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REVIEW

Behavioral self-management strategies for practice and exercise should be included in neurologic rehabilitation trials and care

Bruce H. Dobkin

Purpose of review
Rehabilitation trials and postacute care to lessen impairments and disability after stroke, spinal cord injury, and traumatic brain injury almost never include training to promote long-term self-management of skills practice, strengthening and fitness. Without behavioral training to develop self-efficacy, clinical trials, and home-based therapy may fail to show robust results.

Recent findings
Behavioral theories about self-management and self-efficacy for physical activity have been successfully incorporated into interventions for chronic diseases, but rarely for neurologic rehabilitation. The elements of behavioral training include education about the effects of practice and exercise that are relevant to the person, goal setting, identification of possible barriers, problem solving, feedback about performance, tailored instruction, decision making, and ongoing personal or social support. Mobile health and telerehabilitation technologies offer new ways to remotely enable such training by monitoring activity from wearable wireless sensors and instrumented exercise devices to allow real-world feedback, goal setting, and instruction.

Summary
Motivation, sense of responsibility, and confidence to practice and exercise in the home can be trained to increase adherence to skills practice and exercise both during and after formal rehabilitation. To optimize motor learning and improve long-term outcomes, self-management training should be an explicit component of rehabilitation care and clinical trials.

Keywords
exercise, mHealth, self-efficacy, stroke rehabilitation, wearable sensors

INTRODUCTION

Experimental models and clinical trials of stroke and traumatic brain and spinal cord injury strongly point to the motor learning-related neural adaptions induced by task-related practice of progressive difficulty at a high enough dose to drive goal-directed gains, especially early, but also at any time after injury [1,2,3▪]. Aerobic and resistance exercise also induce neuroplasticity by modulation of similar molecular, cellular, synaptic and genetic adaptations. Thus, efforts to increase walking and affected upper extremity practice, as well as exercise for fitness and strengthening during and beyond the time of formal rehabilitation have a compelling theoretical basis. The results of clinical trials built upon present concepts of motor learning, however, have been less than robust, in part because of their design [4]. One contributing cause may be the lack of home and community practice and exercise to supplement the modest intensity of usual formal training. Another is that little emphasis has been placed on providing timely behavioral training that can lead to self-directed practice and exercise, such as feedback about the quality and quantity of practice, as well as personalized communication to increase motivation, sense of competence,

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KEY POINTS

- After stroke and brain and spinal cord injury, disabled persons often do not practice task-related motor activities, and exercise for strengthening and fitness at home, which may limit the potential effects of rehabilitation interventions during clinical trials and outpatient care.
- Behavioral training in self-management techniques may increase the amount of skills practice and exercise both in between formal therapy sessions and beyond the time of therapist-assisted rehabilitation.
- The most important strategies to train self-efficacy include providing information on the consequences of action/inaction and the links between behavior and health, feedback about performance, instruction to help set and meet goals, frequent review of behavioral goals that the participant has helped set, and follow-up prompts.
- Mobile health applications, wearable wireless motion and other physiologic sensors, and Internet or telephone communication can enable a therapist to remotely monitor adherence, gather daily practice data for feedback and assessment of goal attainment, and obtain continuous outcomes measurements over time.

expectations about positive gains and outcomes, and attention to the learning task [5]. We examine recent work about the potential to augment the efficacy and effectiveness of motor interventions by adding behavioral training to daily care and trial designs.

LOW LEVELS OF PHYSICAL ACTIVITY

Persons who need inpatient stroke rehabilitation do little walking 6–12 months later [6]. Indeed, across 26 studies, hemiparetic persons who could walk in the community took less than half the number of steps as the age-matched norm [7]. In a large longitudinal study, stroke survivors were sedentary 81% of the day at 1, 6 and 12 months after stroke and more so as impairment increased [8,9]. Total sedentary time has emerged as a risk factor for mortality and stroke independent of the amount of physical activity [10]. Reasons for limited exercise, as well as little skills practice, include a lack of first, awareness that this is feasible or desirable, as well as no life-long habit and self-efficacy for routine exercise, second, access to resources that support goal-oriented practice, and third, structured sessions and advice beyond the time of formal rehabilitation that take into account how impairments pose limitations [9]. Indeed, patients often express the sense that they do not know how to exercise safely or how to progress an activity when they are not working directly with a therapist [11]. In addition, rehabilitation services for most newly and chronically disabled persons are usually not driven by the goal of highly functional walking in the community to lessen deconditioning.

