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| **CRITICALLY APPRAISED TOPIC** |

**FOCUSED CLINICAL QUESTION**

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| For middle-aged adults with chronic stroke and reduced gait speed (> 1.0 m/s), is a cognitive priming task (motor imagery) better than movement-based priming (aerobic exercise) for improved motor learning for the task of walking (as measured by improvements in gait speed)? |

**AUTHOR**

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**CLINICAL SCENARIO**

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| A 64-year old retired U.S. Army Veteran was being seen by physical therapy in a VA in-patient rehabilitation unit after he sustained an ischemic CVA 4 months prior. Despite general improvements enabling the patient to withstand an hour of therapy each day and complete most self-care with only supervision, the patient still had deficits in balance, coordination, ambulation, and lower extremity strength. Walking was this patient’s main goal, an activity that was limited by his walking speed and endurance. Through conversation with him and his family, we determined walking speed to be the biggest concern as he felt that he was walking so slowly that it was not functionally useful in daily life or in the community. He also fatigued after shorter distances due to the longer duration of effort walking at slow speeds. The patient did not have any cognitive deficits, outstanding comorbidities or concurrent diagnoses, and was able to ambulate with a quad-cane and use of a functional electrical stimulation device, a Bioness L300 Go, placed on his hamstrings and tibialis anterior on the affected side.As motor learning is an important component in functional recovery after stroke, I wanted to look into the growing area of priming for motor learning to see if this technique could facilitate improvements.1 I chose to look specifically at cognitive and aerobic modes of priming due to their feasibility in an in-patient rehab setting and determine which mode of priming would be more effective for improving this patient’s walking speed and endurance. |

**SUMMARY OF SEARCH**

[Best evidence appraised and key findings]

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| * Eight studies were located that met the inclusion/exclusion criteria and contributed to understanding of this clinical question, including 5 Randomized Controlled Studies (RCTs), 2 Systematic Reviews, and 1 Case Series.
* The current literature does not contain any studies comparing these interventions, and contains very little quality research describing “cognitive priming” in general, so cognitive tasks of motor imagery (MI) and mirror therapy (MT) completed before conventional therapy interventions were used to represent “cognitive priming.”
* Despite a preponderance of evidence supporting use of aerobic and cognitive priming for upper extremity (UE) motor learning, there is limited evidence, especially for aerobic or movement-based priming, as they relate to gait outcomes after stroke. Research quality is further limited by heterogeneity in samples, interventions, and outcome measures.
* There is moderately strong evidence supporting the use of MI and MT, especially MT with use of electrical stimulation, as cognitive priming to improve functional mobility and gait parameters in individuals with subacute and chronic stroke.
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**CLINICAL BOTTOM LINE**

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| The limited available evidence suggests that cognitive priming tasks of MI and MT may induce the desired improvements in gait speed in a 64-year old male who is 4 months post-CVA. Despite general effectiveness, significant heterogeneity in the research limits specific recommendations for treatment parameters or duration at this time. As for aerobic or exercise-based priming, there is no current research supporting effectiveness for gait outcomes in patients after stroke. Due to this patient’s functional and cognitive status, as well as access to electrical stimulation, he is a good candidate for cognitive priming techniques, especially MT with concurrent stimulation. |

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| ***This critically appraised topic has been individually prepared as part of a course requirement and has been peer-reviewed by one other independent course instructor*** |

*The above information should fit onto the first page of your CAT*

**SEARCH STRATEGY**

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| **Terms used to guide the search strategy** |
| **P**atient/Client Group | **I**ntervention (or Assessment) | **C**omparison | **O**utcome(s) |
| “adults” or “middle-aged adults”“stroke” OR “chronic stroke”"gait impairment" OR "gait impairments" OR "walking speed" | “cognitive priming” “motor imagery”“task-oriented motor learning” | “exercise” “movement-based priming”“aerobic exercise” | “gait”“walking speed” “motor control” |

**Final search strategy (history):**

*Show your final search strategy (full history) from PubMed. Indicate which “line” you chose as the final search strategy.*

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| **Search 1** | **Broadened Search 2** | **Broadened Search 3** |
| 1. adults AND stroke
2. neurorehabilitation
3. priming OR “cognitive priming” OR “motor imagery” OR “task-oriented motor learning” OR “movement-based priming” OR “mirror therapy”
4. Gait
5. “walking speed”
6. “motor learning”
 | 1. *adults*
2. neurorehabilitation
3. priming OR “cognitive priming” OR “motor imagery” OR “task-oriented motor learning” OR “movement-based priming” OR “mirror therapy”
4. Gait
5. “walking speed”
6. “motor learning”
 | 1. Adults and stroke
2. neurorehabilitation
3. priming OR “cognitive priming” OR “motor imagery” OR “task-oriented motor learning” OR “movement-based priming” OR “mirror therapy”
4. “motor learning”
 |
| Final: #1 AND #2 AND #3 AND (#4 OR #5 OR #6) | Final: #1 AND #2 AND #3 AND (#4 OR #5 OR #6) | Final: #1 AND #2 AND #3 #1 AND #2 AND #3 AND #4 |
| *Original with all elements of PICO* | *Removal of “stroke” component to broaden search to include other adults and possibly healthy controls* | *Removal of “outcome” requirements (gait, speed, or motor learning) to broaden search to any articles addressing intervention in population* |

*In the table below, show how many results you got from your search from each database you searched.*

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| **Database** | **Search 1** | **Search 2** | **Search 3** | **Search 4** |
| # of results | Limits applied, revised number of results | # of results | Limits applied, revised number of results | # of results | Limits applied, revised number of results | # of results | Limits applied, revised number of results |
| **PubMed** | 26 | Last 10 years, Clinical Trial, Review, Randomized Controlled Trial - 23 | 48 | Last 10 years, Clinical Trial, Review, Randomized Controlled Trial - 44 | 205 | Last 10 years, Clinical Trial, Review, Randomized Controlled Trial - 186 | 10 | Last 5 years - 8 |
| **Cochrane** | 3 | N/A | 10 | N/A | 11 | Last 5 years - 11 | 3 | N/A |
| **Web of Science** | 1 | N/A | 1 | N/A | 8 | Last 5 years - 6 | 1 | N/A |

## INCLUSION and EXCLUSION CRITERIA

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| **Inclusion Criteria** |
| * Patient population of adults with a diagnosis of stroke or chronic stroke (preferably 40-65 years old, > 1-month post-stroke, with gait speed > 1.0 m/s)
* Treated with neurological priming before therapy sessions either cognitive (motor imagery) or movement-based (aerobic exercise)
* Highest quality of available evidence (RCT, systematic review, meta-analysis)
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| **Exclusion Criteria** |
| * Not published in English
* Poster presentations
* Using interventions such as “motor imagery” or “task-oriented motor learning” as additional interventions during therapy and not as a priming activity (ex: done at separate visit rather than before rehab)
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**RESULTS OF SEARCH**

