A clinical examination of OPTIMAL theory application in people with multiple sclerosis: a proof-of-concept study and implications for rehabilitation practice

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We investigated the potential to improve motor learning and performance in people with multiple sclerosis (PwMS) with OPTIMAL theory conditions. OPTIMAL theory predicts that three main factors [i.e. autonomy support (AS), enhanced expectancies (EE), and external focus (EF)] facilitate performance and learning. We examined whether the implementation of all three combined in a consecutive manner during practice would be beneficial for the motor learning and performance in a clinical population facing physical, cognitive, and emotional challenges. Thirty PwMS with mild-to-moderate disability (Expanded Disability Status Scale = 2.0–5.0) were randomly assigned to one of two groups (optimized and control) and practiced a novel motor-cognitive task involving rapid square-stepping to memorized patterns. Following a pretest (no group difference), optimized group participants practiced under each of three factors across practice phase (EE: feedback after good trials; AS: choice of mat color; and EF: external focus to the mat). Control group participants practiced under neutral conditions. The optimized group had significantly shorter movement times than the control group in the practice phase [174.7 (27.4) s vs. 236.8 (35.8) s, *P* < 0.0001], on the 24-h retention test [69.3 (9.3) s vs. 159.7 (15.5) s, *P* < 0.0001], and the 24-h transfer test [146.1 (14.9) s vs. 223.1 (38.9) s, *P* < 0.0001]. Thus, optimized practice combining AS, EF, and EE enhanced motor skill learning. Key factors in the OPTIMAL theory can be used to improve patients' motor learning. Further studies are warranted to extend these proof-of-concept observations for potential clinical applications. *International Journal of Rehabilitation Research* XXX: XXXX–XXXX Copyright © 2024 Wolters Kluwer Health, Inc. All rights reserved.

International Journal of Rehabilitation Research XXX, **XXX**:XXXX–XXXX

Keywords: intrinsic motivation, multiple sclerosis, OPTIMAL theory, rehabilitation

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Received 20 August 2024 **Accepted** 30 November 2024.

Introduction

The OPTIMAL (Optimizing Performance Through Intrinsic Motivation and Attention for Learning) theory, developed by Wulf and Lewthwaite [1–3], emphasizes the relevance of intrinsic motivation and attentional focus for effective motor performance and learning. The motivational factors are autonomy support (AS) and enhanced expectancies (EE), whereas the attentional factor is an external focus (EF). The three factors, examined individually in various ways [3], can boost the acquisition of different types of motor skills. Moreover, they can have additive benefits when two or more factors are combined within an experimental session [4–6]. For example, Khalaji and colleagues examined the speed of performing a memorized square-stepping task by older adults to determine whether implementing EE, AS, and EF during practice would enhance motor learning. They found that the group that practiced the task under such optimized learning conditions had faster stepping times than the nonoptimized control group during the practice phase and on 24-h retention and transfer tests [6].

The OPTIMAL theory of motor learning provides a comprehensive framework for improving motor skills, particularly in rehabilitation settings. Research encompassing individuals with neurologically impaired motor systems indicates that motor learning conditions (e.g. AS, EE, and EF) can significantly improve motor performance. Evidence from physical therapy and motor learning literature demonstrates that these conditions, when applied to the processes of skill acquisition, retention, and transfer, have the potential to improve mobility and motor outcomes [7–11]. The present study extends these observations by examining the responsiveness of the impaired motor system in people with multiple sclerosis (PwMS) to the three core factors of the OPTIMAL theory. PwMS represents a suitable population for this study because of cognitive, motor, emotional, and motivational deficits that may impact motor learning. This approach is consistent with previous findings in intact motor systems and other rehabilitation populations, contributing to a proof-of-concept evaluation of the broader applicability of OPTIMAL principles within clinical rehabilitation settings.

DOI: 10.1097/MRR.0000000000000653

Specifically, the present study examines whether the movement performance and learning benefits of optimized conditions might extend to PwMS. Single factors (e.g. attentional focus) have provided evidence of some motor coordination benefit [9], but the combination of motivational and attentional factors of OPTIMAL has not been investigated in PwMS. Proof of the impact of these OPTIMAL factors may be a precursor for efforts to integrate this framework more fully across rehabilitation programs for PwMS.