ELEMENTS OF SELF-MANAGEMENT AND SELF-EFFICACY

Behavioral change interventions to increase practice and exercise may be suggested during formal rehabilitation, but a 2012 Australian national stroke audit found that only 25% of stroke survivors were informed about elements of a self-management programme [12]. Programmes to encourage the postbrain or spinal cord injury habit of practice and exercise are restrained by many factors, including the burden of new disability on patients and caregivers, time and reimbursement constraints on therapists, limited capacity to remotely measure and intervene on behavior, and poor adherence to minimalist programmes. In the most recent guideline for stroke rehabilitation from the American Heart/Stroke Association, a concensus group called for an emphasis on the important process of fostering exercise self-efficacy and self-monitoring [3▪]. In addition to practice and fitness after new disability, patients and families must manage many other health-related behaviors, such as medications, finances, mood, psychosocial stressors, and barriers in daily life. All require an assessment of readiness for change and ways to tailor management for positive behaviors. One theoretical construct for multiple behavioral changes suggests five stages: precontemplation (no information about consequences of not changing), contemplation (intent at some point but ambivalent), preparation (setting targets for action), action (specific efforts that usually require support), and maintenance (to prevent relapse especially beyond 6 months) [13]. Such diverse new responsibilities require significant support.

Self-management reflects a person's responsibility for the daily conduct of healthy behaviors that may mitigate a disease or disability. Self-efficacy, the confidence in one's capabilities to develop and meet planned goals, increases as self-management proceeds successfully. The central concept in Bandura's self-efficacy theory that has held sway for almost four decades is that belief in one's ability to succeed in a new pursuit strongly contributes to taking up the behavior and achieving important outcomes [14]. Sources of self-efficacy include positive mastery experiences of tasks, vicarious experiences in seeing others succeed, verbal persuasion, and physiological and emotional feedback about success [15]. Social-cognitive-psychological theories of motivation suggest that perceptions of self-determination, such as choice, control, self-monitoring, and collaboration, may lead to sustained efforts to improve skills, exercise and conditioning [16].

Necessary competencies that often require professional assistance include [17] the following:

(1) Problem solving (e.g., What is to be gained by exercise and practice? Can a friend or spouse assist me?). Flexible coping strategies include: define the problem and goal; generate multiple solutions; select a solution; and implement and evaluate.
(2) Decision making (e.g., How do I start to exercise or practice to use my hand better? How do I know how much to do? How do I know if I am doing this correctly?).
(3) Resource utilization (e.g., What home and community resources can help me find a place or advice for exercise and practice, especially after I have reached the limit of my insurance coverage?).
(4) Partnership with a healthcare provider (e.g., Do I only go to my doctors about my medical conditions or can they provide advice about lessening my disabilities? Can they help me make informed choices and give me instruction about exercise and practice?)
(5) Planning and taking action (e.g., Can I make a short-term, realistic plan to exercise, maybe just start with a daily walk for 10 min? How confident am I that I can set doable, but progressive goals and meet them?)
(6) Self-tailoring goals and strategies to perceived needs (e.g., Do I understand what I need to do and why it is important? Can I adhere to the plan?)

Such competencies are especially difficult for the person who is physically and perhaps cognitively impaired and can no longer count on usual premorbid strategies. So how can a neurorehabilitation team help enable more practice and exercise in the home and community, especially during a clinical trial or beyond the time of formal therapy sessions?

