Exercise Interventions to Improve Cognitive Performance in Older Adults – Potential Psychological Mediators to Explain Variation in Findings

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Abstract

Evidence suggests that exercise interventions can improve cognitive performance in older adults and prevent dementia. However, there are inconsistent results across studies. Exercise interventions vary greatly in terms of their environment and specific features. As a consequence, the different types of social interaction, mental engagement and feedback alter the psychological impact of the exercise. In this article, mediating relationships are discussed in terms of the impact that psychological factors related to exercise can have on cognitive performance. The probable psychological mediators discussed here include self-efficacy, attitudes and self-perceptions of ageing, perceived control manifesting in a self-fulfilling prophecy, causal attributions of memory problems and mood. The mechanisms of these mediating relationships are unclear and further research is needed to investigate them. In addition, the magnitude of the effect of psychological mediators and their relative contribution compared with physiological mechanisms in this context should be further investigated.

Keywords

Cognitive performance, exercise intervention, older adults, attitudes to ageing, self-perceptions, self-efficacy, perceived control, exercise environment, memory problems

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Dementia is characterised by severe cognitive deficiencies that impact on functional activities of daily life.[1] With an ageing population, the risk of dementia increases,[2] which is a main cause of disability in later life, more so than some cancers, stroke and cardiovascular disease.[3] Dementia is a worldwide problem. In the UK in 2010, there were estimated to be over 820,000 elderly afflicted with late-onset dementia.[4] This is expected to rise to one million by 2025 and to exceed 1.7 million by 2051.[5] The economic costs of dementia in the UK are estimated to be £23 billion per year (approximately twice as much as cancer).[4]

No cure for dementia is currently available; prevention is key to reducing risk. The nature–nurture debate can be used to illustrate the factors that explain individuals' risk of developing dementia. Dementia risk cannot be entirely explained by genetics: the apolipoprotein E (APOE)-4 allele has been recognised as a risk factor for Alzheimer disease and also for a younger age of onset;[6,7] however, not all individuals who have this allele develop dementia and not all individuals who develop dementia have this allele.[8] Therefore, environmental factors are implicated for their contribution to dementia risk. These include demographic factors[9] such as education, occupation and socioeconomic status, as well as lifestyle factors including diet,[10] smoking,[11] social engagement[12] and physical activity.[13]

Modifiable risk factors for dementia overlap with those for cardiovascular disease.[14] The evidence showing that exercise improves cardiovascular health is well documented.[15] Due to the overlap in risk factors, the scope for physical exercise to improve cognitive performance – with the aim of delaying the onset of dementia – has been widely investigated. A recent review reported that many studies demonstrate that physical exercise can help to maintain cognitive abilities into old age, but not all treatment studies found positive effects.[13] It was further reported that exercise may be more effective if carried out in midlife at the latest to prevent dementia in later life. However, once individuals have developed dementia, some cognitive improvement can still be seen through physical exercise.

Some investigated direct physiological mechanisms for improving cognitive performance through exercise include: encouraging neurogenesis and neurotrophins,[16–18] a reduction in blood lipids,[19] lowering of blood pressure[19] and improved vascular output and cerebral perfusion.[20] The effects of these direct mechanisms are unclear; both acute and longer-term effects of exercise on cognitive improvement have been reported, but there are wide variations in results across studies, with many not finding any effects.[13]

Psychological Mediators

The inconsistent results across exercise interventions designed to improve cognitive performance despite the large number of high-quality trials suggests that they may be explained by differences in the specific features of the interventions. Exercise does not occur independently of its environment, thus it is important

Figure 1: Model of the Proposed Psychological Interactions Brought About by Differences in the Specific Features of an Exercise Intervention

