education and Sport Pedagogy, 28(4), 444-465. https://doi.org/10.1080/17408989.2021.1991297

Macuga, K. L., & Frey, S. H. (2012). Neural representations involved in observed, imagined, and imitated actions are dissociable and hierarchically organized. NeuroImage, 59(3), 2798-2807. https://doi.org/10.1016/j.neuroimage.2011.09.083

Matsuo, M., Iso, N., Fujiwara, K., Moriuchi, T., Matsuda, D., Mitsunaga, W., Nakashima, A., & Higashi, T. (2020). Comparison of cerebral activation between motor execution and motor imagery of self-feeding activity. Neural Regeneration Research, 16(4), 778. https://doi.org/10.4103/1673-5374.295333

Mulder, T., Zijlstra, S., Zijlstra, W., & Hochstenbach, J. (2004). The role of motor imagery in learning a totally novel movement. Experimental Brain Research, 154(2), Article 2. https://doi.org/10.1007/s00221-003-1647-6

Munzert, J., Lorey, B., & Zentgraf, K. (2009). Cognitive motor processes: The role of motor imagery in the study of motor representations. Brain Research Reviews, 60(2), Article 2. https://doi.org/10.1016/j.brainresrev.2008.12.024

Nakano, H. (2012). Brain activity during the observation, imagery, and execution of tool use: An fNIRS/EEG study. Journal of Novel Physiotherapies, 01(S1). https://doi.org/10.4172/2165-7025.S1-009

Neuper, C., Scherer, R., Reiner, M., & Pfurtscheller, G. (2005). Imagery of motor actions: Differential effects of kinesthetic and visual–motor mode of imagery in single-trial EEG. Cognitive Brain Research, 25(3), 668-677. https://doi.org/10.1016/j.cogbrainres.2005.08.014

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., & Moher, D. (2021). Updating guidance for reporting systematic reviews: Development of the PRISMA 2020 statement. Journal of Clinical Epidemiology, 134, 103-112. https://doi.org/10.1016/j.jclinepi.2021.02.003

Ruffino, C., Papaxanthis, C., & Lebon, F. (2017). Neural plasticity during motor learning with motor imagery practice: Review and perspectives. Neuroscience, 341, 61-78. https://doi.org/10.1016/j.neuroscience.2016.11.023

Ruffino, C., Truong, C., Dupont, W., Bouguila, F., Michel, C., Lebon, F., & Papaxanthis, C. (2021). Acquisition and consolidation processes following motor imagery practice. Scientific Reports, 11(1), Article 1. https://doi.org/10.1038/s41598-021-81994-y

Sedgwick, P., & Marston, L. (2015). How to read a funnel plot in a meta-analysis. British Medical Journal (Clinical research ed.), 351, h4718. https://doi.org/10.1136/bmj.h4718

Sharif, M. R., Hemayattalab, R., Sayyah, M., Hemayattalab, A., & Bazazan, S. (2015). Effects of physical and mental practice on motor learning in individuals with cerebral palsy. Journal of Developmental and Physical Disabilities, 27(4), Article 4. https://doi.org/10.1007/s10882-015-9432-6

Siddaway, A. P., Wood, A. M., & Hedges, L. V. (2019). How to do a systematic review: A best practice guide for conducting and reporting narrative reviews, meta-analyses, and meta-syntheses. Annual Review of Psychology, 70(1), 747-770. https://doi.org/10.1146/annurev-psych-010418-102803

Simonsmeier, B. A., Andronie, M., Buecker, S., & Frank, C. (2021). The effects of imagery interventions in sports: A meta-analysis. International Review of Sport and Exercise Psychology, 14(1), 186-207. https://doi.org/10.1080/1750984X.2020.1780627

Online ISSN:2659-5699
DOI: 10.24310/jpehm.5.2.2023.17875

Sterne, J. A. C., Savović, J., Page, M. J., Elbers, R. G., Blencowe, N. S., Boutron, I., Cates, C. J., Cheng, H.-Y., Corbett, M. S., Eldridge, S. M., Emberson, J. R., Hernán, M. A., Hopewell, S., Hróbjartsson, A., Junqueira, D. R., Jüni, P., Kirkham, J. J., Lasserson, T., Li, T., … Higgins, J. P. T. (2019). RoB 2: A revised tool for assessing risk of bias in randomised trials. BMJ, l4898. https://doi.org/10.1136/bmj.l4898

Stumbrys, T., Erlacher, D., & Schredl, M. (2016). Effectiveness of motor practice in lucid dreams: A comparison with physical and mental practice. Journal of Sports Sciences, 34(1), Article 1. https://doi.org/10.1080/02640414.2015.1030342

Taktek, K., Zinsser, N., & St-John, B. (2008). Visual versus kinesthetic mental imagery: Efficacy for the retention and transfer of a closed motor skill in young children. Canadian Journal of Experimental Psychology/Revue Canadienne de Psychologie Expérimentale, 62(3), Article 3. https://doi.org/10.1037/1196-1961.62.3.174

Truong, C., Hilt, P. M., Bouguila, F., Bove, M., Lebon, F., Papaxanthis, C., & Ruffino, C. (2022). Time-of-day effects on skill acquisition and consolidation after physical and mental practices. Scientific Reports, 12(1), 1-9. Academic Search Ultimate.

Vasilyev, A. N., Nuzhdin, Y. O., & Kaplan, A. Y. (2021). Does Real-Time Feedback Affect Sensorimotor EEG Patterns in Routine Motor Imagery Practice? Brain Sciences, 11(9), 1234. https://doi.org/10.3390/brainsci11091234

Wang, X., Casadio, M., Weber, K. A., Mussa-Ivaldi, F. A., & Parrish, T. B. (2014). White matter microstructure changes induced by motor skill learning utilizing a body machine interface. NeuroImage, 88, 32-40. Scopus. https://doi.org/10.1016/j.neuroimage.2013.10.066

Wriessnegger, S., Kurzmann, J., & Neuper, C. (2008). Spatio-temporal differences in brain oxygenation between movement execution and imagery: A multichannel near-infrared spectroscopy study. International Journal of Psychophysiology, 67(1), 54-63. https://doi.org/10.1016/j.ijpsycho.2007.10.004

Zich, C., Debener, S., Thoene, A.-K., Chen, L.-C., & Kranczioch, C. (2017). Simultaneous EEG-fNIRS reveals how age and feedback affect motor imagery signatures. Neurobiology of Aging, 49, 183-197. https://doi.org/10.1016/j.neurobiolaging.2016.10.011