METHODS FOR BEHAVIORAL MODIFICATION

Effective feedback can take simple forms to increase walking progress. In the international SIRROWS [18] trial during inpatient stroke rehabilitation, merely providing the walking speed to patients during a 10-min walk several times a week compared to no feedback led to a significant 22% increase in speed at discharge. But feedback without other support to build self-efficacy is not likely to sustain a training programme. Individualized counseling combined with tailored exercise programmes after stroke can improve long-term physical activity participation and functional exercise capacity [19]. Such personal counseling and goal setting, however, have usually been absent in mobility and upper extremity rehabilitation trials in home settings, unless a therapist or nurse visited [20–22]. When additional elements of behavioral training were included, the results have been informative. For example, in a large trial of repeated verbal instruction and encouragement about how to exercise, to try to get participants who could walk within 90 days after stroke to be more physically active, the results were no better than in the usual care control group [23]. The experimental intervention, however, was limited to a 60-min visit by a therapist at onset and follow-up visits for 30 min every 3 months for the first year and every 6 months in the second year. Other trials suggest that this frequency of contact is inadequate. Also, no feedback about performance was provided and the outcome measure was a self-report about activity. When asked about levels of activity, patients with chronic stroke often over-rate what they say they do [24], which limits the generalizability, reproducibility, and acceptance of self-reports [25].

A meta-analysis of walking interventions carried out in the home and community after stroke suggested that exercise combined with at least one behavioral technique was more effective than task-oriented exercise training alone [26]. The largest effect sizes were for the techniques of goal setting, barrier identification, and self-monitoring. So these should be given in an adequate frequency in a behavioral training programme. The LEAPS trial compared body weight-supported treadmill training (BWSTT) to a home exercise programme starting 2 months after stroke [6]. The hypothesis was that task-related practice by BWSTT would lead to better walking outcomes compared with no specific training for walking. A modest plan to address barriers was suggested by a question posed to all subjects, ‘What is limiting you from achieving your goal for walking?’ In addition, the control group’s personalized instruction about exercise and problem solving in the context of the home, compared with repetitive gait practice only in a clinic for the BWSTT group, may have contributed to the equivalence of the walking-related outcomes [27]. In another trial, home-based upper extremity constraint-induced movement therapy carried out by a family member with about 1 h of therapist instruction a week, compared with clinic-based conventional therapy, led to equivalent improvements after stroke [28▪]. Inadequately supervised home rehabilitation after stroke generally does not improve outcomes [29]. Neither trial, however, planned an examination of their implicit behavioral intervention techniques.

Although goal setting by patients is an important aspect of rehabilitation, goal-setting practices for and by disabled persons in the community are quite variable and probably suboptimal [30,31]. The attributes of well-set goals that correlate with high levels of achievement, as described by Locke *et al.* [32], are clarity about goals, level of challenge, commitment, feedback, modest task complexity, avoidance of conflict between individual goals, and setting attainable short-term goals. Aside from lack of training in behavioral techniques, a contributing factor to the usual inadequacy of what is employed is that the actual amount and quality of exercise and practice is not measured outside of a clinic session, so accurate feedback about performance is not available to make further plans, take action, and self-tailor goals. Indeed, in other disease settings, self-management education alone, without specific feedback about physical activity, tends to work no better than an attention control intervention [33].

SELF-MANAGEMENT STRATEGIES

Behavioral researchers in stroke recommend frequent, personalized information and reinforcement about how to achieve the targets of a practice or exercise intervention. Behavioral change strategies that lead to self-management require education, ongoing contact, tailored information, goal setting, monitoring, feedback, and motivational enhancement. Educational instruction, social supports, and knowledge of environmental barriers also support the practice of walking and healthier behaviors. To build self-efficacy and motivation, a rehabilitation programme must enable incremental successes, use a personalized problem-solving focus to manage confounders and challenges, communicate messages that aim to elicit improvements, and divide the larger task of achieving the major aims for exercise and activity into smaller, more readily accomplished stages [34]. Problem-solving therapy is a defined intervention that aims to increase structure and flexibility by using different coping strategies, depending on the situation. The technique led to better short-term task-specific coping after stroke than no specific intervention [35].

Many behavioral change techniques combine health-promoting interventions. A classification and regression tree method applied to meta-analytic data about a wide range of health-related behaviors searched for the combinations that provided the best synergy [36▪▪]. Table 1 includes the assessed techniques. The most powerful combination was to provide information on the consequences of action/inaction, provide information about the behavior – health link, and use follow-up prompts. Least successful was to provide feedback on performance, without the use of prompt review of behavioral goals, provide information on the consequences, and provide instruction. Thus, feedback alone tends to fail over the long term, but its combination with personalized education and instruction to attain defined interim goals seems especially relevant to achieve success in skills practice and exercise. The best strategies to provide these techniques to enhance practice, exercise, fitness, and participation are still a study in progress. Indeed, even the best type and frequency of feedback has not been established for training motor skills [5].

