

Mental Imagery Training: An Innovative, Resource-Free Approach to Combat Working Memory Decline in Young Adults

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ABSTRACT:

Sedentary behavior and unhealthy lifestyles are increasingly common among young adults and linked to cognitive decline, especially memory. Physical exercise may not be feasible for everyone, highlighting the need for low-burden alternatives. This study examined the association between imagery and memory, and the effects of a single imagery training session on working memory in young adults. In Phase 1, imagery use and ability were assessed using the Sport Imagery Questionnaire (SIQ) and Sport Imagery Ability Questionnaire (SIAQ), while memory function was measured with the Memory Functioning Questionnaire (MFQ). In Phase 2, participants were randomly assigned to an imagery training, an execution training, or a control group. Working memory was assessed using the Sternberg task before and after a single 30-minute intervention. Phase 1 analyses revealed significant positive correlations between self-reported imagery use/ability and memory function ($r = .27 - .48$, all $p < .05$), with no gender differences observed. Phase 2 results showed that, compared to the control group, the imagery training group demonstrated significant improvements in Sternberg task performance. This was evidenced by significant group $\times$ time interactions for response speed across all task conditions ($F(2,90) = 3.35-7.08$, all $p < .05$, partial $\eta^2 = .10 - .14$) and for accuracy in the 3-item condition ($F(2,90) = 4.41$, $p = .015$, partial $\eta^2 = .09$). These findings indicate that imagery is positively associated with memory function in young adults. More

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importantly, a brief session of imagery training can produce measurable, small-to-medium sized improvements in working memory efficiency. These results highlight the potential of imagery-based interventions as a practical and low-cost approach for cognitive support in young adults.

Keywords: imagery, cognition, memory, imagery use, imagery ability.

Introduction

Global health systems face growing challenges from lifestyle-related conditions that threaten long-term well-being [1]. Cognitive health, though critical, is often overlooked, as cognitive decline imposes substantial personal and societal costs [2]. Young adults are particularly vulnerable, as sedentary behavior, screen exposure, and reduced physical activity are common in university life and have been linked to memory impairments [3, 4]. Protecting cognitive health in early adulthood is essential to prevent long-term consequences [5-8]. This aligns with Sustainable Development Goal 3 for healthy lives at all ages [9, 10].

Physical exercise improves memory [11, 12]. However, exercise is not feasible for everyone due to time, motivation, or physical limitations [13, 14]. As a result, exercise-based interventions alone may not fully meet the needs of diverse populations. Low-burden, scalable, non-invasive alternatives are needed, especially those requiring no specialized equipment. This is crucial for inclusive health strategies [15]. Despite this need, cognitively oriented interventions that require minimal infrastructure have received comparatively limited attention in health promotion research targeting young adults.

Mental imagery represents a promising candidate within this context. Imagery training is performed mentally, generating vivid sensory simulations without physical execution [16-18]. Neuroimaging studies further demonstrate that imagery activates regions including the supplementary motor area,

premotor cortex, and parietal lobes, which support internal representation, cognitive control, and information integration [19, 20]. Although imagery benefits attention and executive function [21, 22], its role as a practical memory strategy in young adults remains underexplored.

To address these gaps, this study used a two-phase design in which Phase 1 examined associations between imagery use/ability and memory function, and Phase 2 tested changes in working memory after a single imagery training session, thereby contributing to low-resource cognitive health promotion.

Materials and Methods

Participants

Ninety-two young adults (64 males, 28 females; mean age 22.41 ± 0.99 years) participated. Inclusion criteria were: Malaysian citizenship and age ≥ 18 years. Exclusion criteria included major systemic diseases, acute illness, physical/mental disability, or acute musculoskeletal pain on testing day. Most participants were Malay (94.6%) and engaged in team sports (60.2%). Written informed consent was obtained from all participants.

Measures

Demographic information. Participants were provided with demographic details such as their gender, age, sports achievement, and if they had received any imagery training.

Sport Imagery Questionnaire (SIQ). The SIQ is a 30-item measure assessing imagery use across five

functions using a 7-point Likert scale [23]. Responses are rated on a 7-point Likert scale ranging from 1 (never/rarely) to 7 (often). It has demonstrated good reliability and validity in previous studies [24], and showed acceptable internal consistency in the present study ($\alpha = 0.70-0.88$).

Sport Imagery Ability Questionnaire (SIAQ).