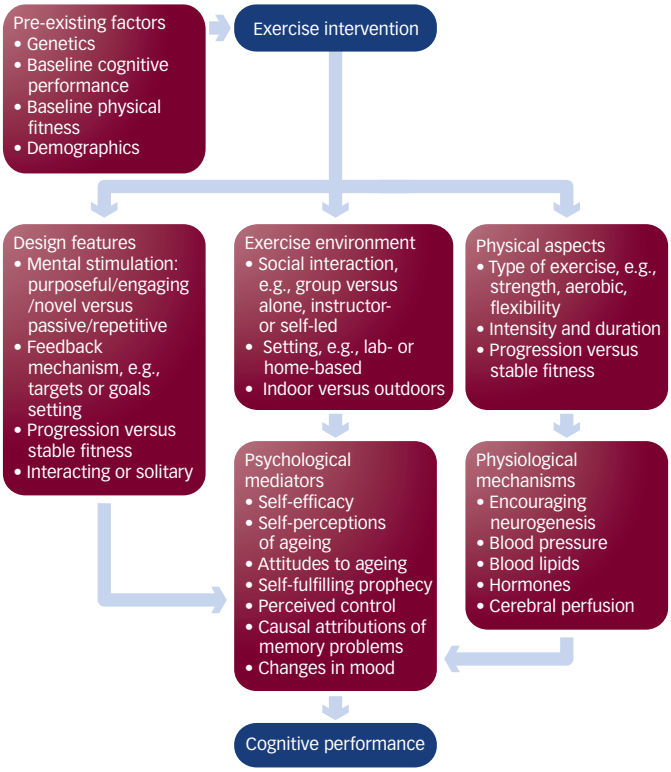
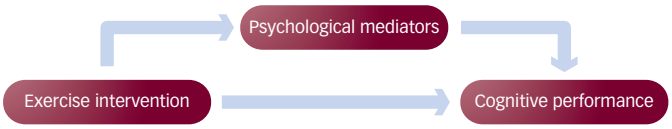


Figure 2: Proposed Mediating Relationship of Psychological Variables in an Exercise Intervention Designed to Improve Cognitive Performance



to consider the interactions between an individual and their environment, as there may be emergent mechanisms that are not captured when this complex relationship is reduced to the internal physiological mechanisms.

Specific features of exercise interventions vary greatly (see *Figure 1*), for example:

- the exercise environment – whether the exercise was carried out indoors or outdoors, in a lab/institution setting or in the community/at home;
- social interaction – whether exercise was carried out in a group or alone, supervised, instructor- or self-led;
- mental engagement – was the exercise mentally passive or novel, stimulating and requiring mental effort?;
- exercise prescription – type of exercise, was there a set intensity and duration?;
- was the exercise purposeful – were there targets and goals set, were there feedback mechanisms to show progress and improved fitness or strength?; and
- were there opportunities for improving self-efficacy using peer comparison or through mastery experiences and achieving goals?

The huge variations of these specific features across exercise interventions would impact differently physiologically and psychologically on participants. Even if the type of exercise was the same, the psychological impact could be markedly different. For example, the experience of an exercise intervention which involved walking on a treadmill in a lab while being observed compared with walking in a group in a local park would involve similar physical movements, but the psychological experience would differ greatly.

It has been suggested that the type of exercise is related to the effectiveness of the intervention, where an improvement in VO_2 max, strength and lung function could be necessary to lead to cognitive improvement.[13] Aerobic exercise interventions have more consistently demonstrated cognitive performance improvements compared with other types of exercise. Additionally, interventions that did not aim to improve aerobic fitness, but rather focused on improving strength, also demonstrated cognitive performance gains. However, this evidence is limited due to the smaller number of studies conducted. Additionally, improvements in VO_2 max did not always correlate with cognitive improvements,[21] suggesting that improving aerobic fitness alone is not sufficient to bring about such changes and that there are other mechanisms involved.

A mediating relationship may emerge due to the psychological impact of the exercise intervention and the subsequent impact of this on cognitive performance (see *Figure 2*). In non-exercise-related observational and intervention studies, positive attitudes to ageing,[22] positive self-perceptions,[23,24] better mood,[25] social engagement[26] and mental stimulation[27] have all been associated with improvements in cognitive functioning, better health and longevity. It may be that the exercise intervention studies that show a larger improvement in cognitive functioning do so because the exercise acts as a vehicle to improving these psychological factors, resulting in a combined impact due to the participants benefiting physiologically (mechanisms mentioned above) as well as psychologically from the exercise.