Table 1. Strategies to change behavior to support skills practice and strengthening and fitness exercising

Enhance motivation	Provide information about exercise-health links; provide information on consequences of action/inaction; prompt decision on intention or goal; prompt self-motivating statements and evaluation of behavior
Planning and preparation	Prompt identification of barriers; set tasks of graded difficulty that are achievable; provide instruction on how to prepare or perform; demonstrate how to perform the task-related behavior; prompt specific goal setting for frequency, intensity, duration of an activity; sign a contract specifying behavioral goals and actions; share comparison performances and changes with peers; prompt opportunity to be a role model; make time for rehabilitation efforts within the daily schedule
Goal striving and persistence	Provide praise or reward for effort and performance; record and provide data for feedback; train to use prompts and environmental cues as reminders; prompt rehearsal; prompt review or reconsideration of set goals; enable self-monitoring and record behavior; provide verbal rewards contingent on achievements; provide follow up prompts well after training; prompt self-talk for encouragement and instruction; manage stress and anxiety

Adapted with permission [36▪▪].

BRAIN AND SELF-MANAGEMENT BEHAVIOR

Neural mechanisms of behavioral change are found in the activations of frontal cortex regions that process choice, cost-benefit, task difficulty and effort, juggle valuation, and anticipate reward and nonreward [37]. Of note, the relation between accomplishing regular physical activity and the cognitive control necessary to do so may be a reciprocal interaction [38▪▪]. Clinical trials suggest that better executive functioning is associated with greater adherence to a programme of exercise and, *vice versa*, that exercise itself improves executive functions such as planning and weighing alternative actions for self-efficacy [39,40]. Indeed, specific training of cognitive control abilities has the potential to improve self-regulation for physical activity [38▪▪]. Cognitive components that could be trained include planning, multitasking, response inhibition, and sequencing. On the other hand, impaired self-awareness, executive dysfunction, memory loss, and mood disorders can interfere with achieving self-efficacy for exercise. An analysis of five randomized trials of self-management programmes for physical activity after stroke and brain trauma found confounders in the designs that left uncertainty about whether this approach can work as well as in healthy persons [41▪▪]. As adults age, they also show decreases in executive functioning, which may limit the effectiveness of self-management training [42]. Thus, formal trials of self-management techniques that are nested within controlled rehabilitation trials for specific populations are necessary.

MOBILE HEALTH AND TELEREHABILITATION STRATEGIES

A rehabilitation therapist with expertise in both motor learning and behavioral self-management techniques is in the best position to develop a collaborative relationship with the patient and optimize the therapeutic alliance that enables adherence and patient-centered care [43]. But nonstandard supports are necessary as well, including mobile health (mHealth) and telerehabilitation technologies [44–47].

Behavioral training might be introduced during formal inpatient rehabilitation, then further developed during outpatient rehabilitation by remote monitoring and supervision through technologies. For example, we have deployed wearable wireless inertial sensors on the ankles that communicate with a smartphone, along with embedding sensors and Bluetooth radio in devices used for strengthening and skills practice. The components gather the type, quantity and quality of these activities in the home and community using signal-processing algorithms. The therapist contacts a patient once a week to offer summary feedback from the daily measurements, particularly those that seem most meaningful to the person (e.g., length of bouts of activity, heart rate with exercise, periods of sedentary time, usual walking speed and distance per bout in the home and outdoors, gait cycle symmetry). The conversation emphasizes behavioral change techniques that include education about behavior-health links (e.g., risk factor management, neuroplasticity, cardiovascular fitness, greater independence), progressive goal setting that is incremental, instruction on ways to meet daily goals, adherence to convenient practice schedules, barrier identification, and self-monitoring [26,36▪▪]. Tailored counseling combined with remote data-driven supervision have been critical components to increase practice and exercise [19,48]. Of course, this overall motor and behavioral training strategy must be compared with conventional postrehabilitation care in randomized clinical trials for the goals of optimizing long-term activity and participation, skills practice, strengthening, and conditioning.