The SIAQ assesses perceived sport imagery ability using a 7-point Likert scale [25]. Participants rate how easily they can image each item on a 7-point Likert scale (1 = very hard to image, 7 = very easy to image) based on their primary sport. The alpha coefficients for the five subscales ranged from 0.82 to 0.88, indicating strong internal reliability across dimensions.

Memory Functioning Questionnaire (MFQ).

The MFQ assesses perceived memory functioning across four domains using a 7-point Likert scale, with higher scores indicating better memory function [26]. It has demonstrated excellent internal consistency ($\alpha = 0.82-0.93$) and has been validated in both adult and young populations, supporting its use in the present study to assess memory-related cognitive function.

Sternberg paradigm. The Test is a widely used paradigm for assessing working memory performance [27]. The task consists of three levels with increasing working memory load (one-, three-, and five-item conditions). Participants identified whether stimuli matched previously memorized items, with reaction time and accuracy recorded.

Procedures

The study received ethical approval. Phase 1 (cross-sectional): Participants completed online

questionnaires (demographics, SIQ, SIAQ, MFQ) in ~10-15 minutes. Phase 2 (experimental): A single 30-minute intervention with three groups: Imagery Training (IT), Execution Training (ET), and Control (CG). A familiarization session was held 7 days before pre-test. Pre-test (Visit 2) and post-test (Visit 3) both used the Sternberg task (~5 minutes).

During the experimental phase, the participants were divided into three groups, including Imagery Group, Execution Group and Control Group (see

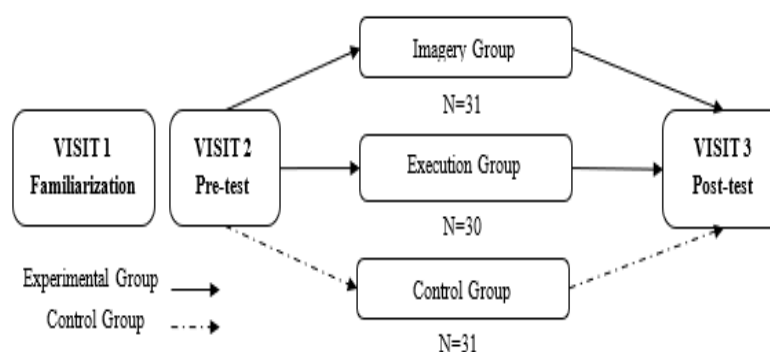


Figure 1).

Imagery Training (IT) Group: Participants listened to a standardized audio script guiding kinesthetic and visual imagery of bodyweight squats while seated quietly. The session consisted of five 1-minute static squat imagery trials with 10-second rest intervals and lasted 30 minutes [28, 29].

Execution Training (ET) Group: After a standardized warm-up, participants completed 5 sets of 1-minute static squat holds (~90° knee flexion) with 10-second rest intervals.

Control (CG) Group: Participants remained seated quietly for 30 minutes and read neutral non-physical activity-related materials.

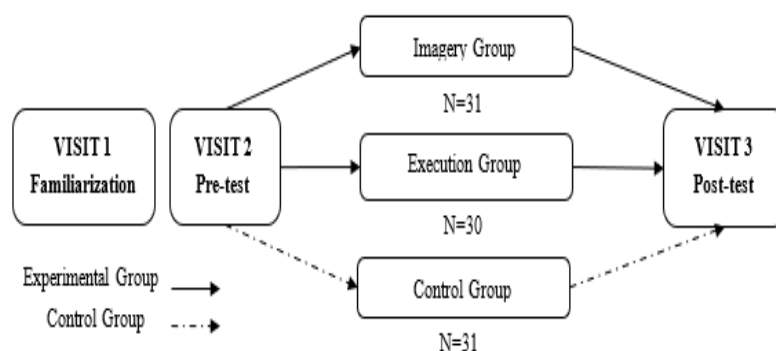


Figure 1 Schematic representation of the overall study design

Data Analyses

A priori power analysis (G*Power) for repeated-measures ANOVA ($f=0.20$, $\alpha=0.05$, power=0.80) indicated $N=84$; our $N=92$ exceeded this. Pearson correlations examined associations between imagery and memory. Independent t-tests

compared genders. Two-way (group $\times$ time) repeated-measures ANOVA tested Sternberg task changes. SPSS 29.0 was used.