**Summary of articles retrieved that met inclusion and exclusion criteria**

*For each article being considered for inclusion in the CAT, score for methodological quality on an appropriate scale, categorize the level of evidence, indicate whether the relevance of the study PICO to your PICO is high/mod/low, and note the study design (e.g., RCT, systematic review, case study).*

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| **Author (Year)** | **Risk of bias (quality score)\*** | **Level of Evidence\*\*** | **Relevance** | **Study design** |
| Charalambous (2018)2 | PEDro (6/10) | 1b (RCT) | HIGH – contains P (stroke), C (exercise priming), and O (locomotor learning based on gait)*Does not compare to cog priming* | RCT |
| Ding (2019)3 | PEDro (9/10) | 1b (RCT) | MODERATE - contains P (stroke), I (cognitive priming), and O (functional motor recovery) *Does not compare to movement-based priming and is studying UE outcomes instead of gait.* | RCT |
| Patel (2017)4 | Downs and Black Checklist (18/27) | 4 (case series) | MODERATE - contains P (stroke), I (cognitive priming and movement-based priming), and O (functional motor recovery) *Used priming types in conjunction not compared and is studying UE outcomes instead of gait.* | Case Series (5 patients given intervention) |
| Statton (2015)5 | PEDro (6/10) | 1b (RCT) | LOW – contains C (exercise priming), and O (motor learning)*Healthy control not stroke patients, does not compare to cog priming, measure of UE learning, not gait.* | RCT |
| Louie & Lim (2019)6 | AMSTAR (9/11) | 1a (systematic review) | MODERATE - HIGH - contains P (stroke), I (mirror therapy cog exercise), and O (gait speed)*Does not compare to exercise-based priming, although most interventions in included studies listed Mirror Therapy as segment before “conventional therapy” it may not be actual priming.* | Systematic Review |
| Broderick (2018)7 | AMSTAR (7/11) | 1a (systematic review) | LOW - contains P (stroke), I (mirror therapy cog exercise), and O (gait speed)*Does not compare to exercise-based priming. No indication from intervention information from included studies that Mirror Therapy was given before conventional therapy, may not be actual priming* | Systematic Review |
| Kumar (2016)8 | PEDro (8/10) | 1b (RCT) | MODERATE – contains P (stroke), I (mental imagery cog exercise), and O (gait speed)*Does not compare to exercise-based priming. No indication that motor imagery training is before therapy (may not be actual priming)* | RCT  |
| Stinear (2008)9 | PEDro (8/10) | 1b (RCT) | MODERATE - HIGH– contains P (stroke), C (movement-based priming), and O (motor learning)*Does not compare to cognitive priming, measure of UE learning, not gait.* | RCT |

\*Indicate tool name and score

\*\*Use Portney & Watkins Table 16.1 (2009); if downgraded, indicate reason why

**BEST EVIDENCE**

The following 2 studies were identified as the ‘best’ evidence and selected for critical appraisal. Rationale for selecting these studies were:

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| * **Charalambous (2018)**2 – This recent RCT studied the implications of a short burst of high-intensity exercise on motor learning of a walking task in patients after a stroke. The use of exercise-based priming to address motor learning as measured by gait changes in a stroke population addressed 3 out of 4 elements of the original clinical question (P, C, and O) making it highly relevant to the clinical question. Also, using the PEDro Score to measure quality, it scored a 6/10, the low-end of “high-quality” category, making it a reliable source of 1b level evidence. Although there are other slightly higher quality RCTs, this was the only one to address lower extremity (LE) function and gait motor learning as an outcome specifically, and therefore I chose to include this over some of the other RCTs detailed above.
* **Louie & Lim (2019)**6– This systematic review assessed the literature on the efficacy of mirror therapy in the stroke population as it relates to gait speed, mobility, and motor recovery. I have chosen this article even though it addressed only 2.5 out of 4 elements of the original clinical question (P, I, and O) as it looked at Mirror Therapy as a cognitive exercise to be used in therapy rather than specifically a cognitive priming task. However, after a review of the interventions provided by included studies, the cognitive exercise of Mirror Therapy is consistently applied prior to the conventional therapy exercises, more similar to a true priming task. With an AMSTAR score of 9/11, it is objectively a “high quality” study that helps to answer the clinical question with more powerful 1a level evidence.
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**SUMMARY OF BEST EVIDENCE**

**(1) Description and appraisal of “A single exercise bout and locomotor learning after stroke: physiological, behavioural, and computational outcomes” by Charalambous et al., 2018**