Online social networks and other smartphone and telerehabilitation features could be added that bolster participation by lessening physical, logistical, and geographical barriers faced by disabled persons [49,50]. Although thousands of commercial mobile phone applications aim to offer support and guidance for exercise and fitness, their persuasive design features [51] rely on a narrow and perhaps overly simplified range of self-management principles [52]. So far, few, if any, are applicable to disabled persons.

For remote-based delivery methods to increase physical activity without a trainer, far more advanced feedback and engagement strategies will be needed from the mHealth and behavioral research communities [53]. Perhaps smart Chatbots or a future-generation Siri armed with machine-learning methods will be able to supply more intelligent engagement and feedback for the disabled person. At present, a single therapist can remotely manage many patients via wireless sensors and the Internet to encourage self-efficacy for home-based practice and exercise. The ability of behavioral strategies combined with remote sensing tools to augment neurologic rehabilitation outcomes is just beginning to be tested.

CONCLUSION

Self-management training may support earlier home discharge after stroke, more daily practice at home during formal and postrehabilitation care and, for clinical trials, may increase compliance, augment outcomes by engaging participants beyond the time of formal practice, and enable posttrial carry over of training. Feedback from frequent interim measurements about progress, enabled by wireless wearable sensors and instrumented exercise devices, will reveal the difference between a goal and reality and enable a timely discussion and instruction about how to reduce the gap. But a fuller spectrum of behavioral techniques may need to be incorporated into trials and daily care in a standardized fashion if clinicians are to maximize self-efficacy for rehabilitation in order to further diminish the impairments and disabilities and increase the participation of disabled persons.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES AND RECOMMENDED READING

Papers of particular interest, published within the annual period of review, have been highlighted as:

■ of special interest
■■ of outstanding interest

1. Langhorne P, Bernhardt J, Kwakkel G. Stroke rehabilitation. Lancet 2011; 377:1693–1702.
2. Dobkin B, Carmichael S. The specific requirements of neural repair trials for stroke. Neurorehabil Neural Repair 2016; 30:470–478.
3. Winstein C, Stein J, Arena R, *et al.* Guidelines for adult stroke rehabilitation ■ and recovery. Stroke 2016; 47:e98–e169.

This overview of interventions places much greater emphasis on the need for self-management strategies compared with past consensus statements.