Results

Phase 1: Cross-sectional

Table 1 presents the descriptive statistics for all variables. Overall, participants reported

relatively high levels of imagery use and imagery ability, whereas MFQ scores were moderate.

Table 1 Means, Standard Deviations of Questionnaire subscales

		Minimum	Maximum	Mean	SD
	CS	2	7	5.39	1.11
	CG	2	7	5.31	1.08
SIQ	MS	2	7	5.49	1.10
	MG-A	2	7	5.23	1.15
	MG-M	2	7	5.47	1.06
	Skill imagery	3	7	5.48	1.01
	Strategy imagery	3	7	5.47	0.99
SIAQ	Goal imagery	3	7	5.69	1.08
	Affect imagery	4	7	5.57	0.97
	Mastery imagery	3	7	5.44	1.04
MFQ	General Frequency of Forgetting	3	6	4.59	0.79
	Seriousness of Forgetting	3	7	4.91	0.93

Restrospective Functioning	2	7	4.52	1.05
Mnemonics Usage	1	7	3.03	1.48

Note: CS = cognitive specific; CG = cognitive general; MS = motivational specific; MG-A = motivational general-affective; MG-M = motivational general-mastery.

As shown in

Table 2, imagery use and imagery ability were positively associated with general frequency of forgetting, seriousness of forgetting, and

retrospective functioning ($r = .26-.51, p < .05$). Negative associations were observed with mnemonics usage, indicating lower reliance on external memory aids among participants with stronger imagery characteristics.

Table 2 Details of Correlation Between Imagery Use, Imagery Ability and Memory Function

MFQ	General Frequency Forgetting	Seriousness of Forgetting	Restrospective Functioning	Mnemonic Usage
CS	.385**	.483**	.284*	-.211
CG	.379**	.459**	.366**	-.308*
SIQ	MS	.482**	.303*	-.223
	MG-A	.447**	.341**	-.298*
	MG-M	.382**	.216	-.227
	Skill imagery	.421**	.454**	-.343**
	Strategy imagery	.407**	.265*	-.366**
SIAQ	Goal imagery	.408**	.383**	-.244
	Affect imagery	.414**	.505**	-.416**
	Mastery imagery	.386**	.280*	-.344**

Note: CS = cognitive specific; CG = cognitive general; MS = motivational specific; MG-A = motivational general-affective; MG-M = motivational general-mastery.

* $p < .05$. ** $p < .01$.

Independent-samples t-tests showed no significant gender differences across SIQ, SIAQ, or most MFQ subscales (all $p > .05$). A significant

difference was only observed for MFQ mnemonics usage, $t(91) = -2.04, p = .044$. Overall, gender demonstrated minimal influence on the primary study variables.

Phase 2: A randomized controlled trial (RCT)

Descriptive statistics for Sternberg task performance are presented in

Table 3.

Table 3 Memory function data across the Imagery, Execution and Control groups Data are mean $\pm$ SD

Test	Test Level	Variable	Imagery	Training	Execution		Control	Group
			(IT)		Training (ET)		(CG)	
			(n=31)		(n=30)		(n=31)	
			Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Sternberg	1-item	Response Time [ms]	620 $\pm$ 113	528 $\pm$ 86	653 $\pm$ 162	503 $\pm$ 86	549 $\pm$ 117	521 $\pm$ 128
		Accuracy [%]	99.6 $\pm$ 1.1	97.1 $\pm$ 9.9	97.1 $\pm$ 9.9	99.2 $\pm$ 1.1	97.7 $\pm$ 4.4	96.9 $\pm$ 4.4
	3-item	Response Time [ms]	678 $\pm$ 114	628 $\pm$ 89	700 $\pm$ 140	603 $\pm$ 93	659 $\pm$ 132	628 $\pm$ 112
		Accuracy [%]	98.3 $\pm$ 2.4	99.2 $\pm$ 2.1	99.2 $\pm$ 1.8	99.8 $\pm$ 1.1	95.3 $\pm$ 4.6	98.4 $\pm$ 2.7
	5-item	Response Time [ms]	836 $\pm$ 150	753 $\pm$ 124	851 $\pm$ 204	729 $\pm$ 133	708 $\pm$ 140	673 $\pm$ 140
		Accuracy [%]	98.6 $\pm$ 1.9	97.9 $\pm$ 2.6	99.1 $\pm$ 1.7	97.5 $\pm$ 2.8	95.0 $\pm$ 8.5	94.0 $\pm$ 8.9

Response time.

