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Higher-Level Hand Motor Function in Aging and (Preclinical) Dementia: Its Relationship with (Instrumental) Activities of Daily Life – A Mini-Review

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Abstract

A causal relationship between physical activity such as walking and cognitive functions – particularly executive functions and memory – has been observed in elderly people with and without dementia. Executive functions play an important role in the (instrumental) activities of daily life [(I)ADL]. However, a close relationship has also been found between motor activity of the upper limb, particularly the hand, and (I)ADL. Indeed, in aging, a decline in hand motor function is related to a decrease in (I)ADL, an increase in functional dependency, admission to a nursing home, and even mortality. This review begins by addressing clinical studies on the effect of age on higher-level hand motor activity. It then discusses higher-level hand motor function in age-related neurodegenerative diseases such as mild cognitive impairment, Alzheimer's disease and vascular dementia. It concludes by discussing the contribution of higher-level hand motor function assessment to the diagnosis of the various subtypes of (preclinical) dementia and by addressing the clinical relevance of studying higher-level hand motor function, procedural learning, and (I)ADL in aging and (preclinical) dementia.

Introduction

Epidemiological studies show that the highest level of cognitive functioning [1] is displayed by people who are physically active to such an extent that breathing and sweating is stimulated and cardiopulmonary fitness is enhanced. A related finding is that physical activity in midlife decreases the risk of dementia by 20–50% [1]. Although these studies do not indicate a causal relationship between physical activity and cognition, others do. In elderly persons without dementia, executive functions in particular respond positively to an aerobic physical activity program that consists of brisk walking [2]. As executive functions contribute significantly to independent functioning and activities of daily life (ADL) [3], these results indicate that older people with and without dementia should stay physically active for as long as possible. Unfortunately, elderly people with and without dementia may become less able to walk due to, for example, impaired gait [4]. There is increasing evidence for a positive relationship between higher cognitive impairments such as executive dysfunctions and higher-level gait disturbances, i.e. gait disturbances excluding musculoskeletal disorders of the lower limbs, peripheral disorders

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such as neuropathy, spasticity, cerebellar syndromes, and extrapyramidal disorders [5]. A decrease in physical activity due to impairment in higher-level gait may therefore have a negative impact on higher cognitive functions and thus on independence in ADL.

Interestingly, besides the above-described close relationship between walking and the ability to function independently, upper-limb function – more specifically hand motor function – also shows a close relationship with ADL. A gradual decline in hand motor function, i.e. fine, complex and gross hand motor function, is related to a reduction in the ability to perform functional daily activities such as moving objects, getting dressed, eating and writing [6, 7], and may hence affect quality of life [7]. The discovery that poor hand motor function is related to a higher level of functional dependence might explain why people with a low hand motor function are more likely to live in a nursing home [8]. Not only is hand motor function, especially grip strength, an important predictor of functional disability in elderly persons, it even appears to be a strong predictor of mortality in, for example, elderly British men [9]; participants with the lowest handgrip strength ran the greatest risk of mortality.

The above-mentioned results suggest a close relationship between hand motor function, the ability to function independently, ADL, institutionalization, quality of life, and even mortality. Since cognitive functioning is also related to the ability to function independently, ADL and institutionalization, it might be worthwhile to examine the relationship between cognition and, in parallel with higher-level gait [5], higher-level hand motor function in, for example, cognitively intact elderly people and elderly people with varying levels of cognitive impairment. The aim of this review is therefore to explore clinical studies that examined higher-level hand motor function in aging and (preclinical) dementia, focusing particularly on mild cognitive impairment (MCI) and Alzheimer's disease (AD). Only one study looked into a possible relationship between higher-level hand motor function and vascular dementia (VaD). Subsequently, the question that will be addressed is whether assessment of higher-level hand motor function may contribute to the diagnosis of the various subtypes of (preclinical) dementia. The review concludes with a discussion of the clinical relevance of studying hand motor activity in aging and (preclinical) dementia.

Methods

Data Sources and Searches

Multiple combinations of the search terms (MESH and advanced searches) aging, hand, humans, motor activity, activities of daily life, muscle strength, motor skills, dementia, Alzheimer's disease, vascular dementia, and frontotemporal dementia were entered in Pubmed, Cinahl, Embase, Web of Science, and PsycINFO for the years 1980–2008. The whole search procedure ended on 1 March 2008.