4. Dobkin B. A Rehabilitation Internet-of-Things (RIoT) in the home to augment motor skills and exercise training. Neurorehabil Neural Repair 2016. (in press).
5. Wulf G, Lewthwaite R. Optimizing performance through intrinsic motivation and attention for learning: the OPTIMAL theory of motor learning. Psychon Bull Rev 2016. [Epub ahead of print]
6. Duncan P, Sullivan K, Behrman A, *et al.* Body-weight-supported treadmill rehabilitation program after stroke. N Engl J Med 2011; 364:2026–2036.
7. English C, Manns P, Tucak C, Bernhardt J. Physical activity and sedentary behaviors in people with stroke living in the community: a systematic review. Phys Ther 2014; 94:185–196.
8. Tieges Z, Mead G, Allerhand M, *et al.* Sedentary behavior in the first year after stroke. Arch Phys Med Rehabil 2015; 96:15–23.
9. Billinger S, Arena R, Bernhardt J, *et al.* Physical activity and exercise recommendations for stroke survivors: a statement for healthcare professionals from the American Heart Association/American Stroke Association. Stroke 2014; 45:2532–2553.
10. Koster A, Caserotti P, Patel K, *et al.* Association of sedentary time with mortality independent of moderate to vigorous physical activity. PLoS ONE 2012; 7:e37696.
11. Saunders D, Greig C, Mead G. Physical activity and exercise after stroke: review of multiple meaningful benefits. Stroke 2014; 45:3742–3747.
12. National Stroke Foundation. National stroke audit – rehabilitation services report 2012 Melbourne, Australia. 2012.
13. Hall K, Rossi J. Meta-analytic examination of the strong and weak principles across 48 health behaviors. Prev Med 2008; 46:266–274.
14. Bandura A. Social cognitive theory: an agentic perspective. Annu Rev Psychol 2001; 52:1–26.
15. Jones F, Riazi A. Self-efficacy and self-management after stroke: a systematic review. Disabil Rehabil 2011; 33:797–810.
16. Winstein C, Kay D. Translating the science into practice: shaping rehabilitation practice to enhance recovery after brain damage. Prog Brain Res 2015; 218:331–360.
17. Lorig K, Holman H. Self-management: history, definition, outcomes, and mechanisms. Ann Behav Med 2003; 26:1–7.
18. Dobkin B, Plummer-D'Amato P, Elashoff R, *et al.* International randomized clinical trial, Stroke Inpatient Rehabilitation With Reinforcement of Walking Speed (SIRROWS) improves outcomes. Neurorehabil Neural Repair 2010; 24:235–242.
19. Morris J, MacGillivray S, Mcfarlane S. Interventions to promote long-term participation in physical activity after stroke: a systematic review. Arch Phys Med Rehabil 2014; 95:956–967.
20. Coupar F, Pllollock A, Legg L, *et al.* Home-based therapy programmes for upper limb functional recovery following stroke. Cochrane Database Syst Rev 2012; 5:CD006755.
21. Duncan P, Studenski S, Richards L, *et al.* Randomized clinical trial of therapeutic exercise in subacute stroke. Stroke 2003; 34:2173–2180.
22. Kwon I, Choi S, Mittman B, *et al.* Study protocol of ''Worth the Walk'': a randomized controlled trial of a stroke risk reduction walking intervention among racial/ethnic minority older adults with hypertension in community senior centers. BMC Neurol 2015; 15:91.
23. Boysen G, Krarup LH, Zeng X, *et al.* ExStroke Pilot Trial of the effect of repeated instructions to improve physical activity after ischaemic stroke: a multinational randomised controlled clinical trial. BMJ 2009; 339: b2810.
24. Resnick B, Shaughnessy M, Nahm ES, *et al.* Inflated perceptions of physical activity after stroke: pairing self-report with physiologic measures. J Phys Act Health 2008; 5:308–318.
25. Ammann B, Knols R, Baschung P, *et al.* Application of principles of exercise training in sub-acute and chronic stroke survivors: a systematic review. BMC Neurol 2014; 14:167.
26. Stretton C, Mudge S, Kayes N, McPherson K. Interventions to improve real-world walking after stroke: a systematic review and meta-analysis. Clin Rehabil 2016. [Epub ahead of print]
27. Nadeau S, Wu S, Dobkin B, *et al.* Effects of task-specific and impairment-based training compared with usual care on functional walking ability after inpatient stroke rehabilitation: LEAPS Trial. Neurorehabil Neural Repair 2013; 370–380.
28. Barzel A, Ketels G, Stark A, *et al.* Home-based constraint-induced move- ■ ment therapy for patients with upper limb dysfunction after stroke (HOME-CIMT): a cluster-randomised, controlled trial. Lancet Neurol 2015; 14:893–902.

Results were equivalent for home and clinic CIMT. Both groups probably benefited from techniques such as goal setting, barrier identification, and personal interactions, but the type and intensity of behavioral strategies were not defined.

29. Mayo N. Stroke rehabilitation at home. Stroke 2016; 47:1685–1691.
30. Scobbie L, Duncan E, Brady M, Wyke S. Goal setting practice in services delivering community-based stroke rehabilitation: a United Kingdom (UK) wide survey. Disabil Rehabil 2015; 37:1291–1298.
31. Sugavanam T, Mead G, Bulley C, *et al.* The effects and experiences of goal setting in stroke rehabilitation – a systematic review. Disabil Rehabil 2013; 35:177–190.
32. Locke E, Latham G, Smith K, Wood R. A theory of goal setting & task performance. Upper Saddle River, NJ: Prentice Hall College Division; 1990.
33. Self-management education programmes for osteoarthritis. Cochrane Database Syst Rev 2014; 1:CD008963.
34. Smith J, Forster A, House A, *et al.* Information provision for stroke patients and their caregivers. Cochrane Database Syst Rev 2008; (2):CD001919.
35. Visser M, Heijenbrok-Kal M, van't Spijker A, *et al.* Problem-Solving Therapy during outpatient stroke rehabilitation improves coping and Health-Related Quality of Life. Stroke 2016; 47:135–142.
36. Dusseldorp E, Van Buuren S, Van Genugten L, *et al.* Combinations of ■■ techniques that effectively change health behavior: evidence from meta-CART analysis. Health Psychol 2014; 33:1530–1540.