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| **Aim/Objective of the Study/Systematic Review:** |
| To determine if acute high-intensity exercise prior to motor practice enhances the retention of motor learning in adults with chronic stroke as measured by changes in gait adaptation during a split-belt treadmill task. |
| **Study Design**[e.g., systematic review, cohort, randomised controlled trial, qualitative study, grounded theory. Includes information about study characteristics such as blinding and allocation concealment. When were outcomes measured, if relevant]Note: For systematic review, use headings ‘search strategy’, ‘selection criteria’, ‘methods’ etc. For qualitative studies, identify data collection/analyses methods. |
| * Randomized Controlled Trial
* 37 participants with chronic stroke were randomized to one of three groups [control, treadmill walking (TMW), or total body exercise on a cycle ergometer (TBE)].
* Each participant completed an evaluation and two experimental sessions that were 24 hours apart.
* At the initial session they completed the split-belt treadmill activity with priming (depending on group), and at the second session they completed the activity without any priming to measure retained learning and changes in adaptation.
* Baseline clinical testing, blood serum collection, medication and demographic information, walking speed, and step characteristics were taken at the initial evaluation.
* Gait data was recorded and analyzed using Vicon Nexus Matlab and blood serum was collected pre- and post-intervention were measured at both treatment visits.
* Locomotor learning measures of early asymmetry, magnitude of adaptation, and adaptation rate were recorded at visit 1 while locomotor learning measures of magnitude of retention and re-adaptation rate were measured and calculated at visit 2.
	+ Early Asymmetry: average of 1st 10 strides in a session
	+ Magnitude of Adaptation: difference between average of 1st 10 strides and last 10 strides in a given session
	+ Adaptation Rate: number of strides needed before stride length fell within “final adapted state” (mean +/- standard deviation of last 30 strides)
	+ Magnitude of Retention: Difference between early asymmetry of session 1 and session 2
	+ Re-Adaptation Rate: number of strides needed before stride length fell within “final adapted state” (mean +/- standard deviation of last 30 strides)
* Dual-rate computational modeling was used to analyze adaptation in step length asymmetry based on models from Smith (2006) and Joiner and Smith (2008).10,11
* Behavioral measures were analyzed using SPSS at P < 0.05
* Modeling-based analyses were completed in Matlab.
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| **Setting**[e.g., locations such as hospital, community; rural; metropolitan; country] |
| The Neuromotor Behaviour Lab at the University of Delaware through the department of Physical Therapy. |
| **Participants**[N, diagnosis, eligibility criteria, how recruited, type of sample (e.g., purposive, random), key demographics such as mean age, gender, duration of illness/disease, and if groups in an RCT were comparable at baseline on key demographic variables; number of dropouts if relevant, number available for follow-up]Note: This is not a list of the inclusion and exclusion criteria. This is a description of the actual sample that participated in the study. You can find this descriptive information in the text and tables in the article. |
| * 37 subjects participated in the study (control = 13; TMW = 12; TBE = 12)
	+ Subjects were included if they were between 21 and 85 years old, diagnosed with unilateral chronic stroke (> 6 months), able to walk for 4 minutes without assistance from another person (assistive devices allowed), had a resting HR between 40 and 100 bpm, and a resting BP between 90/60 and 170/90 mmHg.
	+ Subjects were excluded if they had a cerebellar stroke, additional neurological conditions, LE botulinum toxin injection in last 4 months, were currently undergoing PT, were unable to walk outside prior to stroke, had coronary artery bypass graft or MI in past 3 months, severe musculoskeletal pain, communication issues, neglect, or unexplained dizziness in last 6 months.
* No significant between-group differences at baseline.
* Subjects were generally middle-aged with mean age of each group ranging from 55-62 years old with 58-69% being male. There was great variability in average time post stroke, mean of each group ranged from 54 to 85 months with a range of 9 – 303 months.
* Since patients with cerebellar stroke were excluded, the strokes of included subjects were 46-66% right-sided lesion with a majority (53-83%) due to ischemic lesions.
* As for behavioral measures and function, the average Fugl-Meyer LE (FMLE) was 22-24 +/- 7, average self-selected walking speed (SSWS) was 0.85-1.02 +/- 0.30, and average fast-walking speed (FWS) 1.00 +/- 0.25 to 1.18 +/- 0.26.
* Due to the short duration of the study (an initial evaluation and then 2 sessions 24 hours apart) all 37 subjects that met inclusion/exclusion criteria completed both testing sessions (no dropouts).
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| **Intervention Investigated**[Provide details of methods, who provided treatment, when and where, how many hours of treatment provided] |
| *Control* |
| Session 1: Subjects completed 1 minute of baseline walking and then 5 minutes of low-intensity treadmill walking (25% of their fast-walking speed (FWS)) before 15 minutes of split-belt treadmill walking adaptation task. Measures of gait (step and stride length, speed, asymmetry, magnitude and rate of adaptation) were captured by video, ground force plates, and computer modelling equations.Session 2: (24 hours later)Subjects completed only the 15 minutes of split-belt treadmill walking adaptation task. Measures of gait (step and stride length, speed, asymmetry, magnitude of retention and rate of re-adaptation) were captured by video, ground force plates, and computer modelling equations.All sessions took place at Neuromotor Behaviour Lab, and totalled ~3.75 hours with 36 total minutes of walking. |
| *Experimental* |
| Session 1: **Treadmill Walking**: Subjects completed 1 minute of baseline walking and then 5 minutes of high-intensity treadmill walking (70-85% age-predicted HRmax or 13-15 on 6-20 Borg Rate of Perceived Exertion (RPE) Scale if taking beta blockers) before 15 minutes of split-belt treadmill walking adaptation task. **Total Body Ergometry:** Subjects completed 1 minute of baseline walking and then 15 minutes of split-belt treadmill walking adaptation task before 5 minutes of high-intensity total-body exercise (70-85% age-predicted HRmax or 13-15 on 6-20 Borg RPE Scale if taking beta blockers). Measures of gait (step and stride length, speed, asymmetry, magnitude and rate of adaptation) were captured by video, ground force plates, and computer modelling equations.Session 2: (24 hours later)Subjects completed only the 15 minutes of split-belt treadmill walking adaptation. Measures of gait (step and stride length, speed, asymmetry, magnitude and rate of adaptation) were captured by video, ground force plates, and computer modelling equations.All sessions took place at Neuromotor Behaviour Lab, and totalled ~3.75 hours with 36 total minutes of walking. |
| **Outcome Measures**[Give details of each measure, maximum possible score and range for each measure, administered by whom, where] |
| **Baseline Measures:*** Fugl-Meyer Lower Extremity (FMLE): This sub-scale of the Fugl-Meyer test focuses on the functional mobility of the lower extremity. It has been well-validated in chronic stroke patients, and is recommended by the StrokEDGE Taskforce.12 It is a 17-item subscale scored 0 – 2 for each item, with a maximum possible score of 34.12 A cut-off score of 21 has been proposed to indicate high-functioning individuals.13
* Self-Selected Walking Speed (SSWS): this simple measure has been shown to be of vital importance as it is a reliable measure of function, disability, risk, and prognosis. In patients with chronic stroke, the minimal detectable change has been identified as 0.18 m/s with speeds of < 0.8 – 1.0 m/s being indicative of increased community ambulation and independence.14

**BDNF and lactate in Blood Serum**: due to possible mediation between exercise and motor learning by brain derived neurotrophic factor-BDNF and lactate, blood serum was collected pre- and post-intervention session 1 for all groups and analyzed for presence of these two components. This was completed by a registered nurse for all participants, and then centrifuged, and analysed by appropriate kits to detect these components. There is not yet an established range or minimal detectable change consistently reported for BDNF, studies have shown average range to be 18-32 ng/ml.15,16 Normal blood lactate has been found to be ~ 1.3mmol/L and has generally been shown to increase with increased exertion during exercise.17,18**Locomotor Learning:** these were calculated by computational modelling as described above based on video recording of walking and established models of adaptation and learning processes.10,11 * Early Asymmetry: average of 1st 10 strides in a session
* Magnitude of Adaptation: difference between average of 1st 10 strides and last 10 strides in a given session
* Adaptation Rate: number of strides needed before stride length fell within “final adapted state” (mean +/- standard deviation of last 30 strides)
* Magnitude of Retention: Difference between early asymmetry of session 1 and session 2
* Re-Adaptation Rate: number of strides needed before stride length fell within “final adapted state” (mean +/- standard deviation of last 30 strides)
 |
| **Main Findings**[Provide summary of mean scores/mean differences/treatment effect, 95% confidence intervals and p-values etc., where provided; you may calculate your own values if necessary/applicable. You may summarize results in a table but you must explain the results with some narrative.] |
| **Baseline:*** No statistically significant differences between groups at baseline (P = 0.194 – 0.835)
* Both intervention groups had significantly higher average intensity (% of max intensity) and time at high-intensity (% of total time) than the control during the intervention (P < 0.001)

**BDNF and lactate in Blood Serum**: * The difference in lactate (mmol/L) from pre- to post-intervention session 1 for control, TMW, and TBE were -0.5 ± 0.31, 1.18 ± 0.97, and 5.08 ± 2.45 respectively. There was a statistically significant difference between both intervention groups and control and between TBE and TMW.
* The difference in BDNF (ng/mL) from pre- to post-intervention session 1 for control, TMW, and TBE were -2.35 ± 13.93, -1.66 ± 7.14, and -1.63 ± 10.05 respectively. There were no statistically significant differences between any groups.