Figure 1 illustrates the potential mechanisms of these variables during an exercise intervention. The mechanisms of this potentially mediating relationship are further discussed in this paper.

Increases in Self-efficacy

Exercise interventions may act as a vehicle to improve self-efficacy through mastery experiences and peer comparisons if the design and features of the exercise environment allow it. Self-efficacy or beliefs can enhance or hinder cognitive performance through a variety of processes, including motivational, affective and meta-cognitive aspects.[28] Albert Bandura coined the term 'self-efficacy' as "the belief in one's capabilities to organize and execute the courses of action required to manage prospective situations".[29] He implicated self-efficacy as a precursor to other cognitions[30] and therefore as a determinant of how people think, behave and feel. He also posed that the most effective way to develop a strong sense of self-efficacy is through mastery experiences.

One study in Clifford and colleagues' review[13] assessed self-efficacy. However, they only investigated this in the domain of physical self-efficacy, rather than self-efficacy for cognitive performance.[31] Utilising self-report measures, they found that, on average, participants in both high- and low-intensity strength training groups improved their physical self-efficacy similarly, while the control

group did not. They used a social cognitive perspective to offer an explanation, whereby the experience of mastery associated with participation in a regular strength training programme resulted in enhanced perceptions of physical self-efficacy.[30] Furthermore, they suggested two principal mechanisms by which self-efficacy could be enhanced by exercise:[32]

- individuals alter their perceptions of their physical competence by comparing their current performance to past performance as well as performance of their peers; and
- internal feedback from exercise-induced sensations improved self-efficacy (e.g., 'I do not have to put as much effort in to lift this weight as I used to' or 'I do not feel as out-of-breath after walking that distance'), rather than positive feedback from others.

The scope for individuals to compare their physical performance to past performance depends on the type of exercise undertaken and on whether it allows the perception of progression; for example, increases in weights or reps for strength training, or speed or time taken to walk or jog a certain distance. Additionally, whether exercise is undertaken in a class or alone will determine whether participants can compare their performance or progression to that of their peers. Another mechanism through which self-efficacy could be enhanced is through positive feedback from others, which could include peers in an exercise group, exercise instructors or experimenters. These potential mechanisms highlight the importance of a controlled study design and the potential impact that social interaction could have on self-efficacy and consequent cognitive performance.

The majority of the interventions in the Clifford et al. review[13] did not require participants to explicitly set individual goals. However, most provided some level of feedback which individuals may have utilised to set goals for themselves. Not controlling for potential-enhanced self-efficacy gains (either through the study design by giving and/or restricting feedback or statistically from self-report measures) makes it difficult to infer whether a mediating interaction is present or whether the effects of the exercise on cognitive performance improvements are occurring independently of improvements in self-efficacy or other psychological mechanisms. Enhancing self-efficacy may also play a role in improving motivation, effort exerted, adherence and dropout rates for exercise interventions and perhaps for promoting long-term effects and behaviour change; it should therefore not be neglected in investigations.

The degree to which self-efficacy is transferable across domains has been debated. Evidence suggests that domain-specific self-efficacy may not be transferable to a general measure of self-efficacy but may be transferable to another domain.[33] This was demonstrated as a result of a self-defence class for women whereby improvements in physical self-efficacy and beliefs about their ability to protect themselves influenced other domains of self-efficacy that were not targeted during the training and were also unrelated – e.g., self-efficacy of interpersonal coping skills.[33] Their results also illustrated the lack of sensitivity of a general self-efficacy measure compared with their multidomain questionnaire to identify changes in beliefs and self-perceptions resulting from a novel and social intervention. Their multidomain questionnaire was contextualised, as it assessed self-efficacy in a variety of activity domains including academic achievement, assertiveness, conscientiousness, sports and interpersonal coping skills. This is different to a general self-efficacy measure, which assesses general beliefs about oneself, for example, whether you believe that you are a generally competent person.