We hypothesized that the group practicing a novel motor task under optimal learning conditions, such as AS, EE, and EF, would demonstrate a more efficient immediate skill acquisition with better performance on the 24-h retention and transfer tests. Group differences were expected to be evident in enhanced intrinsic motivation and positive emotional states compared to participants practicing under the nonoptimized (control) conditions. Additionally, under optimized conditions, we anticipated enhanced motor-cognitive efficiency and reduced mental workload associated with the performance and learning of the square-stepping task. To our knowledge, this study is the first to examine all OPTIMAL factors combined in the clinical field.

Methods

Participants

Thirty people diagnosed with multiple sclerosis (MS) were recruited from an MS Comprehensive Center in August 2024 (see Table 1). The necessary sample size for this study was calculated using G*Power v3.1 [12]. We used a repeated-measures analysis of variance (ANOVA) design with a within-between interaction, which involved two groups and three measurement times. We assumed a power of 0.91 ($1 - \beta$), an alpha of 0.05, and a large effect size [f(V) = 0.75] based on previous research that investigated the influence of OPTIMAL interventions on motor performance in healthy individuals and those with neurological conditions [4,6,13,14]. The analysis suggested a sample size of 30 participants was adequate for this study.

Individuals who met the following criteria were included in the study: (1) clinical diagnosis of MS, (2) older than 18 years of age, (3) Expanded Disability Status Scale (EDSS): 2.0–5.0, (4) ability to walk without aid, (5) Timed 25-Foot Walk test >5 s, and (6) normal score on the Mini-Mental State Exam. Individuals who had severe visual impairment were excluded. Participants had no experience with the task. The study protocol received approval from the university's ethics committee (protocol ID: IR. UI. REC. 1402. 122) and Iranian Registry of Clinical Trials (IRCT20240709062370N2). Before taking part in the study, all participants signed an informed consent document.

Table 1 Demographic and clinical characteristics of the participants

Variables	Groups	Mean ± SD	*P*-value
Age (years)	Optimal	42.5 ± 8.66	0.69
	Control	41.3 ± 8.61	
Height (m)	Optimal	1.64 ± 0.07	0.94
	Control	1.65 ± 0.09	
Weight (kg)	Optimal	63.00 ± 13.90	0.45
	Control	67.10 ± 15.60	
MS duration (years)	Optimal	15.10 ± 7.39	0.75
	Control	14.30 ± 6.28	
EDSS score (0–10)	Optimal	2.93 ± 1.06	0.18
	Control	2.50 ± 0.59	
TUG (s)	Optimal	17.30 ± 10.09	0.38
	Control	14.10 ± 9.69	
T25-FW (s)	Optimal	13.30 ± 7.30	0.51
	Control	11.00 ± 10.94	

Values for these measures are pretest scores.
EDSS, Expanded Disability Status Scale; MS, multiple sclerosis; T25FW, Timed 25-foot walk; TUG, Timed Up and Go test.