**Locomotor Learning:*** There were no significant differences between any groups for early asymmetry, magnitude or rate of adaptation during intervention session 1.

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|  | **Control** | **TMW** | **TBE** | P |
| Early Asymmetry (avg difference between 1st 10 strides) | 0.133 ± 0.152 | 0.134 ± 0.069 | 0.114 ± 0.068 | 0.734 |
| Magnitude of Adaptation (difference between avg of 1st 10 strides and last 10 strides in session 1) | Not given numerically (Fig 3 B) | Not given numerically (Fig 3 B) | Not given numerically (Fig 3 B) | 0.732 |
| Adaptation Rate (number of strides before stride length fell within “final adapted state” (mean ± SD for last 30 strides)) | Not given numerically (Fig 3 C) | Not given numerically (Fig 3 C) | Not given numerically (Fig 3 C) | 0.892 |

* There were also no significant differences between any groups for magnitude of retention (P = 0.618) or re-adaptation rates (P = 0.297) in intervention session 2. Specific mean and SD are not given in the paper, but are shown graphically in Figure 3D and 3E for magnitude of retention and re-adaptation rates respectively.

Taken together, we see the only significant change between groups is the increase in lactate not only between the interventions and control, but also between the treadmill walking and cycle ergometer groups. All other asymmetries and changes in gait were consistent across the three groups, showing no impact or effect for high-intensity aerobic priming for locomotor training in patients with chronic stroke regardless of type of exercise (treadmill walking or total body cycle ergometry) or timing of priming intervention (before or after locomotor task) |
| **Original Authors’ Conclusions**[Paraphrase as required. If providing a direct quote, add page number] |
| In contrast to other research on high-intensity aerobic priming to affect motor learning in the upper extremity (UE) of both healthy subjects and patients with chronic stroke, there was no significant change in locomotor learning in a split-belt treadmill task after high-intensity aerobic priming by either treadmill walking or full body cycle ergometry based on measures of adaptation and retention over a span of 24 hours. This finding was contrary to their hypothesis that an acute exercise bout would improve locomotor learning in people with chronic stroke. These authors then went on to discuss possible reasons for their non-significant results regarding aerobic priming for LE motor learning in patients after stroke, when other research on the population has had very positive results regarding motor learning in the UE. Here are their summarized discussion points: (page 2010 – 2012)* Prior studies tested learning of visuomotor tracking task or time-on-target task where subjects would be given more explicit instructions, feedback, or reinforcement than subjects in this study received while completing implicit sensorimotor learning task of walking. The authors propose that different successes with these different forms of learning, amounts of instruction, and types of feedback, suggest that the role of aerobic priming may be dependent on the type of learning.
* Furthermore, different types of learning may rely on slightly different “neural bases” or processing pathways, explaining the difference in results. Research supports that sensorimotor learning is typically cerebellar-dependent, while visuomotor learning relies more heavily on the primary motor cortex. Therefore, high-intensity exercise may benefit one process of learning, but not all.
* Lastly, other learning tasks in the research have been relatively simple tasks performed with the subject seated and only using one UE to complete activity. It is possible that due to the complex, dynamic challenges of walking do not see the same benefits from high-intensity exercise as more simple tasks.

Although not specifically mentioned in my CAT question, these authors discuss the role of BDNF, a substance that is proposed to moderate the effect between exercise and learning. Although this study found no significant change in levels of BDNF for any group, the authors propose that the proposed effects of BDNF may be due to a genetic variation: ‘BDNF Val66Met’ that may influence the impact of BDNF on learning.  |
| **Critical Appraisal** |
| **Validity**[Summarize the internal and external validity of the study. Highlight key strengths and weaknesses. Comment on the overall evidence quality provided by this study.] |
| PEDro Score: 6/10 Although the study explicitly mentions random allocation to groups, they do not address the concealment of allocation, blinding of subjects, or blinding of therapists administering the baseline testing (Fugl-Meyer LE or self-selected walking pace) or interventions. Although the majority of the data collected and measured for this study was captured by video software and computational models that are inherently less affected by bias than therapists conducting an intervention, we cannot be sure to what extent the researcher conducting the trial may have influenced results. Due to the nature of the interventions, each group doing a different activity, it would be impossible to blind the subjects or researchers to the intervention, but blinding of researchers completing baseline testing and final analysis of the results is not only feasible but would improve internal validity of the study. There is no comment on feedback given, encouragement, or blinding of researchers during analysis of results and measures, therefore we cannot be sure whether or not these impacted results. Despite the limitations described above, the similarity of the groups at baseline, follow-up with all participants, and publication of results for all key outcome measures and participants are positive features that increase the strength of the study. Although some outcomes are given numerically, they also show the results in graphs (Figure 3 A-E) with data points for all participants as well as clear depiction of group means and error. As for the external validity, the study does a good job of clearly defining inclusion and exclusion criteria, and despite the relatively small number of subjects (n = 37), baseline characteristics such as gender, side of the lesion, and time after stroke were equally distributed or contained large ranges of scores increasing applicability. However, the population was generally younger, 55-62 years old, with relatively limited variability in range of scores, potentially limiting the generalizability to patients with chronic stroke of all ages. Additionally, the majority of the strokes were due to ischemic lesions, which may limit generalizability as well. The study is also limited in their short window of follow-up. The researchers themselves identify other studies that found effects of motor learning to be further increased after 7 days, which may or may not have affected their findings. Overall, despite some limitations in blinding of treatments and small sample with short follow-up time due to highly specific patient population being studied, I feel this study has moderate evidence quality due to their randomization, reporting of results, and follow up with all participants. It is possible that there is a treatment effect that was not identified in this particular study and that a more specific time post-stroke (current range from 9 – 303 months post-stroke) or a longer follow-up would have changed the results. Lastly, there are many potential variables in this study such as timing of intervention, type of aerobic exercise, and the many components of the complex task of walking that could have further mitigated or skewed results that were not addressed in this study. Overall, I feel that the results are most likely valid, that there is minimal change in complex locomotor learning after one intervention, but am not convinced that this is generalizable to all patients after stroke.  |
| **Interpretation of Results**[This is YOUR interpretation of the results taking into consideration the strengths and limitations as you discussed above. Please comment on clinical significance of effect size / study findings. Describe in your own words what the results mean.] |
| Although aerobic exercise as a mode of movement-based priming has been validated in other studies with healthy controls, longer intervention duration and follow-up, and in motor learning tasks involving the upper extremity (UE), the results of this study clearly showed no significant changes in learning as measured by either adaptation or retention.1,4,5,9 It is possible that given the low power of the study (small sample with no effect size) that a type II error has occurred, but this cannot be determined without further research. Although this study showed no changes in locomotor learning in 24 hour window, it remains to be seen if a longer treatment intervention (multiple visits) or longer follow-up time would lead to similar non-significant results. It is possible that the complexities of locomotor learning, or the process of intrinsic sensorimotor learning are not affected by high-intensity aerobic priming, but this low-powered study with non-significant results does not currently support the efficacy of high-intensity aerobic priming for locomotor learning. Although no strong positive results were found, patients tolerated all interventions without any adverse events, indicating that there is unlikely additional harm introduced with this intervention. |
| **Applicability of Study Results**[Describe the relevance and applicability of the study to your clinical question and scenario. Consider the practicality and feasibility of the intervention in your discussion of the evidence applicability.] |
| Although this study does not compare the interventions in my clinical question, it is the best available evidence for the effect of aerobic exercise priming on motor learning as it relates to changes in gait in a population of patients with chronic stroke. This study thoroughly investigates the results of high-intensity aerobic priming through use of different timing of the intervention (before or after the split-belt treadmill task) and type of exercise (walking or cycle ergometer). They do not, however, look at long-term learning or function, other intensity levels (low or moderate-intensity), and do not report changes in self-selected walking speed after the intervention, as would further explain possible effects of the aerobic priming intervention. It was the only study currently available looking at aerobic priming on lower extremity function in patients with chronic stroke, making it the most appropriate study to answer that part of the clinical question, despite some of its limitations in methodology and power.  |