In the context of this paper, a mechanism through which self-efficacy beliefs could transfer from the physical to the cognitive performance domain as a result of improvements during exercise interventions could be through challenging individuals' self-perceptions of ageing, thus challenging what they believe they are capable of despite their advancing age. It is these core beliefs and self-perceptions of ageing that could be affected, thus individuals' perceived control over their functional health and whether they believe their decline is evitable. If individuals believe they have some control over their future health, and their ability to maintain it as they age and potentially improve it, then this would influence their lifestyle behaviours.

Self-Perceptions and Attitudes Towards Ageing

The elderly have been found less likely to engage in preventative health behaviours compared with younger age groups,[34,35] despite the continued benefit that these behaviours provide throughout the lifespan.[36] Longitudinally, individuals aged 50–80 years with more positive self-perceptions of ageing at baseline were found to be significantly more likely to engage in preventative health behaviours when followed over the next two decades. Age, education, gender and race were not found to be predictive of preventative health behaviours. These behaviours included eating a balanced diet, exercising and following directions for taking medication prescribed.[37] It was hypothesised that this reduction in healthy behaviours (such as disengagement from exercise) was due to the perception that physical deterioration and illness was inevitable. Negative stereotypes reinforce attitudes that the elderly are too weak to exercise and health improvements are not possible. This would then diminish their major motivation for engaging in health-promoting behaviours. Additional evidence of how skewed perceptions can influence preventative health behaviours was found in a study which showed that individuals taking vitamin pills were shown to smoke more, leading to adverse health issues due to an overestimate of the perceived health protection afforded by the vitamin supplements.[38]

There is evidence of the longitudinal effects of negative self-perceptions on longevity, whereby older individuals who had more positive perceptions of ageing (which was measured up to 23 years earlier) lived for an average of 7.5 years longer.[23] This prediction remained even after controlling for age, sex, socioeconomic status, functional health and loneliness. Additionally, investigators found that this relationship was partly mediated by cognitions (e.g., the 'will to live'). There is also evidence for the longitudinal effects of negative self-perceptions of ageing on a faster functional health decline, categorised as: not being able to do a full time job, visit friends/relative, carry out heavy work around the house and walking up and down stairs.[24] The mean difference between groups continued to increase significantly over time. It could be argued that this relationship is reciprocal, whereby those with worse health have more reinforcement of negative attitudes that are consequently perpetuated. However, the association remained even when only those with the same baseline functional health were included in the analysis, indicating the precipitating rather than perpetuating effect of negative self-perceptions on health decline.

Attitudes Across Cultures

A study conducted with young and old groups of Chinese hearing, American deaf and American hearing individuals found interesting

results on memory tasks,[39] whereby there was an interaction effect between age, culture and disability impacting on performance. The three groups of younger participants performed similarly. However, the older Chinese and older American deaf participants outperformed the older American hearing group. There was also a positive correlation among older participants between views towards ageing and memory performance. Supported hypotheses were based on the theory that there is a psychosocial process that contributes to memory loss through negative stereotypes regarding memory in older age. The American deaf and Chinese participants would have had less exposure to negative stereotypes of ageing due to their independence from American mainstream culture while not sharing other common characteristics to reduce confounding cohort effects. These cultures both regard elders in high esteem, therefore providing positive stereotypes of ageing.[40,41] This study highlights cultural differences in the psychosocial ageing process, suggesting that the generalisability of findings may be limited. However, these novel findings further support the extent to which negative stereotypes can impact on cognitive performance.

Self-fulfilling Prophecy of Age-related Decline

As previously mentioned, the degree to which an individual perceives their future health is inevitable (e.g., age-related decline) will affect their present health behaviours, such as levels of physical activity, diet and other lifestyle choices. Consequently, this reduction in present healthy behaviours would lead to a quicker decline, thereby resulting in a self-fulfilling prophecy. The self-fulfilling prophecy has been defined as: "in the beginning, a FALSE definition of the situation evoking a new behaviour which makes the originally false conception TRUE".[42] In an exercise intervention context, a participant's motivation, adherence and effort are likely to be affected by their perception of potential benefits. If a participant believes their cognitive decline is inevitable and exercise cannot alter this, then this may influence how they approach and carry out the exercise; for example, with a lower intensity and lower adherence to session attendance. Therefore, it is important to assess attitudes towards ageing as a mediator in an intervention context.