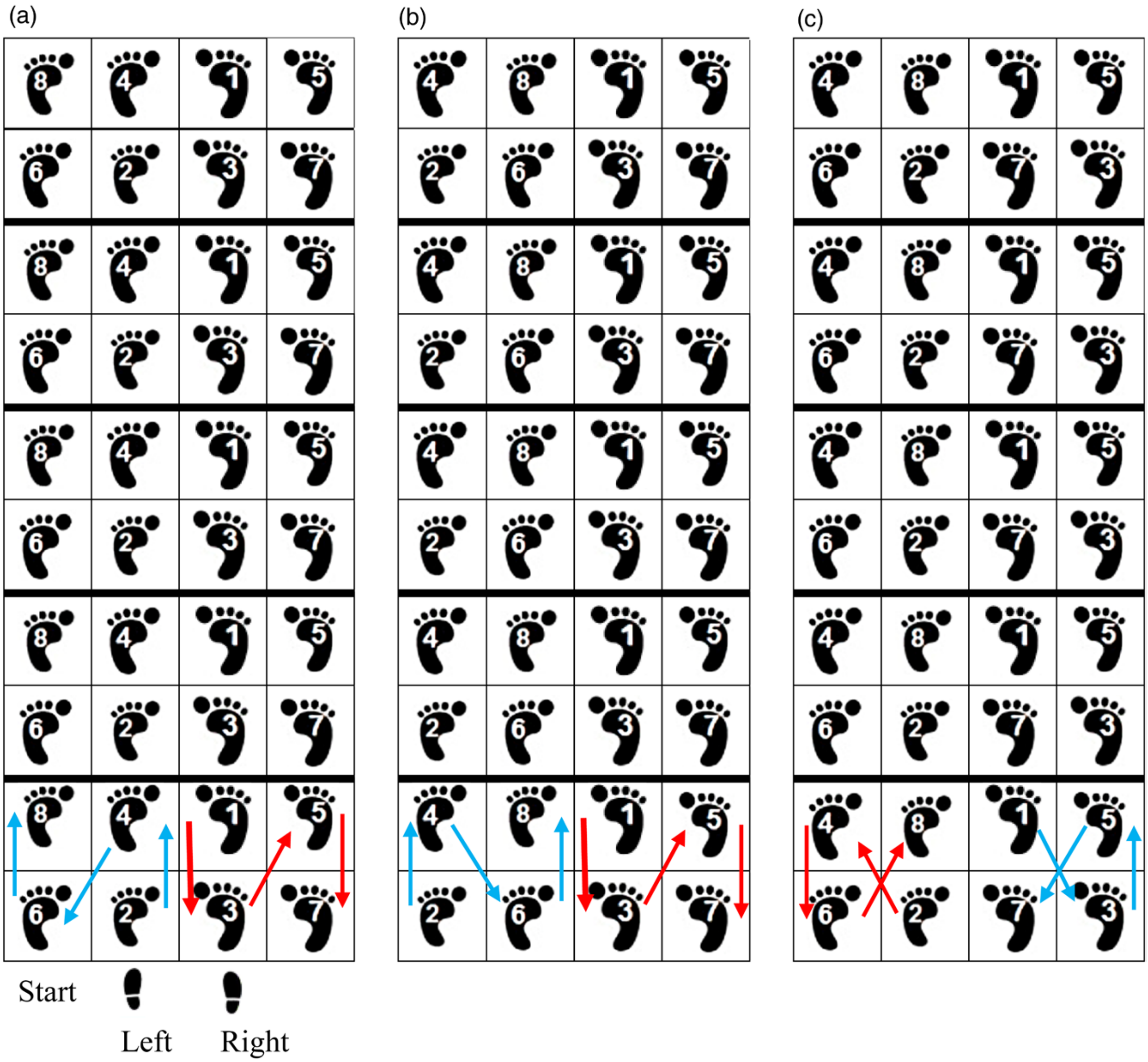
Motor task

The square-stepping task used in this study was identical to the one described in Khalaji *et al.*'s [6] study. It is based on the square-stepping task [15], originally designed as a balance training exercise to prevent falls in older individuals. The task involves a sequence of forward, backward, lateral, and diagonal steps on a thin felt mat of 40 cells, each measuring 10 inches by 10 inches (25.4 cm × 25.4 cm). Each pattern requires making eight unique steps across two rows; the sequence of eight steps repeats five times, for a total of 40 steps over 10 rows. Participants were instructed to execute each pattern as fast as possible. Each trial was timed using a digital stopwatch. Figure 1 illustrates the three patterns used in this experiment.

Procedure

Participants were allocated randomly to either the optimized group (*n* = 15: 12 women and three men) or the control group (*n* = 15: 12 women and three men). Before the experimenter demonstrated the patterns, each participant was initially presented with the pattern on paper and asked to memorize it (Fig. 1). Then, participants were allowed to physically reproduce the demonstrated pattern to familiarize themselves with the task. They were asked to execute the pattern as fast as possible. If participants mistakenly stepped into a wrong square, they were asked to rectify the error and proceed. Next, each participant completed four trials in a pretest. Subsequently, participants completed the practice phase, which consisted of three blocks of four trials. The instructions for these three blocks were contingent upon the group. In the optimized group, participants practiced under one of six possible randomly assigned orders (i.e. EE-AS-EF, EE-EF-AS, AS-EE-EF, AS-EF-EE, EF-EE-AS, or EF-AS-EE). Under the AS condition, participants could choose the mat color (green, red, or blue). All of the other blocks had a white mat. Control group participants were provided with the mat of the same color as selected by