**(2) Description and appraisal of “The Efficacy of Lower Extremity Mirror Therapy for Improving Balance, Gait, and Motor Function Poststroke: A Systematic Review and Meta-Analysis” by Louie and Lim, 2019**

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| **Aim/Objective of the Study/Systematic Review:** |
| This systematic review with meta-analysis aims to review recent literature (studies through 2018) to determine the efficacy of mirror therapy in improving balance, gait, and motor function when used on the lower extremity (LE) in patients with chronic stroke.  |
| **Study Design**[e.g., systematic review, cohort, randomised controlled trial, qualitative study, grounded theory. Includes information about study characteristics such as blinding and allocation concealment. When were outcomes measured, if relevant]Note: For systematic review, use headings ‘search strategy’, ‘selection criteria’, ‘methods’ etc. For qualitative studies, identify data collection/analyses methods. |
| * Systematic review of 17 studies published through May 2018 with separate meta-analyses of gait speed, mobility, balance, and motor recovery.

**Search Strategy:** The following online databases were searched for relevant articles from their respective inceptions until May 2018: PubMed, MEDLINE, Cochrane, Embase, Cumulative Index to Nursing and Allied Health Literature (CINHAL), Physiotherapy Evidence Database (PEDro), and PsychINFO. * Searches combined keywords relating to stroke, mirror therapy, and “mobility recovery”, more detail given in Methods section, page 108.
* Two separate researchers reviewed the titles and abstracts of the articles found in the search. They then used relevant articles to search for additional relevant references.

**Selection Criteria:** researchers were instructed to select studies that met the following inclusion criteria: were RCTs published in English that measured an outcome relevant to this study (gait speed, balance, mobility, or LE motor function), sample participants age 18+ with diagnosis of stroke, and intervention included mirror therapy for LE so that the image of the affected LE was replaced by an image of the unaffected LE. * Interventions that used stimulation in addition to mirror therapy were included
* Interventions were the mirror was placed in front of the whole body for visual feedback rather that in front of the affected limb were excluded.

**Methods:** Researchers established their question and methods based on the Cochrane Handbook for Systematic Reviews of Interventions. * After literature search and study selection as described above, the same two independent researchers reviewed the articles to find relevant data points regarding the sample, intervention, and outcomes.
* The two researchers then assessed study quality using the Cochrane Collaboration’s Tool for Assessing Risk of Bias, with the help of a third researcher when a consensus could not be reached between the two of them.
* Data regarding the subjects and samples of the studies were combined, meta-analyses were conducted as possible on outcome measures reported in the studies (gait speed, balance, mobility, and motor recovery)
* Standard Mean Differences (SMD) with 95% confidence intervals were used to show pooled effects. (SMD classification: 0.2-0.49: small effect, 0.5-0.79: moderate effect, >0.8: large effect)
* Heterogeneity was calculated and explained by I2 (25-50%: low, 50-75%; moderate, >75%: high)
 |
| **Setting**[e.g., locations such as hospital, community; rural; metropolitan; country] |
| This study was conducted by researchers in Canada (Rehabilitation Services and Department of Physical Therapy at the University of British Columbia, and the Rehabilitation Research Program at the Vancouver Coastal Health Research Institute). The studies themselves were collected from various online databases, collecting research from many different locations and settings. |
| **Participants**[N, diagnosis, eligibility criteria, how recruited, type of sample (e.g., purposive, random), key demographics such as mean age, gender, duration of illness/disease, and if groups in an RCT were comparable at baseline on key demographic variables; number of dropouts if relevant, number available for follow-up]Note: This is not a list of the inclusion and exclusion criteria. This is a description of the actual sample that participated in the study. You can find this descriptive information in the text and tables in the article. |
| **Included Studies:*** 179 studies were identified originally, resulting in 81 relevant articles for review that produced 17 RCTs that met the inclusion/exclusion criteria.
* Studies were evaluated for risk of bias using the Cochrane Collaboration’s tool (results shown in Figure 2) with only a few studies reporting low risk of bias, and few with high levels of bias, while the majority could be scored as moderate due to inadequate information to assess.
	+ Due to the nature of the intervention, no studies were able to blind participants and personnel, and are therefore at increased risk of performance bias, while generally, risk of selection, detection, and attrition biases were lower in the selected studies.
* Within the larger sample, only 6 of the 17 studies reported drop-out or adverse events resulting in patient drop out. In four of the 6 studies, drop-up was reportedly due to the mirror therapy intervention and therefore occurred more in the intervention group while in the other 2 studies, drop outs occurred in similar rates in both groups.

