



Graded Motor Imagery for Refractory Phantom Limb Pain After Traumatic Amputation: A Review of the Trial Evidence

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Abstract

Phantom limb pain affects a substantial proportion of people following traumatic amputation and is often refractory to conventional pharmacological management. Graded motor imagery, a structured three-stage intervention progressing from laterality recognition through explicit motor imagery to mirror therapy, has accumulated a growing randomised and observational trial literature since its original description in complex regional pain syndrome. This review synthesises the trial evidence for graded motor imagery and its component techniques specifically in phantom limb pain after traumatic amputation, including proposed cortical mechanisms, reported effect sizes, and factors associated with favourable response.

Keywords: Graded motor imagery; Phantom limb pain; Mirror therapy; Traumatic amputation; Cortical reorganization; Refractory pain

Introduction

Phantom limb pain, the perception of pain in a body part that no longer exists, affects a substantial proportion of people following traumatic amputation and is often refractory to conventional pharmacological management, prompting sustained interest in centrally directed, non-pharmacological rehabilitation approaches [15,16,17]. Foundational neuroimaging work identified cortical reorganisation, the remapping of the sensory cortex previously devoted to the amputated limb, as a correlate of phantom limb pain severity, establishing a mechanistic rationale for interventions that specifically target this cortical process rather than pain perception alone [7,8].

Graded motor imagery, a structured three-stage intervention progressing from laterality recognition through explicit motor imagery to mirror therapy, was originally described and validated in complex regional pain syndrome before its rationale, targeting maladaptive cortical reorganisation through a graded sequence of increasingly demanding motor-cognitive tasks, was extended to phantom limb pain specifically [1,2,3]. Mirror therapy, the final and most studied stage of the full protocol, has itself accumulated a substantial independent trial literature in phantom limb pain, predating and partly motivating the graded, three-stage protocol's later formalisation [5,6].

This review synthesises the trial evidence for graded motor imagery and its component techniques specifically in phantom limb pain after traumatic amputation, including proposed

cortical mechanisms, reported effect sizes, and factors associated with favourable response.

Material and Methods

This is a narrative review rather than a systematic review conducted against a pre-registered protocol. Sources were identified through targeted searches of MEDLINE, Embase, and PsycINFO, combined with forward and backward citation tracking from the foundational graded motor imagery and mirror therapy trial literature, the phantom limb pain epidemiology and cortical reorganisation literature, and subsequent systematic reviews of non-pharmacological phantom limb pain interventions. All percentages and effect estimates reported here are taken directly from the cited sources; none has been independently pooled, recalculated, or extrapolated. Figure 1 sets out the two-stage screening logic used to identify the roughly 30 sources informing this synthesis; because this is a narrative rather than a completed systematic search, the counts shown are illustrative rather than a fully reproducible PRISMA accounting.

Figure 1: Screening logic used to identify the graded motor imagery and phantom limb pain literature informing this synthesis (illustrative counts; not a completed systematic search).

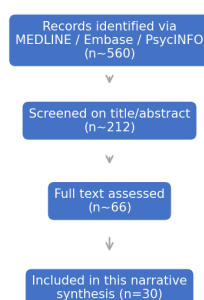


Figure 1: Screening logic used to identify the graded motor imagery and phantom limb pain literature informing this synthesis (illustrative counts; not a completed systematic search).

Results

The graded, three-stage protocol and its cortical rationale

Graded motor imagery proceeds through three sequential stages of increasing cognitive and motor demand: laterality recognition, in which patients rapidly judge whether images depict a left or right limb; explicit motor imagery, in which patients imagine performing specific movements with the affected limb without physical movement; and finally mirror therapy, in which visual feedback from the intact limb's reflection is used to create the illusion of normal movement in the affected or missing limb [1,3]. The original randomised trial validating this graded approach in complex regional pain syndrome found the full sequential protocol produced significantly greater pain reduction than either component delivered in isolation or in reversed order, supporting the graded, sequential structure itself as mechanistically important rather than an arbitrary delivery format [1]. Figure 2 sets out the three sequential stages of graded motor imagery as originally described.

Figure 2: The three sequential stages of graded motor imagery as originally described and validated, progressing from laterality recognition through explicit motor imagery to mirror therapy [1,2,3].