Subsequently, by hand-searching, we added (a combination of) the search terms hand function, hand motor function, hand motor activity, fine motor function, complex motor function, gross motor function, manual dexterity, grip strength, muscle strength, hand impairment, hand disability, mild cognitive impairment, MCI, subcortical ischemic vascular dementia and frontotemporal dementia and searched for relevant papers in the above-mentioned databases. The searches were limited to the English language. Other relevant articles were found by going through the literature list in the various studies. Data were also collected from the personal files of the authors.

Literature Selection

The searches were performed separately by two researchers (E.S. and W.D.). The initial selection was based on the title and the abstract and met the following criteria: (1) based on the classification of Kluger et al. [10], clinical human studies examining fine hand motor function (e.g. assessed by tasks that require hand/finger coordination of one hand, eye-hand coordination), complex hand motor function (e.g. alternating movements of two hands with a visuospatial component), and gross hand motor function (e.g. grip strength, velocity); and (2) clinical studies involving cognitively intact elderly persons and elderly persons with cognitive impairment, in particular, MCI, AD, VaD, and frontotemporal dementia (FTD). As the present review focuses on higher-level hand motor function, studies that addressed disturbances in hand motor function due to musculoskeletal disorders of the upper limb, peripheral disorders such as neuropathy or changes in motor unit firing rates, spasticity, cerebellar syndromes, and extrapyramidal disorders were excluded. Studies that added no information to those already included in this review were also excluded. This applied only to some studies on hand motor function in aging.

The abstracts of full-length articles/reports were read carefully. The full-length papers/reports were then collected and included in the review. There was no disagreement between the reviewers.

As the final number of studies on the relationship between hand motor function, aging, and dementia was limited, they were all (n = 25) included in the review (aging: 14; MCI/AD: n = 10, VaD: n = 1, FTD: no studies).

Hand Motor Function in Aging, MCI and AD

The clinical studies on hand motor function in this review have two key strengths: (1) they all explicitly state the specific diagnosis, e.g. AD instead of elderly person with 'dementia'; and (2) some of them include different groups, i.e., elderly persons without dementia, elderly people with MCI and AD patients, thus making it possible to draw a direct comparison between groups.

Effect of Aging on Hand Motor Function

In general, clinical studies reveal an age-related decline in fine hand motor function (e.g. precision grip), in complex hand motor function (e.g. moving blocks from one side to another) and in gross hand motor function (e.g. pinch and grip force) (see table 1 for details of the various studies) [7, 11]. A close relationship exists between fine, complex, and gross hand motor function. For example, precision grip requires a fine-tuned target-related grasping force [12]. Elderly people are less able than younger people to adapt this force to changing targets. Moreover, the finger pinch force declines in both hands and becomes more variable [13]. The latter finding implies that elderly people use their index finger more and their middle finger less during finger pinch force tasks. These findings confirm that elderly people are less able to control or adjust the amount of force to fit the task (i.e. more coarse and less fine gradation of force with age), and to coordinate the force of individual digits [14], which is essential for ADL [14]. One of the causes of the variable force control is a decline in strength [15]. To compensate for a decline in precision-grip force, elderly persons may increase their grip force [16] by, for example, applying grip patterns that produce more strength [17].

Two examples of everyday fine-motor functional tasks that take more time for elderly people to perform are pouring milk and removing money from a wallet [6]. The ability to perform functional tasks is stable until approximately the age of 65 [18]. After that, a mild decline in fine hand motor function was noticed, with a greater decline after the age of 75. These findings indicate a nonlinear relationship between age and fine hand motor function [18]. In contrast, grip force (gross hand motor function) declines linearly between the age of 50 and 83, irrespective of gender [19]. However, in the oldest women, the decline in grip strength remains constant. Remarkably, a decline in grip strength does not necessarily imply an inability to open medication containers, for instance [20].

Another factor that might influence the relationship between age and task performance is familiarity with the task. In one study, the participants had to perform drawing and writing tasks [21]. In general, the elderly subjects had lower mean peak acceleration and exerted less pressure. Also, the elderly persons' movements were slower and less automated. Notably, the difference between elderly and younger people was less evident when it came to signing their names, a highly automated task. However, familiarity with a task does not always have a positive effect on performance. A study applying kinematic analysis revealed that, irrespective of age, the duration of a stroke by the right hand was shorter when it was made towards the body (adductive movement) than away from the body (abductive movement) [22]. This finding refutes the theory that familiarity generates a positive effect, as the normal direction of the right hand during writing is away from the body [22].