**Resulting Sample:*** 633 participants were identified from the 17 RCT studies included in the analysis that were identified as described above. The final sample included both male and female, but had a slight majority of male subjects in those that identified subject genders (57.2% male). The final sample included patients with both ischemic and hemorrhagic strokes to both the right and left sides, and included both acute and chronic stroke patients (time of intervention post-stroke ranges from 5.7 days to 42.5 months). Additionally, the sample contained patients of varying ages with mean ages ranging from 44.5 (6.1) to 69.6 (12.2).
 |
| **Intervention Investigated**[Provide details of methods, who provided treatment, when and where, how many hours of treatment provided] |
| *Control* |
| * All studies compared mirror therapy (MT) to a control intervention, the majority (47%) compared MT to sham MT, while other common control groups were sham MT with conventional therapy (23.5%), conventional therapy (17.8%), or some type of cognitive task (11.8%).
* All control interventions were time-matched to the intervention, regardless of type of control treatment being received. Total control time ranged from 30 – 60 minutes of treatment 3 – 6 days/week, for 2 – 12 weeks.
 |
| *Experimental* |
| * Although all studies included MT, the timing and duration of the MT varied across trials, only 3 studies looked at MT alone (17.7%), while 2 studies (11.8%) employed bilateral MT, and the majority of trials, 9 trials (53.9%), looked at MT in conjunction with conventional therapy. Additionally, there were 5 studies (23.5%) that looked at MT and stimulation (NEMS or rTMS) together.
* Interventions ranged from 30 – 60 minutes in total with 15 – 60 minutes of MT, for , 3 – 6 days/week, for 2 – 12 weeks resulting in a range of total intervention time ranging from 360 minutes to 1800 minutes.
* The position of the subject and mirror were consistent across trials with most subjects sitting upright in a long-sitting position with mirror between lower extremities. One study did use video feedback rather than mirrors.
* The joints moved during MT varied across trials, ranging from ankle-only (5 trials) to ankle, knee, and hip (11 trials).
 |
| **Outcome Measures**[Give details of each measure, maximum possible score and range for each measure, administered by whom, where] |
| **Motor Function:*** Fugl-Meyer Assessment of Motor Recovery after Stroke (FMA): an assessment of recovery after stroke that analyzes motor function (upper and lower extremity sub-categories), sensation, balance, joint range of motion (ROM), and pain using 133 items scored 0-2 for a total score of 266 when using all sub-scales or total of 34 when using only the LE motor function subscale.12 It is well validated in stroke population and recommended by StrokEDGE taskforce.12 A cut-off score of 21/34 on the LE subscale has been proposed to indicate high-functioning individuals.13
* Motor Assessment Scale (MAS): a short assessment of 8 items that are scored 0 – 6 with 6 indicating normal motor behavior for the given task.19 Tasks include bed mobility, transfers, seated balance, walking, upper extremity movements and dexterity, and general tone.19 It has been shown to have excellent reliability in chronic and acute stroke, with adequate to excellent construct validity.19
* Brunnstrom Stage: A ranking system with 7 identified stages of recovery based on available voluntary functional movement after stroke. Scale ranges from 1 (mostly flaccid presentation) to 7 (return of normal function).20ct a Due to highly specific descriptions of stages, they are commonly used to describe spasticity, motor recovery, and progress.20 They have been shown to be reliable and responsive measures measures20
* Stroke Impairment Assessment Set (SIAS): This measures 9 categories of motor function (tone, sensory function, range of motion, pain, trunk function, visuospatial function, speech, and sound-side function) that are divided into 22 items where 5 items (motor function) are scored from 0 – 5 where 5 indicates optimal function, and 17 items scored 0 – 3 where 3 indicates optimal function.21
* DF ROM: a measure taken that can indicate extensibility of plantarflexors, a muscle group that is normally limited in stroke patients.22 Normal range of motion ranges from 0 degrees to 16.5 degrees in non-weight bearing in normal adults.23

**Balance:*** Berg Balance Scale (BBS): this 14-item measure of balance and fall risk has been well-validated in the stroke population, and is scored 0 – 4 5 where 4 indicates optimal function, for a maximum score of 56.24 A cut-off of 45/56 has been identified for patients with stroke.24
* Functional Reach Test (FRT): a measure of dynamic stability, measuring distance patient can reach forward while maintaining their balance.25 Reported normal distances range from 15.2 cm to 27.1 cm, with a reported MDC of 3.7 cm.25

**Gait and Mobility:*** 10-Meter Walk Test (10MWT): a quick, short measure of gait speed, subjects are timed while walking at their normal pace for a distance of 10-meters.26 The MCID has been shown to be 0.06 – 0.16 m/s depending on the study with established cut-off scores of >0.8 m/s being indicative of community ambulation.14,26
* Modified Emory Functional Ambulation Profile: a measure of functional ambulation that takes level of assistance and different environmental situations. Patient’s scores are calculated based on their time to complete the task and which assistive device they use. Modifiers range from x1, “no assistance,” to x6, “AFO + hemi-walker or AFO + quad cane.”27 the measure has been shown to have excellent reliability and validity, with MDC of 7.18 – 8.81.27
* Functional Independence Measure (FIM): a measure of disability based on the level of assistance needed to complete a given task. It is an 18-item measure (13 motor and 5 cognitive) where each item is scored from 1 – 7 with 7 indicating normal performance of the task.28 The measure has been shown to have high validity, responsiveness, and internal consistency.28
* Functional Ambulation Category (FAC): A quick, observational measure of walking ability with clearly defined and described movements for each ranking.29 The categories range from 0 (nonfunctional ambulation) to 5 (ambulator-independent), and can be used for quick evaluation of patient functional gait.29 The measure has been shown to have excellent reliability and validity in the stroke population, and a cut-off score of >4/5 as predictive of community ambulation at 6 months.29 30
* Timed-Up-and-Go (TUG): A measure of functional mobility and gait that is commonly used to assess fall risk in older adults and those with balance deficits.31 A cut off of >14 seconds has been shown to indicate falls risk in older stroke patients, and the MDC has been determined to be 2.9 seconds in those with chronic stroke. 31
* Gait Speed: this simple measure has been shown to be of vital importance as it is a reliable measure of function, disability, risk, and prognosis. In patients with chronic stroke, the minimal detectable change has been identified as 0.18 m/s with speeds of > 0.8 – 1.0 m/s being indicative of increased community ambulation and independence.14
* Features of Gait: objective measurements of step and stride length. These measures are taken to ascertain differences between paretic and non-paretic limb as estimate of gait asymmetry.32
 |
| **Main Findings**[Provide summary of mean scores/mean differences/treatment effect, 95% confidence intervals and p-values etc., where provided; you may calculate your own values if necessary/applicable. Use a table to summarize results if possible.] |
| Researchers classified a SMD of 0.2 - 0.49 as a small effect, a SMD of 0.5 - 0.79 as a moderate effect, and a SMD > 0 .8 as a large effect**Gait Speed**: * 9 of the 17 studies provided data regarding gait speed, a summed mean difference (SMD) of between-group changes in gait speed was completed using the data from 6 of those 9 studies in which mirror therapy was conducted without additional stimulation. They found a large effect size (SMD = 1.04, 95% CI = 0.43, 1.66, P < 0.001).
	+ 1 of the 6 studies compared MT to conventional therapy while the other 5 compared MT to sham MT, when that study was excluded from the analysis, the effect size increased to SMD = 1.24 (95% CI = 0.63, 1.85, P < 0.001).
	+ In sub-group analyses separating based on the chronicity of the stroke, the effect sizes of MT in patient with subacute stroke were much larger than those with chronic stroke; as SMD = 1.36 (95% CI = 0.31, 2.40, P = 0.01) and SMD = .77 (95% CI = 0.03, 1.58, P = 0.06) for subacute and chronic stroke sub-groups respectively. A moderate effect size for chronicity.
	+ The largest effect size found related to gait speed changes was comparison of MT in combination with stimulation, resulting in SMD = 1.58 (95% CI = 0.6, 2.56, P = 0.002).