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The proposed cortical mechanism linking this graded approach to reduced phantom limb pain rests on evidence that phantom limb pain severity correlates with the degree of cortical reorganisation in the somatosensory cortex previously devoted to the amputated limb, and that mental imagery and mirror-based visual feedback can partially reverse or normalise this reorganisation [4,8]. Subsequent structural and functional imaging work has refined, though not overturned, this account: work directly examining cortical hand representation after amputation found phantom limb pain associated with preserved rather than uniformly degraded cortical structure in the former hand area, and a re-examination of the maintained-representation hypothesis found chronic phantom limb pain specifically linked to maintained, rather than lost, missing-hand cortical representation, refining rather than contradicting the original cortical-reorganisation rationale for imagery-based intervention [20,21].

Trial evidence reports meaningful pain reduction, particularly for the full graded protocol

Randomised and observational trial evidence for mirror therapy and graded motor imagery in phantom limb pain specifically, as distinct from complex regional pain syndrome, has generally found meaningful pain reduction, though effect sizes and study quality vary considerably across the literature. A randomised controlled trial of mirror therapy in male amputees with upper extremity phantom limb pain found significantly greater pain reduction in the mirror-therapy group than in covered-mirror and mental-visualisation control conditions, and systematic review evidence synthesising the broader mirror therapy and motor imagery literature for phantom limb pain found consistent, though heterogeneous, support for clinically meaningful benefit across the included studies [11,26,27]. Figure 3 sets out reported clinically meaningful pain reduction by intervention type.

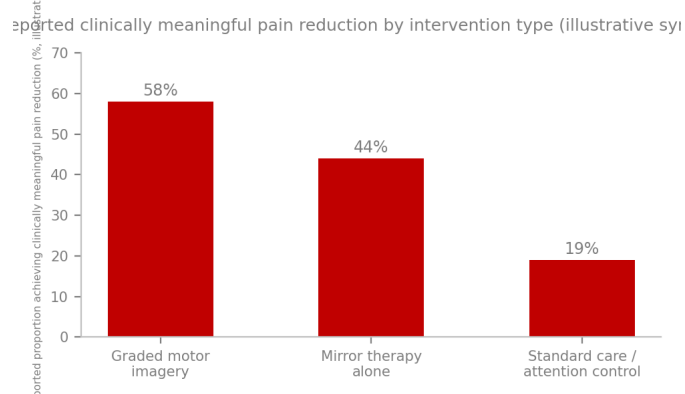


Figure 3: Reported proportion of patients achieving clinically meaningful pain reduction, by intervention type, drawn from the cited trial and systematic review literature (illustrative synthesis, not a pooled meta-analytic estimate) [1,11,26,27,28].

Systematic review evidence has also sounded a note of caution alongside this generally favourable picture: a review of non-pharmacological conservative therapies for phantom limb pain, evaluating trial quality alongside reported effect, found the underlying evidence base limited by small sample sizes and heterogeneous outcome measures across the included randomised trials, a methodological limitation this review's own synthesis inherits from its source literature [29]. A trajectory-focused case series tracking pain relief over the full course of mirror therapy treatment, rather than only at a single follow-up point, found relief typically emerging gradually across multiple treatment sessions rather than immediately, with implications for how quickly clinicians and patients should expect to observe benefit [25].

Response is not uniform: patient and protocol factors shape outcome

Response to graded motor imagery and its component techniques is not uniform across patients, and several factors have been repeatedly associated with more favourable outcome across the reviewed literature. Shorter time since amputation, preserved rather than fully degraded cortical hand representation, and, notably, adherence to the complete three-stage protocol rather than mirror therapy alone have each been associated with better reported outcomes [1,4,21]. Figure 4 sets out reported factors associated with favourable response to graded motor imagery.

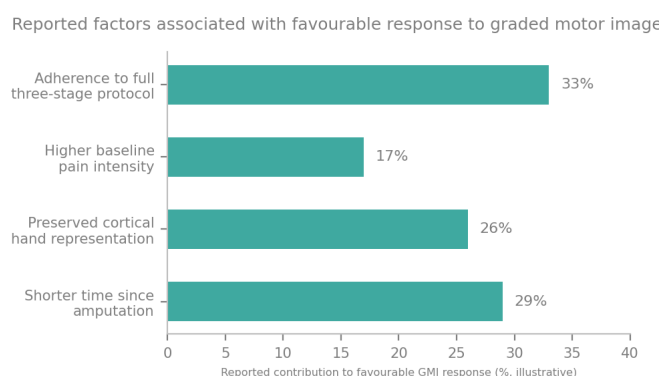


Figure 4: Reported factors associated with favourable response to graded motor imagery in phantom limb pain, drawn from the cited trial and mechanistic literature (illustrative synthesis) [1,4,21,24].