Fig. 1



(a and b) The patterns presented during the pretest, practice phase, and retention test. (c) The pattern presented to all participants in the transfer test. The sequence began with alternating steps from right to left through cells 1–8. The same sequence was repeated five times to complete each trial.

their optimized group counterpart of the same sex. In the EE condition, participants received quantitative feedback on their three best (i.e. fastest) trials in that block. Feedback was written on a paper and presented to them at the end of the EE block (e.g. they would have received the following feedback: trial 1: 04:52 min:s, trial 4: 3:41 min:s, and trial 3: 2:30 min:s). In the EF condition, participants were instructed to 'concentrate on the squares and stay inside them'. Between blocks, participants were provided 1–3-min breaks. After the practice phase, we asked the participants to complete the questionnaires, which included the Intrinsic Motivation Inventory (IMI), the Positive Affect subscale of Positive and Negative Affect Schedule (PANAS), conscious motor processing (CMP), and the Rating Scale Mental Effort (RSMF). Twenty-four hours following the practice phase, all participants completed retention (i.e. practiced patterns) and transfer (i.e. a new pattern) tests of learning, each consisting of four trials on a white mat (see Fig. 1). No instructions or feedback were provided on these tests.

Primary measure

The total movement time to complete the 40 steps of a trial of the task was measured using a stopwatch. The

Table 2 Detailed statistical results are provided for the primary measures across the pretest, practice blocks, retention test, and transfer test

Phase	Test	F (df$_1$, df$_2$)	P-value	η_p^2
Pretest	Group comparison	$F(1, 28) = 0.007$	0.934	0.00
Practice blocks	Main effect of group	$F(1, 28) = 34.61$	<0.0001	0.55
	Main effect of practice block	$F(1.52, 42.63) = 22.76$	<0.0001	0.91
	Interaction of block and group	$F(1.52, 42.63) = 22.76$	<0.0001	0.45
Retention test	Group comparison	$F(1, 28) = 376.18$	<0.0001	0.93
Transfer test	Group comparison	$F(1, 28) = 51.20$	<0.0001	0.65

task time was measured from the moment the participant's foot touched the initial square and stopped when their foot reached the end of the mat. The time of each block was obtained from the average time of four trials.

Secondary measures: motivational/psychological measures

Intrinsic motivation was assessed with the IMI [16], which is commonly used in neurological rehabilitation [17,18]. All scales demonstrated acceptable internal consistency in this study (see Table 2).

We used the short form of the PANAS to gauge participants' emotional states after the practice phase [19].

To assess the extent of conscious processing during the task performance, we used the CMP subscale of the Movement Specific Reinvestment Scale [20].

The RSME [21] was used to assess an individual's subjective experience of mental exertion during task performance.

Statistical analyses

Movement time was averaged across four trials per block. We used separate one-way ANOVAs to evaluate the differences in movement time between the two groups during the pretest, retention, and transfer tests.

To analyze the changes during task practice, we conducted a 2 (group) × 3 (block) factorial ANOVA with repeated measures on the last factor. Partial eta squared (η_p^2) was employed to estimate effect size in ANOVAs, where $\eta_p^2 = 0.01$, 0.06, and 0.14 were estimates for small, moderate, and large effect sizes, respectively [22].

We employed separate one-way ANOVAs to assess the differences between groups across the motivational/psychological measures (i.e. IMI, PANAS, CMP, and RSMF) and IMI subscales.

Results

Participant characteristics

Table 1 presents the descriptive data for the optimized and control groups. There was no significant difference between both groups in age, height, weight, duration of MS, and EDSS (F_s (1, 28) ≤ 1.37, P ≥ 0.18).

Primary measure: movement time

In the pretest, no significant difference in movement time was observed between the optimized group [mean (M) = 291.4 s, SD = 41.5] and the control group (M = 292.2 s, SD = 41.6) (see Table 1 and Fig. 2, left).

Figure 2 (middle) displays the movement times (in seconds) for both the optimized and control groups across practice blocks. Although movement times decreased in both groups throughout practice, the optimized group (M = 174.7 s, SD = 27.4) showed a greater reduction than the control group (M = 236.8 s, SD = 35.8). Mauchly's test indicated a violation of sphericity for the main effect of the practice block, $\chi^2(2) = 10.16$, $P = 0.006$. Therefore, Greenhouse-Geisser corrections ($\varepsilon = 0.76$) were applied to adjust the degrees of freedom for effects related to the practice block. The interaction between the practice block and group was significant ($P < 0.0001$), as were the main effects of both the practice block and group (see Table 1) ($P < 0.0001$).