**Mobility:*** Although 7 of the 17 studies analyzed mobility in terms of level of assistance needed and transfer ability, only 5 of the 17 studies provided data. A SMD of between-group changes was completed using the data from those 5 studies where MT was compared to sham MT. They found a small effect size (SMD = 0.46, 95% CI = 0.01, 0.09, P = 0.05).
	+ Sub-group analysis based on chronicity of the stroke or addition of stimulation to MT intervention found no effect.
	+ Sub-group analysis based on unilateral or bilateral training found that bilateral training with MT produced a moderate effect size (SMD = 0.73, 95% CI = 0.21, 1.25, P = 0.006).

**Balance:*** 6 of the 17 studies studied balance as an outcome (postural sway or functional balance outcome measure), a SMD was determined using available data from 4 studies. They found no significant effect of MT on balance outcomes when compared to sham MT (SMD = 0.69, 95% CI = -0.08, 1.14, P = 0.08).
	+ Sub-group analysis was still insignificant when 1 study of chronic patients with bilateral training movements was removed, leaving the sample with 3 studies of subacute patients completing unilateral training movements.
	+ However, in a sub-group analysis of MT in combination with stimulation, the effect size was large and significant (SMD = 1.14, 95% CI = 0.60, 1.68, P < 0.001).

**Motor Function:*** 10 of the 17 studies measured motor function changes, 8 of which provided data from outcome measures (FMA, SIAS, or Brunnstrom Stage), while the others only measured strength. An analysis of between-group changes was completed using the data from 7 of those 10 studies in which mirror therapy was conducted without additional stimulation. They found a small effect size (SMD = 0.47, 95% CI = 0.21, 0.74, P < 0.001).
	+ In sub-group analyses based on the chronicity of the stroke, the effect sizes of MT in a patient with subacute stroke were slightly larger than those with chronic stroke; as SMD = 0.50, 95% CI = 0.19, 0.81, P = 0.002 and SMD = 0.40, 95% CI = -0.09, 0.89, P = 0.11 for subacute and chronic stroke sub-groups respectively.
	+ Unlike other outcomes being measured, in an analysis of MT done in combination with stimulation showed no significant changes compared to MT alone.
 |
| **Original Authors’ Conclusions**[Paraphrase as required. If providing a direct quote, add page number] |
| The authors conclude that there is evidence of “a significant improvement in gait speed, mobility, and motor recovery” (page 118) as evidenced by the large and significant effect sizes when comparing MT to control in these areas. This analysis does not support any significant effects of MT on balance improvement. Sub-group analysis in this study allows for further insight regarding efficacy of MT as it is likely to be more effective in subacute stroke patients, when MT involves movement of both limbs, and when compared to sham MT. Additionally, the addition of stimulation to MT interventions results in larger, significant improvements for gait speed and balance. Therefore, the authors conclude MT has a large benefit in gait speed for patients after stroke, and smaller benefits in motor function and mobility.  |
| **Critical Appraisal** |
| **Validity**[Summarize the internal and external validity of the study. Highlight key strengths and weaknesses. Comment on the overall evidence quality provided by this study.] |
| With an AMSTAR score of 9/11, it is objectively a “high quality” study that helps to answer the clinical question with more powerful 1a level evidence. (a priori design provided: yes; two independent data extractors: yes; comprehensive search: yes; status of publication: no; list of studies: no; characteristics of studies: yes; quality assessment: yes; quality assessment used in conclusions: yes; appropriate methods to combine studies: yes; publication bias assessed: yes; conflict of interest stated; yes.)* The authors study validity is strengthened by their use of protocol with comprehensive literature search across multiple databases, duplicate researchers investigating and selecting articles for inclusion, and analysis and reporting of data for included studies. Their exhaustive search included hand-searching reference lists of articles found for additional relevant articles, further increasing their search of available literature and limiting selection bias. Researchers also presented the quality assessment of included articles graphically, clearly showing strengths and limitations of each included article. A common limitation is lack of blinding of participants and personnel due to the nature of the intervention, a finding the authors acknowledge in their report. They also describe some instances of increased risk of bias, allowing for more transparency to bias that may be impact their findings. The authors provide measures of heterogeneity for all outcomes and mention use of random effects models to account for large expected values of heterogeneity.
* That being said, the authors inclusion of only RCTs for this analysis results in limited search and inclusion of grey research, a possible source of publication bias. Researchers report that due to the high rate of positive and significant results, they suspect that research with negative results may not be published as often, but give no indication of searches for un-published literature on the topic. As for the quality of included studies, only a few were “high quality” with low risk of bias, while most were of “moderate-quality” as identified by the Cochrane Risk of Bias Tool. Although the authors acknowledge this, it may impact the results, and therefore slightly weakens the results of this review.