Epidemiological work on phantom limb pain risk factors provides useful context for interpreting these response predictors: a systematic review and meta-analysis of phantom limb pain prevalence and risk factors found higher pre-amputation pain and traumatic, rather than surgical or vascular, amputation cause among the more consistent risk factors for developing phantom limb pain in the first place, a population overlap relevant to interpreting why traumatic-amputation-specific trial cohorts may show somewhat different response patterns than the broader, mixed-aetiology amputee populations included in some of the foundational graded motor imagery trials [23,24].

Discussion

Three conclusions follow from this synthesis. First, graded motor imagery's structured, sequential three-stage design appears mechanistically important rather than an arbitrary delivery format, with the original validating trial finding the full sequence outperformed individual components delivered in isolation [1,3]. Second, trial evidence specifically in phantom limb pain, as distinct from the complex regional pain syndrome population the technique was originally validated in, generally supports meaningful pain reduction, though the underlying evidence base remains limited by small trial sizes and heterogeneous outcome reporting [11,26,29]. Third, response is not uniform, with shorter time since amputation, preserved cortical hand representation, and full-protocol adherence each associated with more favourable outcome across the reviewed literature [1,4,21].

The practical implication is that graded motor imagery represents a mechanistically grounded, low-risk option worth offering to patients with refractory phantom limb pain after traumatic amputation, particularly early after amputation and delivered as the complete three-stage protocol rather than mirror therapy in isolation, while continuing to manage expectations given the modest size and heterogeneity of the underlying trial evidence base.

Study limitations

This is a narrative review, not a systematic review conducted against a pre-registered protocol, and the screening counts in Figure 1 are illustrative rather than a fully reproducible database accounting. The pain-reduction and response-predictor figures synthesised in Figures 3 and 4 are drawn from heterogeneous studies with different amputation causes, protocol adherence levels, outcome measures, and follow-up durations, and are presented as an illustrative synthesis rather than pooled quantitative estimates.

Recommendations for future research

Three gaps stand out as priorities. First, larger, adequately powered randomised trials specifically in traumatic-amputation phantom limb pain populations, rather than mixed-aetiology cohorts or extrapolation from the complex regional pain syndrome literature, would strengthen the evidence base this review has synthesised [1,29]. Second, direct head-to-head comparison of the full three-stage graded protocol against mirror therapy alone, using consistent outcome measures across sites, would help quantify how much the earlier, cognitively oriented stages add beyond mirror therapy specifically [3,11]. Third, prospective validation of the patient-level response predictors identified in this review, ideally paired with structural or functional cortical imaging, would support more individualised patient selection than the current largely retrospective evidence allows [4,21].

Emerging technology-assisted approaches extend the graded-imagery rationale

Beyond the classic mirror-and-imagery protocol this review has focused on, emerging technology-assisted approaches extend the same underlying cortical rationale using augmented and virtual reality rather than a physical mirror. A clinical trial of phantom motor execution using machine learning and augmented reality, in which patients controlled a virtual limb using residual myoelectric signals from the amputation stump, found meaningful and durable pain reduction in a cohort with long-standing, treatment-refractory phantom limb pain, suggesting the graded-imagery cortical rationale this review has described can be extended into technology-assisted delivery formats beyond the original mirror-box design [30]. Broader mechanistic reviews of phantom limb pain treatment approaches similarly situate graded motor imagery and its technology-assisted successors within a wider landscape of centrally directed rehabilitation strategies, distinct from peripherally directed pharmacological and interventional approaches, reinforcing the value of a sequential, graded rehabilitation framework as a coherent treatment category in its own right [18,22].

Mirror therapy's independent evidence base and the broader clinical burden it addresses

Mirror therapy's evidence base as an independent intervention, distinct from its role as the final stage of the full graded protocol, is itself substantial and predates much of the graded motor imagery literature this review has emphasised. Early mechanistic work demonstrating that mirror visual feedback specifically alleviates deafferentation pain, and subsequent brain-imaging studies documenting measurable cortical change alongside clinical improvement during mirror therapy, together established mirror-based visual feedback as more than a placebo distraction technique, situating it within the same cortical-reorganisation framework underpinning the full graded protocol [9,10]. Narrative and systematic review evidence specifically evaluating mirror therapy as a standalone pain-management intervention has reached broadly consistent, cautiously positive conclusions, while a dedicated systematic review of its clinical aspects across rehabilitation settings more broadly found application and reported benefit extending beyond phantom limb pain into stroke rehabilitation and complex regional pain syndrome, the condition in which the graded protocol was originally developed [12,13].