Perceived Control

The self-fulfilling prophecy involves the concept of perceived control. An example of how this is relevant in this context could be, for instance, individuals who do not believe they have control over their future decline are less likely to try and slow down. When Levy and colleagues[24] found the association between negative self-perceptions and future functional decline, they also investigated the interaction of perceived control in this relationship. Perceived control was found to act as a partial mediator whereby self-perceptions of ageing predicted functional health over time, self-perceptions of ageing predicted the mediator perceived control and perceived control remained a significant predictor of functional health over time even when the self-perceptions of ageing were included.

Perceived control is similar to the concept of 'locus of control', which was derived from Rotter's Social Learning Theory.[43] Control beliefs were conceptualised as being either internal or external, where 'internal' refers to control residing within oneself and 'external' refers to control residing elsewhere (e.g., in other people or being due to chance). The aforementioned studies have demonstrated the positive effects of having stronger perceived control on health outcomes. However, there is evidence to suggest this may not be a simple linear relationship; having stronger perceived control can also be associated with poorer health outcomes, depending on the circumstances.[44,45] This hypothesis is based on the circumstances where there is a mismatch between perceived control and the environmental affordance, i.e., the actual amount of control an individual objectively has over a situation.[46] This incongruence could be detrimental to health in a situation where an individual does not have personal control; strong control beliefs could initiate a physiological stress response. The long-term effects of this could have a detrimental impact on health and stressful events have been implicated in triggering the early symptoms of dementia.[47]

A further complication of understanding this relationship is introduced when sense of control is conceptualised as a state rather than a trait. Significant associations have been found between older age and lower sense of control at baseline and also for a gradual decreasing sense of control with age over a period of one year (93 % of the sample were aged between 45 and 85).[48] Patterned results of decline have also been found whereby participants aged 18–50 years showed high and stable levels of perceived control compared with older participants who demonstrated successive downward steps of reduced perceived control.[49] Physical impairment and low levels of education accounted for a substantive amount of the low sense of control in older participants, the latter accounting for more. However, other demographic factors (race, gender, marital status, occupation, income or earnings) and physical ageing (perceived health, malaise, aches and pains, exercise or body weight) did not contribute to a low sense of control. It may be that physical impairment was closely related to physical ageing, which overruled these effects.

Causal Attribution of Memory Problems

Self-perceptions and stereotypes could impact on future decline through the attribution of cognitive problems to particular causes. There was evidence of age differences in attributing causes of memory problems in a study where 39.2 % of participants aged 25–85 years considered themselves forgetful.[50] Across groups increasing with age this proportion increased: 29.6 % among 25–35-year-olds, 34.2 % among 40–50-year-olds, 41.5 % among 55–65-year-olds and 52 % among 70–85-year-olds. Although a slightly higher proportion in the oldest group experienced hindrance from their forgetfulness compared with the youngest group (22.7 versus 17 %), the extent to which participants worried about their forgetfulness did not differ largely from the youngest group (47 %) to the older groups (62.2 % among 40–50-year-olds, 64.4 % among 55–65-year-olds and 61.5 % among 70–85-year-olds). When participants were asked to indicate the cause of their forgetfulness, the older participants were more likely to attribute their forgetfulness to their age. On the other hand, younger participants attributed memory problems to tension, emotional problems, poor concentration, lack of exercise and insufficient mental exercise. Already in the 40–50-year-old age group, there was a relatively high percentage of participants who attributed their forgetfulness to age. It is possible that these attributions are age-biased; it is likely that older adults experience memory issues due to emotional problems as the young do, but they are using ageing as a default cause.