Overall, for the 1-item condition, a significant main effect of time was found, $F(1,90) = 46.43$, $p < .001$, partial $\eta^2 = .34$, whereas the group effect was not significant, $F(2,90) = 1.81$, $p = .170$. A significant group $\times$ time interaction was observed, $F(2,90) = 7.08$, $p = .001$, partial $\eta^2 = .14$, indicating greater improvement in the IT and ET groups. In the three-item condition of the Sternberg task, a significant time effect was observed, $F(1,90) = 32.64$, $p < .001$, partial $\eta^2 = .27$, but no group effect

was found, $F(2,90) = 0.08$, $p = .919$. The group $\times$ time interaction was significant, $F(2,90) = 3.53$, $p = .033$, partial $\eta^2 = .07$, with greater improvement in the IT and ET groups. For the 5-item condition, significant effects of time, $F(1,90) = 33.19$, $p < .001$, partial $\eta^2 = .27$, and group, $F(2,90) = 5.94$, $p = .004$, partial $\eta^2 = .12$, were found. A significant group $\times$ time interaction was also observed, $F(2,90) = 3.35$, $p = .039$, partial $\eta^2 = .07$, indicating greater improvement in the IT and ET groups than the CG (in Figure 2).

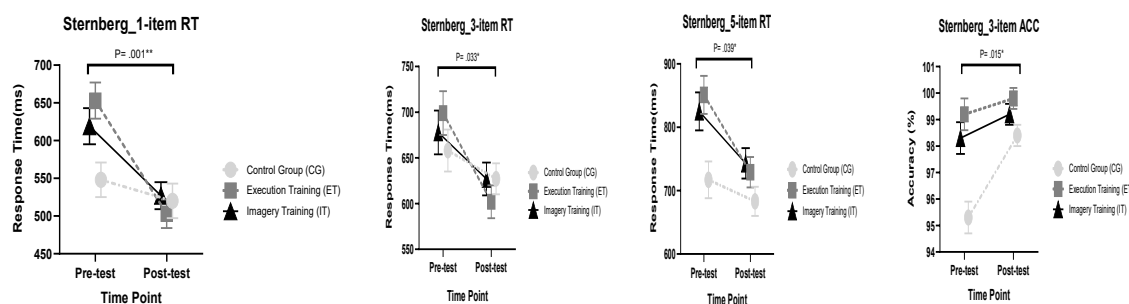


Figure 2 Estimated Marginal Means of Response Time and Accuracy ($\pm$ SEM) for Each Group Across Pre- and Post-Test Sessions in the Sternberg Paradigm Task.

Accuracy.

Accuracy in the one-item condition was not different between groups, $F(2,90) = 0.57$, $p = .57$, time, $F(1,90) = 0.23$, $p = .64$, or group $\times$ time interaction, $F(2,90) = 2.45$, $p = .09$, were observed. On the three-item level of the Sternberg paradigm, a significant was observed in the main effect of group ($F(2,90) = 13.69$, $p < .001$, partial $\eta^2 = .23$), with overall accuracy higher in the imagery and execution training groups than in the control group. A significant main effect of time was also observed ($F(1,90) = 16.73$, $p < .001$, partial $\eta^2 = .02$), importantly, a significant main effect of group $\times$ time interaction was detected ($F(2,90) = 4.41$, $p = .015$, partial $\eta^2 = .09$; Figure 2). For the 5-item condition, a significant group effect was found, $F(2,90) = 7.50$, $p = .001$, partial $\eta^2 = .14$, with higher accuracy in the IT and ET groups than the CG. However, no significant effects of time, $F(1,90) = 2.89$, $p = .09$, or group $\times$ time interaction, $F(2,90) = 0.17$, $p = .85$, were observed.

Discussion

The present study contributes to the innovative approaches to sustainable global development by demonstrating that imagery training represents a low-cost, non-invasive, and scalable strategy for supporting memory-related cognitive efficiency in young adults. Within the broader context of global health and human performance, identifying interventions that enhance cognitive function without reliance on pharmacological treatment,

specialized equipment, or high physical demands is increasingly important. Imagery, as examined in this study, aligns well with these priorities by offering a resource-efficient means of cognitive support that can be implemented across educational, athletic, and health-related settings.