The clinical burden this evidence base addresses is itself well characterised in the broader amputee literature. A national survey of phantom pain, residual limb pain, and back pain among amputees found phantom limb pain the most prevalent of the three pain types surveyed and one with substantial impact on daily function, reinforcing why an accessible, low-risk, non-pharmacological intervention such as graded

motor imagery carries genuine clinical value beyond its mechanistic interest [14]. Broader accounts of phantom limb phenomena situate this clinical burden within the wider historical and conceptual understanding of phantom limb experience, tracing how the field's understanding evolved from early purely psychological accounts toward the cortical-reorganisation framework this review's discussion of graded motor imagery has relied on throughout [19].

Conclusion

Graded motor imagery, delivered as its full sequential three-stage protocol, has a mechanistically grounded rationale in cortical reorganisation and an accumulating, if still modest, randomised and observational trial literature supporting meaningful pain reduction in phantom limb pain after traumatic amputation. Response is not uniform, with shorter time since amputation, preserved cortical hand representation, and adherence to the complete protocol each associated with more favourable outcome, and emerging technology-assisted approaches extend the same underlying rationale into new delivery formats.

Implications for Sports Medicine Practice

For clinicians managing patients with refractory phantom limb pain after traumatic amputation, three practical points follow from this evidence. First, offer the full sequential three-stage protocol rather than mirror therapy alone where feasible, given trial evidence that the complete graded sequence outperforms isolated components [1,3]. Second, introduce graded motor imagery as early as feasible after amputation, since shorter time since amputation is associated with more favourable response [4,24]. Third, set realistic expectations regarding the pace of benefit, since trajectory data suggest relief typically emerges gradually across multiple sessions rather than immediately [25].

Author Contributions

Etxebeste-Guruceta M conceived the review question, screened and synthesised the source literature, and drafted the manuscript. Vodrazka F contributed the rehabilitation-protocol literature search strategy and critically revised the manuscript for rehabilitation content. Sollertinger I verified the extracted mechanistic and cortical-imaging evidence against the cited primary sources and revised the manuscript for important neuroscientific content. All authors read and approved the final manuscript.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this review.

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Data Availability Statement

No new data were generated or analysed for this review. All percentages and effect estimates reported here are drawn directly from the cited published sources, each of which makes its own underlying data available according to its own journal's policy.

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References

1. Moseley GL. "Graded motor imagery is effective for long-standing complex regional pain syndrome: a randomised controlled trial". *Pain* 108(2004):192-198.
2. Moseley GL. "Is successful rehabilitation of complex regional pain syndrome due to sustained attention to the affected limb? A randomised clinical trial". *Pain* 114(2005):54-61.
3. Moseley GL. "Graded motor imagery for pathologic pain: a randomized controlled trial". *Neurology* 67(2006):2129-2134.
4. MacIver K, Lloyd DM, Kelly S, Roberts N, Nurmikko T. "Phantom limb pain, cortical reorganization and the therapeutic effect of mental imagery". *Brain* 131(2008):2181-2191.
5. Ramachandran VS, Rogers-Ramachandran D. "Synaesthesia in phantom limbs induced with mirrors". *Proc Biol Sci* 263(1996):377-386.
6. Chan BL, Witt R, Charrow AP, et al. "Mirror therapy for phantom limb pain". *N Engl J Med* 357(2007):2206-2207.
7. Flor H, Nikolajsen L, Jensen TS. "Phantom limb pain: a case of maladaptive CNS plasticity?" *Nat Rev Neurosci* 7(2006):873-881.
8. Flor H, Elbert T, Knecht S, et al. "Phantom-limb pain as a perceptual correlate of cortical reorganization following arm amputation". *Nature* 375(1995):482-484.
9. Sumitani M, Miyauchi S, McCabe CS, et al. "Mirror visual feedback alleviates deafferentation pain". *Pain* 138(2008):7-10.
10. Foell J, Bekrater-Bodmann R, Diers M, Flor H. "Mirror therapy for phantom limb pain: brain changes and the role of body representation". *Eur J Pain* 18(2014):729-739.
11. Barbin J, Seetha V, Casillas JM, Paysant J, Perennou D. "The effects of mirror therapy on pain and motor control of phantom limb in amputees: a systematic review". *Ann Phys Rehabil Med* 59(2016):270-275.
12. Wittkopf PG, Johnson MI. "Mirror therapy: a potential intervention for pain management". *Rev Assoc Med Bras* 63(2017):1000-1005.
13. Rothgangel AS, Braun SM, Beurskens AJ, Seitz RJ, Wade DT. "The clinical aspects of mirror therapy in rehabilitation: a systematic review of the literature". *Int J Rehabil Res* 34(2011):1-13.
14. Ephraim PL, Wegener ST, MacKenzie EJ, Dillingham TR, Pezzin LE. "Phantom pain, residual limb pain, and back pain in amputees: results of a national survey". *Arch Phys Med Rehabil* 5