Attributing memory problems to age rather than tension or emotional problems impacts on whether individuals act to overcome the problems. Attributing memory problems to age establishes the perceived locus of

control as external because ageing is inevitable, individuals may therefore surrender to memory problems as inevitable, thus not making the effort to overcome them in terms of employing memory strategies. Furthermore, attributing memory problems to age establishes them as chronic, as opposed to acute in the case of emotional causes. This expectation of chronic reoccurring memory problems rather than an isolated episode would further reinforce the attitude of inevitable age-related decline. In a research context when participants are recruited based on self-reported memory problems this could be problematic, and may also lead those succumbing to memory problems to put in less effort or concentration in testing conditions.

Changes in Mood

The environment of exercise can affect mood; for example, outdoor exercise was found to bring about more positive changes in mood (greater pleasant affective states) compared with indoor exercise.[51] Moreover, depression has been associated with poorer cognitive performance longitudinally, whereby there is an acceleration in age-related decline compared with age-matched controls.[52] Depression is an overall risk factor for dementia,[53] heart disease and stroke in women.[54] There is a high prevalence of depressive symptoms in individuals over 65 years old (approximately 15 %, with major depression affecting about 4 %[53]). There is observational evidence of the protective effect of physical activity on depression in middle-aged and older adults, which included disabled participants.[55] Other associations found include depression with no regular physical exercise and higher wellbeing with regular exercise.[56] The presence of these associations necessitates a closer look at improvements in mood in interventions to indicate whether it could act as a mediator for cognitive performance improvements after exercise.

The association between depression and poorer cognitive performance is a controversial one due to the lack of understanding of the causal pathways and mechanisms involved. One review reported that subjective memory complaints were inconsistently related to current cognitive impairment, but more strongly related to risk of decline in the future.[57] It was suggested that the inability to sustain effort on memory tasks due to poor motivation results in poorer performance on cognitive tasks, thus masking actual cognitive capabilities. However, patients with a major depressive episode demonstrated similar impairment across cognitive tasks of varying difficulties (auditory verbal learning test, recall and recognition) that correlated with depression severity.[57,58] This suggested that effort is not the main determinant of cognitive performance among those with depression because impairment would have been worse in more difficult tasks compared with easier tasks if this was the case. This suggests that more complex mechanisms cause the associations between depressive symptoms and lower cognitive performance.

The majority of studies in the Clifford and colleagues' review[13] did not include measures of mood. However, the studies that did include measures of mood found improvements in mood (e.g., anxiety and vigour) in exercise groups, but not in control groups.[31,59] Among these studies, cognitive improvements in the exercise groups were not universal for all participants, suggesting that mood improvements may not be the only mediator. Furthermore, several studies showed that physiological improvements do not necessarily correlate with improvements in psychological measures.[31,60] The latter study failed to find an association between strength training intensity levels (high or low) and improvements in psychological outcomes. They implied that cognitive behavioural mechanisms (e.g., enhanced self-efficacy) might be more important to consider than physiological mechanisms.

Conclusion

Exercise does not occur independently of its environment; interventions vary greatly in terms of their environment and specific features, and consequently the different types of social interaction, mental engagement, goal setting and feedback will alter the psychological impact of the exercise. As psychological factors impact on cognitive performance, this suggests a mediating relationship. The probable psychological mediators discussed here include self-efficacy, self-perceptions and attitudes to ageing, perceived control manifesting in a self-fulfilling prophecy, causal attributions of memory problems and mood. It is apparent that exercise can improve the cognitive performance of older adults in many interventions; however, inconsistent results across studies may indicate that the specific features of the effective interventions are having a psychological effect that consequently impacts on cognitive performance. Therefore, future research using exercise interventions to improve cognitive functioning should include measures of psychological variables to further our understanding of the interaction effect. Potentially, the effectiveness of interventions could improve if they facilitate a positive psychological impact – for example, improving self-efficacy through goal setting and feedback – thus challenging negative self-perceptions of ageing. Further research is needed to investigate the magnitude of the effect of psychological mediators and their relative contribution compared with physiological mechanisms in an exercise intervention aiming to improve cognitive performance in older adults. ■

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