All in all, most of the evidence points to a decline in fine, complex, and gross hand motor function in elderly people, particularly after a certain age. The results of only one study suggest that familiarity with the task does not always have a beneficial effect on performance.

Effect of MCI and AD on Hand Motor Function

Assessment results of fine hand motor function by applying the Finger-to-Thumb test [23], Purdue Pegboard [24], and a pointing/touching task [25] revealed significant differences between elderly persons without dementia, elderly persons with MCI, and AD patients. In these studies, AD patients performed worse than MCI patients who, in turn, performed worse than the healthy controls (see table 2 for details on the diagnosis of MCI and stage of AD). However, when controlling for the presence of stroke, the MCI patients did not perform significantly worse on the Purdue Pegboard than subjects without cognitive impairments [24].

Differences in the performance of the three groups were observed not only for fine hand motor activity, but also for complex hand motor functions, which were assessed by the Assembly test of Purdue Pegboard, alternating movements of both hands, and Luria's three different movements by one hand [10, 26]. In addition, patients with mild AD performed slower on a task for gross hand motor function – finger tapping – than elderly persons without dementia [10] and patients in a very early stage of dementia [27].

The discovery that gross hand motor activity such as speed is particularly affected in AD has been confirmed at a somewhat more subtle level in studies using kinematic analyses of hand movements (table 2). These studies indicated that, compared with healthy controls, AD patients take longer to prepare movements, perform more slowly, show changing velocity profiles, and need more time to reach peak velocity; the latter symptom could be observed as a problem when initiating movements. In addition, they demonstrated variability in force when writing and when performing tasks in which a non-ink pen or a cursor had to be moved towards a target [28, 29]. AD

Table 1. Clinical studies examining the influence of aging on hand function

Authors	Number	Age, years	Gender	Measurements	Main findings
Desrosiers et al., 1999 [11]	1*: 360 2*: 264	>60 (mean 73.9)	M: 181; F: 179 M: 136; F: 128	gross and fine manual dexterity, global UE performance, UE motor coordination, grip strength, tactile recognition, point discrimination, touch/pressure threshold	gross and fine manual dexterity ↓, global UE performance ↓, UE motor coordination ↓, grip strength ↓, tactile recognition ↓, point discrimination ↓, touch/pressure threshold ↓
Ranganathan et al., 2001 [7]	Y: 27 O: 28	20–35 65–79	M: 13; F: 14 M: 12; F: 16	handgrip strength, maximum pinch force, steady pinch force, precision pinch posture, speed, point discrimination	handgrip strength ↓, maximum pinch force ↓, steady pinch force ↓, precision pinch posture ↓, movement speed ↓, two-point discrimination ↓
Voelcker-Rehage and Alberts, 2005 [12]	Y: 14 O: 12	19–28 67–75	M: 8; F: 6 M: 6; F: 6	Mini Model force transducer for isometric precision grip force	reduced ability to adjust force to changing targets; force-tracking can be trained but performance of older persons lower than that of younger persons
Keogh et al., 2006 [13]	Y: 13 O: 14	23.8 (± 4.7) 75.7 (± 2.5)	n.a. n.a.	assessment of tri-digit finger pinch force by XTran 250 N S-beam load cell transducer and BC302 117.6 N	older persons show less control over finger-pinch force, use their index finger more and their middle finger less than younger persons
Shim et al., 2004 [14]	Y: 12 O: 12	26.5 (±3.1) 26.0 (±2.4) 86.7 (±9.6) 78.3 (±2.9)	M: 6 F: 6 M: 6 F: 6	assessment of maximal and submaximal force of all digits by transducers for fingers and thumb	decline in digit coordination, necessary for producing combinations of force and moment
Sosnoff and Newell, 2006 [15]	Y: 15 O: 33	24.9 (±3.8) 70.9 (±5.6)	M: 9; F: 6 M: 15; F: 18	isometric force assessment of the abduction of the index finger	strong relationship between the variability in force and strength
Gilles and Wing, 2003 [16]	Y: 16 O: 15	18–29 59–70	M: 5; F: 11 M: 6; F: 9	assessment of grip force during up and down movements, with changes in load force (cylindrical force transducer)	higher grip force in older persons than in younger persons; adjusting grip force to changes in load force similar in older and younger persons
Wong and Whishaw, 2004 [17]	VY: 48 Y: 74 O: 16	5–12 15–63 56–77	M: 28; F: 20 M: 34; F: 40 M: 5; F: 11	assessment of grasping patterns by grasping beads of various diameters	older persons showed fewer different grasp patterns than younger persons and selected grasps that produced the largest force
Shiffman, 1992 [6]	40	24–87	M: 20; F: 20	strength, milk pouring, removing money from a wallet	different prehension patterns and frequency, performance time ↑, hand strength ↓
Smith et al., 1999 [18]	Y: 56 O: 38	20–58 66–87	M: 22; F: 34 M: 12; F: 26	fine and coarse hand functions	coarse motor time ↑, fine motor time ↑↑
Frederiksen et al., 2006 [19]	8,342	45–98	n.a.	measurement of handgrip strength during a follow-up of 4 years, using a hand dynamometer	men showed more strength than women; hand grip strength showed an age effect
Rahman et al., 2002 [20]	O: 51	60–84	M: 9; F: 42	assessment of grip and pinch strength by opening containers that were connected to a Jamar dynamometer through sensors	grip and pinch strength were weakly related to the force needed to open most of the containers
Mergl et al., 1999 [21]	57	45 (± 20)	M: 25; F: 32	drawing and writing tasks	peak velocity ↓, speed ↓, movement automation ↓, writing pressure ↓
Morgan et al., 1994 [22]	Y: 12 O: 12	18–27 (21.2) 63–74 (69.9)	M: 6; F: 6 M: 6; F: 6	connecting targets with a zigzag pattern	stroke duration ↑, pauses ↑, accuracy + peak velocity ↓