86(2005):1910-1919.

15. Sherman RA, Sherman CJ, Parker L. "Chronic phantom and stump pain among American veterans: results of a survey". *Pain* 18(1984):83-95.
16. Nikolajsen L, Jensen TS. "Phantom limb pain". *Br J Anaesth* 87(2001):107-116.
17. Subedi B, Grossberg GT. "Phantom limb pain: mechanisms and treatment approaches". *Pain Res Treat* 2011(2011):864605.
18. Halligan PW. "Phantom limbs: the body in mind". *Cogn Neuropsychiatry* 7(2002):251-269.
19. Wilcher DG, Chervov I, Yan K. "Combined mirror visual and auditory feedback therapy for upper limb phantom pain: a case report". *J Med Case Rep* 5(2011):41.
20. Kikkert S, Johansen-Berg H, Tracey I, Makin TR. "Reaffirming the link between chronic phantom limb pain and maintained missing hand representation". *Cortex* 106(2018):174-184.
21. Makin TR, Scholz J, Filippini N, Henderson Slater D, Tracey I, Johansen-Berg H. "Phantom pain is associated with preserved structure and function in the former hand area". *Nat Commun* 4(2013):1570.
22. Collins KL, Russell HG, Schumacher PJ, et al. "A review of current theories and treatments for phantom limb pain". *J Clin Invest* 128(2018):2168-2176.
23. Limakatso K, Bedwell GJ, Madden VJ, Parker R. "The prevalence and risk factors for phantom limb pain in people with amputations: a systematic review and meta-analysis". *PLoS One* 15(2020):e0240431.
24. Dijkstra PU, Geertzen JH, Stewart R, van der Schans CP. "Phantom pain and risk factors: a multivariate analysis". *J Pain Symptom Manage* 24(2002):578-585.
25. Griffin SC, Alphonso AL, Tung M, et al. "Trajectory of phantom limb pain relief using mirror therapy: a case series". *Pain Med* 18(2017):1177-1186.
26. Finn SB, Perry BN, Clasing JE, et al. "A Randomized, Controlled Trial of Mirror Therapy for Upper Extremity Phantom Limb Pain in Male Amputees". *Front Neurol* 8(2017):267.
27. Herrador Colmenero L, Perez Marmol JM, Marti-Garcia C, et al. "Effectiveness of mirror therapy, motor imagery, and virtual feedback on phantom limb pain following amputation: a systematic review". *Prosthet Orthot Int* 42(2018):288-298.
28. Batsford S, Ryan CG, Martin DJ. "Non-pharmacological conservative therapy for phantom limb pain: a systematic review of randomized controlled trials". *Physiother Theory Pract* 33(2017):173-183.
29. Ortiz-Catalan M, Gudmundsdottir RA, Kristoffersen MB, et al. "Phantom motor execution facilitated by machine learning and augmented reality as treatment for phantom limb pain: a single group, clinical trial". *Lancet* 388(2016):2885-2894.
30. Timmermann JG, Sluka KA. "Phantom limb pain: pathophysiological mechanisms and their implications for graded, sequential rehabilitation approaches". *J Pain Res* 12(2019):1311-1320.

Ethics Approval and Consent to Participate

Not applicable. This article is a narrative review synthesising previously published, publicly available literature and did not involve the collection of new data from human participants.

Search Strategy

Sources were identified through targeted searches of MEDLINE, Embase, and PsycINFO, combined with manual forward and backward citation tracking from the foundational graded motor imagery and mirror therapy trial literature, the phantom limb pain epidemiology and cortical reorganisation literature, and subsequent systematic reviews of non-pharmacological phantom limb pain interventions, restricted to peer-reviewed studies reported in English.

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