No significant gender differences were observed across imagery or cognitive measures. This finding is broadly consistent with prior research in non-clinical adult populations, which has reported minimal or inconsistent gender effects when multidimensional imagery assessments are employed [23, 30]. Although some studies have identified small gender differences on specific imagery-related or spatial tasks, such effects tend to be task-dependent and highly sensitive to assessment modality, stimulus characteristics, and analytic approach [31, 32]. The present study utilized different measures of imagery, which may reduce systematic bias toward any single cognitive style and attenuate gender-related differences. In young adult populations, males and females often share broadly comparable educational experiences, cognitive demands, and exposure to similar technological and visual environments [33]. Such shared developmental and sociocultural contexts may contribute to convergence in imagery-related and cognitive profiles during this life stage.

Accordingly, the absence of significant gender differences in the present study, alongside mixed findings in the existing literature, highlights the importance of considering sample characteristics,

measurement approaches, and sociocultural context when interpreting gender effects. Future research should seek to further standardize assessment tools, examine more diverse young adult samples, and explicitly investigate the influence of cultural, educational, and social factors to clarify the nuanced relationship between gender and imagery-related cognitive processes.

The observed associations between imagery use, imagery ability and memory performance are consistent with a substantial body of cognitive research demonstrating that mental imagery enhances both encoding and retrieval processes. Dual Coding Theory provides a foundational account, proposing that information represented through both verbal and non-verbal systems benefits from complementary memory traces, resulting in more robust and durable memory representations [34, 35]. By generating mental images, verbal information is supplemented with perceptual representations, producing richer and more durable memory encoding [36]. From an applied perspective, this mechanism helps explain why young adults with stronger imagery ability in the present sample reported fewer everyday memory difficulties, as internally generated images may serve as efficient and self-sustaining mnemonic supports. Importantly, such internally driven strategies reduce reliance on external aids or compensatory techniques, which is particularly relevant in contexts where cognitive resources, instructional support, or technological access may be limited.

Beyond representational richness, Information Processing Theory further suggests that imagery enhances the structural organization and cohesiveness of internal representations, thereby reducing the cognitive effort required during retrieval [37-39]. Rather than expanding memory capacity, imagery appears to optimize how information is accessed and acted upon. This distinction is critical from a sustainability standpoint: interventions that improve efficiency

rather than demand additional resources are more likely to be adopted broadly and maintained over time. The relevance of imagery-based approaches is underscored by evidence from clinical and aging populations, where imagery interventions have shown benefits for individuals with neurological injury, mild cognitive impairment, and early-stage Alzheimer's disease [40-42], highlighting their potential translational value across the lifespan.

The experimental findings from the Sternberg task further clarify the mechanisms underlying these associations. Across memory-load conditions, imagery training was associated with faster response times relative to the control condition, while accuracy remained largely stable under low to moderate cognitive demands. This pattern indicates that imagery selectively enhanced working-memory processing efficiency rather than memory storage capacity. Such dissociation between speed and accuracy suggests improvements in executive access, response preparation, and temporal coordination of cognitive processes, rather than changes in representational fidelity.

Notably, the benefits of imagery were load-dependent. Under low and moderate memory loads, imagery training appeared to induce a state of neural readiness or cognitive priming, reducing the temporal cost of stimulus encoding and response initiation. Neurocognitive evidence indicates that motor imagery engages prefrontal, premotor, and parietal regions involved in executive control and action planning [43, 44]. Rather than accelerating serial memory scanning itself, imagery likely lowers the processing intercept, placing the cognitive system in a more responsive state prior to task execution. Such priming effects are particularly valuable in everyday environments that demand rapid but accurate information processing.

As task demands approached higher memory loads, the pattern of results revealed clear boundary

conditions. While imagery continued to support faster responding, accuracy gains did not emerge and descriptive speed-accuracy trade-offs became more apparent. This finding is consistent with capacity-based models of working memory, which posit diminishing returns as cognitive demands approach functional limits [45, 46]. Importantly, these constraints do not undermine the value of imagery; rather, they highlight its role as an efficiency-enhancing intervention rather than a capacity-expanding one. From a sustainability perspective, understanding such boundary conditions is essential for realistic and responsible application of cognitive training strategies.