This analysis of 122 trials of theory-based behavioral change techniques for exercise and diet found preferable combinations that led to greater success of the interventions. The context of the application of such techniques and other mediators such as attitude, self-efficacy and skill will interact with these strategies.

37. Kolling N, Behrens T, Wittman M, Rushworth M. Multiple signals in anterior cingulate cortex. Curr Opin Neurobiol 2016; 37:36–43.

38. Buckley J, Cohen J, Kramer A, *et al.* Cognitive control in the self-regulation of
■■ physical activity and sedentary behavior. Front Hum Neurosci 2014; 8:1–15.

On the basis of controlled trials of exercise in older persons, structural and functional imaging and behavioral outcomes suggest a strong interaction between better executive function and self-efficacy for exercise and *vice versa*.

39. Moore S, Hallsworth K, Jakovljevic D, *et al.* Effects of community exercise therapy on metabolic, brain, physical, and cognitive function following stroke: a randomized controlled pilot trial. Neurorehabil Neural Repair 2015; 29:623–635.

40. Best J, Nagamatsu L, Liu-Ambrose T. Improvements to executive function during exercise training predict maintenance of physical activity over the following year. Front Human Neurosci 2014; 8:353.

41. Jones T, Dean C, Hush J, *et al.* A systematic review of the efficacy of self-
■■ management programs for increasing physical activity in community-dwelling adults with acquired brain injury. Syst Rev 2015; 4:51.

Only five randomized controlled trials through 2012 that met most PRISMA criteria were found that included at least one of the following self-management components: problem-solving, goal-setting, decision-making, self-monitoring, coping strategies, or another approach to facilitate behavior change with at least one programme goal focusing on increasing physical activity and outcomes measured by a self-report of activity or self-efficacy or by an accelerometer step counter. Criteria for success were uncertain for both face-to-face and telephone reinforcement.

42. French D, Olander E, Chisolm A, McSharry J. Which behaviour change techniques are most effective at increasing older adults' self-efficacy and physical activity behaviour? A systematic review. Ann Behav Med 2014; 48:225–234.

43. Jesus T, Silva I. Toward an evidence-based patient-provider communication in rehabilitation: linking communication elements to better rehabilitation outcomes. Clin Rehabil 2016; 30:315–328.

44. Dobkin B. Wearable motion sensors to continuously measure real-world activities. Curr Opin Neurol 2013; 26:602–608.

45. Dobkin B, Dorsch A. The promise of mHealth: daily activity monitoring and outcome assessments by wearable sensors. Neurorehabil Neural Repair 2011; 25:788–798.

46. Dorsch A, Thomas S, Xu X, *et al.* SIRRACT: an international randomized clinical trial of activity feedback during inpatient stroke rehabilitation enabled by wireless sensing. Neurorehabil Neural Repair 2015; 29:407–415.

47. Mohr D, Schueller S, Montague E, *et al.* The behavioral intervention technology model: an integrated conceptual and technological framework for eHealth and mHealth interventions. J Med Internet Res 2014; 16: e146.

48. Clanchy K, Tweedy S, Trost S. Evaluation of a physical activity intervention for adults with brain impairment: a controlled clinical trial. Neurorehabil Neural Repair 2016. [Epub ahead of print]

49. Lorig K, Ritter P, Laurent D, Plant K. Internet-based chronic disease self-management: a randomized trial. Med Care 2006; 44:964–971.

50. Lorig K, Ritter P, Plant K, *et al.* The South Australia health chronic disease self-management internet trial. Health Educ Behav 2013; 40:67–77.

51. Matthews J, Win K, Oinas-Kukkonen H, Freeman M. Persuasive technology in mobile applications promoting physical activity: a systematic review. J Med Syst 2016; 40:72.

52. Pagoto S, Bennett G. How behavioral science can advance digital health. Transl Behav Med 2013; 3:271–276.

53. Foster C, Richards J, Thorogood M, Hillsdon M. Remote and web 2.0 interventions for promoting physical activity. Cochrane Database Syst Rev 2013; 9:CD010395.