On the retention test, the optimized group (M = 69.3 s, SD = 9.3) had significantly shorter movement times compared with the control group (M = 159.7 s, SD = 15.5) ($P < 0.0001$). Similarly, on the transfer test, the optimized group (M = 146.1 s, SD = 14.9) performed significantly faster than the control group (M = 223.1 s, SD = 38.9) ($P < 0.0001$). These findings are illustrated in the right panels of Fig. 2 and detailed in Table 1.

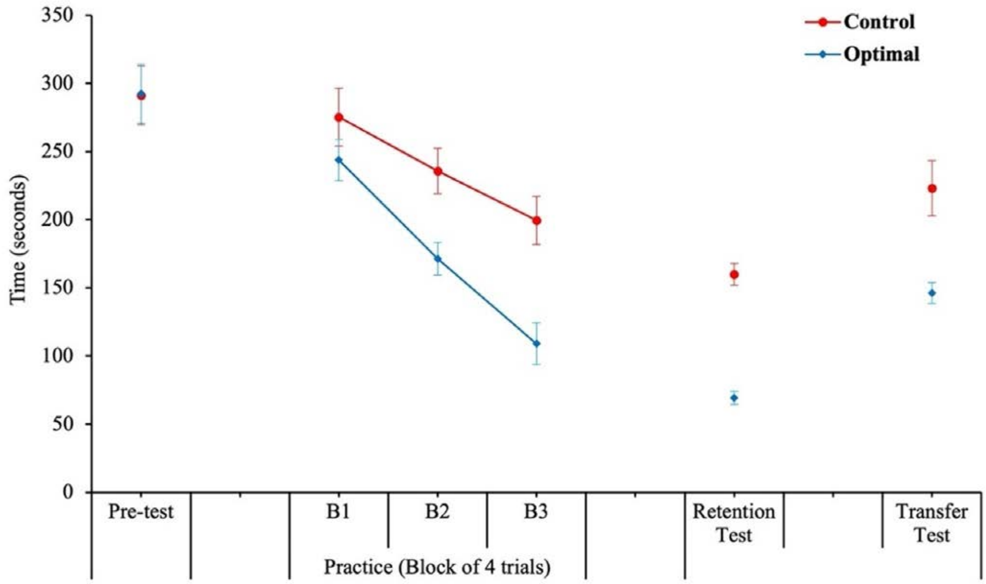
Secondary measures: motivational/psychological factors

There were significant group differences in IMI, PANAS, CMP, RSMF, and IMI subscales after the practice phase. The optimized group reported higher levels of intrinsic motivation, as well as positive affect, compared to the control. Additionally, the optimized group showed lower levels of CMP and mental effort after the practice phase (see Table 3).

Discussion

OPTIMAL theory-based application of the three motivational and attentional factors (i.e. AS, EE, and EF) provided in combination, to a challenging motor-cognitive activity (i.e. the memorized square-stepping task) in PwMS resulted in improved movement performance compared with the same activity performed without these situational enhancements. These performance gains were sustained in retention and transfer tests conducted 1 day later. Moreover, participants in the optimized condition reported more positive motivational and attentional experiences, aligned with the applied interventions. Such experiential enhancements may hold significance as patient-centered outcomes, complementing performance benefits.

Fig. 2



Task time of the optimized and control groups during the pretest, practice phase, retention, and transfer tests as a function of blocks of four trials. The statistical results are provided in Table 1. Error bars represent ±2 SE.