SMC = Primary sensorimotor cortex; SMA = supplementary motor area; PMC = lateral premotor cortex; VY = very young; Y = young; O = old; 1* = first measurement; 2* = second measurement; n.a. = not available; UE = upper extremity.

Table 2. Studies examining the influence of MCI, AD and VaD on hand function

Authors	Age, years	Number	Stage	Gender	Measurements	Main findings
Aggarwal et al., 2006 [24]	HC: 74.6 (6.7) MCI: 78.7 (7.0) AD: 81.9 (6.7)	558 198 60	 n.a. n.a.	M: 188; F: 370 M: 65; F: 133 M: 23; F: 37	Purdue Pegboard	AD versus MCI: score Purdue Pegboard ↓ MCI versus HC: score Purdue Pegboard ↓
Bellgrove et al., 1997 [28]	HC: 73–88 AD: 73–88	12 12	 MMSE 15–27	M: 2; F: 10 M: 2; F: 10	connecting illuminated targets	movement speed ↓, kinematic irregularities ↑, cycles of acceleration and deceleration ↑, time to prepare movements ↑, movement efficiency ↓, errors ↑
Camarda et al., 2007 [25]	HC: 69.7 (9.1) MCI: 69.7 (7.9) AD: 70.8 (6.4)	11 11 11	 CDR 0.5 MMSE 17–24	M: 5; F: 6 M: 5; F: 6 M: 5; F: 6	pointing at/touching illuminated targets	AD versus MCI/HC: ↓ reaction time, ↓ peak of acceleration, ↓ peak of velocity, ↓ peak of deceleration
Economou et al., 2007 [26]	HC: 58–88 (8.9) MCI: 62–90 (6.2) AD: 60–87 (8.2)	27 31 15	 CDR 0.5 CDR 1.0	unknown	Luria's alternating hand movements Luria's unimanual 3-stage movements	MCI versus HC: ↑ impairment on alternating movement test, ↓ uni-manual 3-stage movements AD versus MCI: ↑ impairment on alternating movement test, ↓ uni-manual 3-stage movements
Franssen et al., 1999 [23]	MCI: 72.6 (9.4) AD: 73.3 (7.70	69 101	GDS 3 GDS 4	unknown unknown	finger to thumb	MCI showed worse performance compared to cognitively intact people; AD patients performed worse than cognitively intact people
Ghilardi et al., 1999 [29]	HC: 61–74 AD: 61–74	9 9	 MMSE 9–24	M: 3; F: 6 M: 3; F: 6	moving a cursor to a target	multiple curves in patient trajectories, discontinuous segments, changing velocity profiles
Goldman et al., 1999 [27]	HC: 73.2 (7.7) MCI: 72.0 (7.5) AD: 73.7 (7.8)	43 40 20	CDR; 0 CDR 0.5 CDR 1	M: 21; F: 22 M: 19; F: 21 M: 9; F: 11	finger tapping reaction time and movement time on the Fitts task: movement of a stylus to a target	no differences on finger tapping between the three groups AD versus MCI: ↓ reaction time, ↓ movement time MCI versus HC: no differences
Hall and Harvey, 2008 [32]	HC MCI AD VaD Total group: 79.3 (65–94)	11 46 129 74	n.a. n.a. n.a. n.a.	total group: M: 82; F:178	finger tapping	no differences between groups
Kluger et al., 1997 [10]	HC: 69.9 (8.6) MCI: 73.9 (8.2) AD: 71.6 (8.1)	41 25 25	 GDS 3 GDS 4	M: 56.1% M: 56% M: 40%	gross motor function: finger-tapping speed, hand strength fine motor function: Purdue and Grooved Pegboard (dominant and nondominant hand) complex motor function: assembly test of Purdue Pegboard	MCI versus HC: score Purdue Pegboard ↓, score Grooved Pegboard ↑, score assembly test of Perdue Pegboard ↓ AD versus HC: finger-tapping speed ↓, score Purdue Pegboard ↓, score Grooved Pegboard ↑, score assembly test of Perdue Pegboard ↓
Schröter et al., 2003 [30]	HC: 65.6 (7.9) MCI: 60.6 (11.1) AD: 70.6 (11.2)	40 39 35	 MMSE 23–30 MMSE 15–30	M: 17; F: 23 M: 16; F: 23 M: 18; F: 17	task 1: drawing circles task 2: drawing circles while performing a second task	HC versus MCI: number of changes of direction of velocity ↑ AD versus HC: frequency of handwriting per day ↓, velocity variation ↑, relative velocity ↑, number of changes of direction of velocity ↑
Slavin et al., 1999 [31]	HC: 66–88 AD: 66–88	16 16	 MMSE 0–27	M: 4; F: 12 M: 4; F: 12	writing 4 cursive l's in a single smooth movement at a comfortable speed	stroke length variability ↑, stroke duration variability ↑, peak velocity variability ↑