An additional concern for the internal validity of the study is the variation with which the mirror therapy was given and additional high variation in the control treatment. Although researchers attempted to tease this out through sub-group analyses, we cannot be sure what the exact role that any combination of interventions (MT, MT + conventional PT, MT + stimulation, MT + stimulation + conventional, etc) or how the different control interventions (sham MT or conventional PT) may affect results. As for external validity, I feel the inclusion of 633 participants with variation in age, type of stroke, and time-since stroke allow for increased confidence in the applicability to patients after stroke in general, but that the sub-group analyses offer more specific and useful results for application of results to particular patients. That being said, the high levels of heterogeneity persist, potentially weakening the external validity due to the extreme variation in outcome measures, patient populations, and interventions.  |
| **Interpretation of Results**[This is YOUR interpretation of the results taking into consideration the strengths and limitations as you discussed above. Please comment on clinical significance of effect size / study findings. Describe in your own words what the results mean.] |
| This systematic review and meta-analysis provides moderately strong evidence that mirror therapy (MT) can significantly improve gait speed, motor function, and mobility in patients after stroke when compared to sham MT and even conventional therapy. Overall, given the quality (AMSTAR 9/11) and recent publication of this review, it is of inherently higher quality than any one study currently available on cognitive priming or MT. Despite risk of publication bias, and heterogeneity of sample and interventions, this collection of evidence supports the general use of MT for improvement of gait and function in individuals with subacute to chronic stroke. The article itself is quality and found statistically significant and large effect sizes of MT on gait improvement. However, the heterogeneity significantly limits the clinical utility of the results as no specific treatment parameters can be obtained. From the effect sizes, the clinical utility of this intervention is maximized in patients who are limited in gait and who fall into the subacute stage of rehabilitation (1 – 7 months post-stroke in this paper) rather than chronic (9 – 37 months). Although the precise treatment parameters to reproduce these results are unclear, the subgroup analyses identify a more specific patient population that would benefit from MT. The evidence is positive but not as strong for motor function, mobility, and balance due to either small effect sizes or no effects being generally found. Here again, the use of subgroup analyses was useful in increasing specificity of the population or intervention, and results in larger, significant effect sizes that provide meaningful clinical information. One additional point of interest is the inclusion of MT done in conjunction with electrical stimulation. This dual intervention produced large, significant effect sizes in both gait improvement and balance, making it an appropriate and specific intervention if feasible and accessible in the clinic. Overall, this article supports the clinical utility of MT in patients after stroke, especially those in the subacute stage. Although it lacks evidence for specific intervention parameters, the interventions used are described at length, and subgroup analyses add useful clinically meaningful insight.  |
| **Applicability of Study Results**[Describe the relevance and applicability of the study to your clinical question and scenario. Consider the practicality and feasibility of the intervention in your discussion of the evidence applicability.] |
| Although this systematic review does not specifically analyze cognitive priming as identified in my clinical question, the methodology of mirror therapy is commonly described as a motor imagery technique, an image- or cognitive-based method of priming.1 Therefore, I felt this was the strongest available evidence (level 1a) to answer my clinical question about cognitive priming as it relates to gait outcomes in a population of patients after stroke. This review specifically speaks to gait speed, the most important outcome to the patient who inspired this CAT, making it especially relevant to the clinical question. Although my clinical question is looking at patients with chronic stroke, this article identifies the subacute stroke category as patients between 2 weeks and 6 months after their stroke, meaning the original patient who was 4 months post-stroke falls into this subacute category rather than chronic stroke. The review identifies very few instances of adverse events related to the intervention, indicating that it is a safe intervention to implement in this specific population.The variation in treatment frequency and duration as well as possible variations in intervention (MT, MT + conventional PT, MT + stimulation, MT + stimulation + conventional, etc) makes it more challenging to determine the appropriate intervention to see significant effects in the given clinical scenario. Although most interventions in this study had high intervention frequencies (3-6 times per week), this is actually still feasible in the in-patient setting of this clinical scenario as therapy sessions occurred 5 times per week for an hour each time. It would therefore, be feasible to introduce 30 minutes of MT in combination with 30 minutes of conventional therapy as described in many of the articles included here, but as there are no results given in relation to frequency or duration of treatment intervention, there is no guidance in the literature of how to specifically introduce this treatment into the therapy. Lastly, although not included in the original clinical question, the use of additional stimulation to increase the effect of the results is slightly limited due to the need to purchase and maintain these materials. However, in a clinical setting that already has access to this equipment, it would be feasible to add this component to the intervention.Overall, I found this to be highly related to the clinical question at hand, as it provides information in regards to the population, intervention, and specific outcome measures in question.  |

**SYNTHESIS AND CLINICAL IMPLICATIONS**

[Synthesize the results, quality/validity, and applicability of the two studies reviewed for the CAT. Future implications for research should be addressed briefly. Limit: 1 page.]

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| **Synthesis of Evidence:** The results of the two articles reviewed above can be taken together to provide overall limited quality evidence surrounding which type of priming is more effective for inducing motor learning changes needed for improvements in gait after stroke. No one study directly addressed the clinical question, so after reviewing the available literature, the two articles presented were chosen to speak to the efficacy of cognitive and aerobic priming independently. Although each article is best available evidence, comparison is complicated by large differences in interventions, specifically the duration of intervention, outcome measures, and follow-up time. There is a preponderance of clinically significant and positive evidence for both cognitive and aerobic priming techniques in the rehabilitation of motor learning in the upper extremity (UE), and research has shown both types of priming to be effective both in conjunction4 and independently3,5,9 in the UE. However, the findings of Charalambous et al. suggest that this result may not occur in priming for lower extremity (LE) rehabilitation.2 This study found no significant changes in gait adaptations or indications of motor learning in the LE after a bout of high intensity aerobic priming in patients after stroke.2 With this, there is not currently any evidence of significant efficacy of aerobic priming as it relates to gait outcomes in patients after stroke.2 Furthermore, there is limited evidence on cognitive priming specifically, and therefore interventions such as motor imagery (MI) and mirror therapy (MT) were used due to the similar cognitive processes with these tasks.1 In addition to the evidence presented above, another systematic review found a moderate effect size of MT on gait speed, and an RCT found a significant improvement in gait speed after 3 weeks of intervention with MI.7,8 Taken together, there is significantly more, quality evidence for efficacy of cognitive priming for gait improvements in patients after stroke than aerobic priming.6–8**Implications for Clinical Practice:** Though the quality and evidence on these specific interventions is currently limited, there is support for use of cognitive priming tasks such as MI8,33,34 and MT3,6,7,35 in patients after stroke who have persisting limitations in gait 4 months after their stroke. Clinically, MI in particular is an effective and feasible intervention that could be used as a “mental warm-up” and completed without sacrificing therapy time or requiring additional resources.8,33,34 MT has also shown to be effective in this population for improvements in gait speed, motor function, and mobility, with added benefits when used in conjunction with electrical stimulation.6 This may not be as clinically feasible depending on cost or accessibility of stimulation devices, but has been shown to improve gait outcomes when used consistently before traditional therapy interventions.6 Research currently is unable to inform treatment parameters, but it is worth noting many follow a modified protocol first described by Sütbeyaz et al. that consists of 30 min of MT each day, 5 days a week, for 4 weeks.6,36As for aerobic or exercise priming, despite preliminary support for the proposed mechanisms of this movement-based priming, current research does not indicate any specific added benefit for gait from aerobic priming.1,2,5 Possible future advancements in research may change this recommendation, but it has yet to be shown as efficacious as other therapy interventions, and may be more difficult due to mobility and cardiovascular limitations common after stroke.1,2**Implications for Future Research:** Due to the difficulties in finding appropriate evidence to answer this clinical question, there are many viable directions for future research that are clinically meaningful. The first and foremost, further research on aerobic priming should be done that incorporates both high and moderate intensity aerobic exercise, and immediate through long-term effects. The current evidence by Charalambous is limited to one high-intensity aerobic priming session and one 24-hour follow-up.2 Furthermore, the authors’ proposed a variety of explanations for why their results were different from those seen in priming for UE motor learning including: different type of learning, feedback, instruction, and complexity of the tasks. Each of these potential mediators of motor learning in the LE offer different avenues for research to test these mechanisms of priming effectiveness.2 Secondly, both modes of priming would benefit from research regarding the optimal timing, frequency, and duration of interventions. As this would improve clinical utility and application of research to patient rehabilitation. Although the research on cognitive priming generally supports the intervention when compared to conventional practice, there is little agreement on most effective intervention parameters.1,6,7 A standardization of intervention could also improve homogeneity of future samples, improving the validity of future studies. Applicability of aerobic priming would benefit from these studies as well, if deemed efficacious by future studies described above.Lastly, it would be most compelling to have these interventions studied through direct comparison in a RCT of patients after stroke who have been randomized to aerobic or cognitive priming, or a control group of conventional therapy during their rehabilitation. This would allow direct comparison of these interventions and provide insight into both immediate and long-term outcomes. This is a much larger undertaking, but would be most helpful in discerning best practice.  |

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