The implications of imagery-based interventions extend beyond the laboratory, offering a metabolically efficient and resource-light alternative to traditional physical or resource-intensive cognitive training. This makes them particularly suitable for real-world contexts where physical activity is constrained, such as during injury rehabilitation, in aging populations, managing chronic health conditions, or in settings with limited space or equipment. Aligned with the objectives of sustainable global development, imagery training requires minimal infrastructure, can be reliably delivered in remote or low-resource formats, and is culturally adaptable across diverse populations and environments. As such, it represents a promising and equitable tool for supporting cognitive health, facilitating lifelong learning, and maintaining functional independence in everyday life.

When situated within a broader sustainability and public health context, imagery training can be interpreted as a contributor to multiple United Nations Sustainable Development Goals (SDGs), which makes its application applicable at levels beyond the cognitive capabilities of an individual. Given that imagery-based interventions represent an accessible and non-pharmacological method of aiding cognitive health, they align with the SDG 3 (Good Health and Well-Being) goals, especially

when medical, technological, or professional resources are limited. In educational contexts, the observed benefits for memory efficiency and learning-related cognitive processes in young adults suggest clear relevance to SDG 4 (Quality Education), as imagery offers a mentally based, low-burden strategy to support academic functioning and lifelong learning. Notably, the lack of conditions regarding specialized equipment, facilities, or financial investment contributes to the increasing the possible scope of imagery training in a range of socioeconomic and cultural settings, which improves the concept of SDG 10 (Reduced Inequalities). Moreover, the minimal material and energy demands associated with imagery-based approaches reduce dependence on resource-intensive infrastructures, indirectly supporting the objectives of SDG 13 (Climate Action) through environmentally sustainable models of cognitive health promotion. All these attributes put imagery training in a strong position as a viable example of sustainable cognitive and healthcare innovation that can both align individual gains with general global development goals.

Several limitations of the present study should be acknowledged when interpreting the findings. First, the sample consisted of young adults, which limits the generalizability of the results to other age groups or populations with distinct cognitive or health profiles. While this focus allowed for a controlled examination of imagery-related mechanisms in a relatively homogeneous group, future research should extend these findings to older adults, clinical populations, and individuals from diverse educational and cultural backgrounds. Such extensions are particularly important in the context of global health and sustainable development, where cognitive interventions must be adaptable to heterogeneous populations.

Second, although the Sternberg task provided a well-established and sensitive measure of working-memory processing efficiency, it captures a specific aspect of memory function under controlled

laboratory conditions. Future studies should incorporate ecologically valid memory tasks and real-world cognitive outcomes to better assess the translational relevance of imagery-based interventions. This would strengthen the applicability of imagery training in educational, occupational, and health-related settings where sustainable cognitive support is most needed.

Third, the imagery intervention employed in the present study was relatively short-term. While the observed efficiency gains are theoretically meaningful, longitudinal research is required to determine the durability of these effects and to examine whether repeated or sustained imagery practice leads to cumulative benefits or transfer to broader cognitive domains. Understanding the dose-response characteristics of imagery training will be critical for designing scalable and time-efficient interventions aligned with sustainability goals.

Finally, the current study primarily focused on behavioral outcomes. Although the findings are theoretically grounded in established neurocognitive frameworks, future work would benefit from the integration of neurophysiological measures, such as functional neuroimaging or electrophysiological indices, to directly examine the neural mechanisms underlying imagery-induced efficiency gains. Such multimodal approaches would provide deeper insight into how imagery modulates executive networks and clarifies individual differences in responsiveness to imagery-based training.

In conclusion, the present findings demonstrate that imagery operates as a mechanism-specific modulator of executive control, enhancing the

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efficiency of working-memory access and response execution without affecting structural capacity. By integrating cognitive theory with rigorous experimental evidence, this study establishes imagery not only as a theoretically grounded cognitive strategy but also as a sustainable, scalable, and practically viable approach to supporting mental performance. Within the broader framework of global health and sustainable development, imagery-based interventions offer a feasible pathway to promote cognitive resilience and sustainable functioning, especially in varied, underserved, or resource-limited environments, thereby contributing to more inclusive and adaptive strategies for lifelong cognitive well-being.

Conclusion

This study shows that mental imagery is associated with fewer memory difficulties and improves working memory processing efficiency in young adults. Acute imagery training enhances response speed without reducing accuracy, suggesting improved processing efficiency rather than memory capacity. As a low-cost and accessible approach, imagery may provide practical benefits for cognitive performance in educational, occupational, and health settings.

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