Table 3 Motivational characteristics and psychological variables for the optimized and control groups after the practice phase

	Cronbach's alpha	Groups	*N*	Mean	SD	*F* (1, 28)	*P*-value	η_p^2
Intrinsic Motivation Inventory	0.86	Control	15	2.43	0.23	308.64	<0.0001	0.92
		Optimized	15	3.91	0.23			
Interest/enjoyment	0.89	Control	15	2.20	0.33	243.71	<0.0001	0.90
		Optimized	15	4.30	0.4			
Perceived competence	0.86	Control	15	2.07	0.55	79.41	<0.0001	0.74
		Optimized	15	4.09	0.68			
Value/usefulness	0.96	Control	15	2.00	0.64	152.04	<0.0001	0.84
		Optimized	15	4.64	0.53			
Pressure/tension	0.70	Control	15	3.47	0.69	25.69	<0.0001	0.48
		Optimized	15	2.17	0.71			
Perceived choice	0.88	Control	15	2.13	0.52	361.29	<0.0001	0.93
		Optimized	15	4.80	0.17			
Positive Affect Schedule–Short Form	0.89	Control	15	2.24	0.64	94.67	<0.0001	0.77
		Optimized	15	4.12	0.38			
Conscious motor processing	0.86	Control	15	3.39	0.82	20.06	0.0001	0.42
		Optimized	15	2.27	0.52			
Rating Scale Mental Effort	–	Control	15	94.00	33.97	6.65	0.015	0.19
		Optimized	15	65.33	26.42			

Cronbach's alpha refers to internal consistency.

One or more of the three optimizing factors (AS, EE, and an EF of attention) has been associated with motor performance and learning advantages across diverse clinical populations or conditions, such as MS [9], Parkinson's disease [14], stroke [23,24], apraxia of speech [25], Down's syndrome [26], ligament repairs [27], and cancer-chemotherapy [28].

To date, few studies in healthy or nonclinical populations have utilized all three factors, finding (fully) optimized conditions or groups to perform better than those without optimization [4–6,29] or with fewer OPTIMAL factors deployed [30]. The present study findings indicate that the three-factor optimization effect extends to a clinical population, PwMS.

What does it mean that the motor performance and learning of PwMS can be enhanced through provision of situational features (optimizing conditions of practice)? Motor performance is a function, presumably, not only of the current status of the central and peripheral motor system (damage, constraints, and affordances) but also of the context and conditions under which motor performance is attempted, including the contributions of the performer's mind and body and of the therapy climate created by the clinician. Optimizing conditions would appear to have the potential to nudge the nervous system into better states for performance, learning, and neuroplasticity despite initial conditions [31]. Contributions from AS, EE, and an external attentional focus are considered to influence the brain's capacity for dynamic effective connectivity or goal-action coupling [3] through reward-dopamine relationships and clarity of goals. Multiple sclerosis has many manifestations, some of which are familiar to those with other chronic conditions or to performers affected by transitory circumstances; commonalities can include brain connectivity-affecting catastrophizing thoughts and negative appraisals, as well as anxiety and depression [32]. Moments of positive or negative appraisal of capability or decline can affect daily decisions, which may become patterns of behavior that help or hurt continued participation and engagement in active and meaningful activities.

Implications for clinical practice

What might this proof-of-concept OPTIMAL demonstration mean for rehabilitation practice? Certainly, clinical assessments taking into account the OPTIMAL framework (e.g. attention- and expectancy-enhancing statements, minor choices such as in the order of performed elements) provide opportunities to uncover latent motor capabilities that typically administered clinical tests may underplay. For example, the same clinical assessment of static balance capability (the Balance Error Scoring System) administered under 'optimized' versus standard (neutral) instructions to the same participants, resulted in maximal balance performance that was 16% better under the optimized than neutral condition for the same participants [29]. Rehabilitation can entail multiple interventions directed at varied health and functional targets. Optimized conditions could be developed to enhance the effectiveness of many therapeutic interventions [33,34]. To date, research on clinical interventions of OPTIMAL theory has typically been limited to single factors (e.g. attentional focus) and particular outcomes [such as gait or balance [9]], thus not taking advantage of the apparently additive effects, or to case studies in which multiple factors are employed [25]. A randomized trial in stroke rehabilitation for arm recovery [24] featured both motivational factors of OPTIMAL primarily, with limited focus on the external attentional element, and that trial was designed to address paretic arm rehabilitation, rather than multiple outcomes for stroke survivors such as those involving mobility and cognition. Mechanisms to continue instantiating optimal conditions, such as longer-term intermittent clinical supports or patient instruction in self-directed approaches, may be required to generate longer-term impacts of these conditions.

Turning relatively short-term demonstrations of positive performance and learning effects into multiple rehabilitation sessions aimed at multifaceted therapeutic outcomes is something innovative clinicians are already attempting. More extensive formal evaluations of these impacts, and over the longer term, are warranted.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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