n.a. = Not available; CDR = Clinical Dementia Rating Scale [49]; GDS = Global Deterioration Scale [50]; HC = healthy controls.

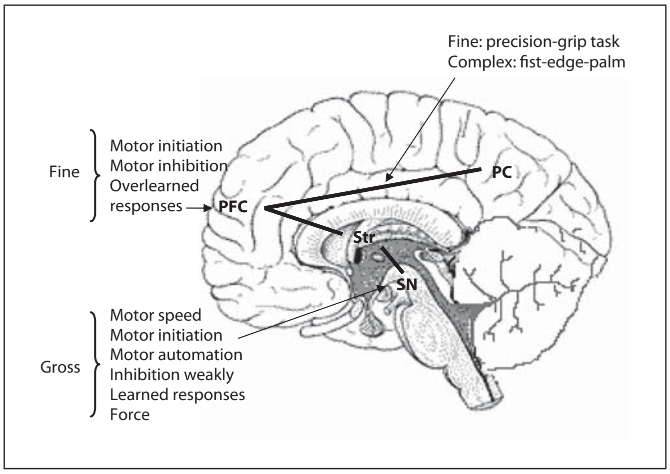

Fig. 1. Contribution of the frontostriatal, nigrostriatal and frontoparietal system to fine and gross motor hand function. PFC = Prefrontal cortex; Str = striatum; SN = substantia nigra; PC = parietal cortex; Fine = fine hand motor function; Gross = gross hand motor function.

patients showed more variation in velocity during writing not only in comparison with healthy controls, but with MCI patients as well [30]. In contrast with healthy controls, AD patients showed signs of perseveration by writing more letters than required [31]. The authors interpret this finding as a deficit in monitoring one's own behavior, an executive dysfunction. Furthermore, the handwriting of AD patients, and to a lesser extent of MCI patients, was less automated and smooth than that of healthy controls [30], thereby implying that a decline in hand movement coordination and automation, i.e. in fine hand motor activity, coincides with a decline in cognitive functioning [30].

Taken together, MCI patients and, to a larger extent, AD patients show impairment in fine and complex hand motor activity when compared with healthy elderly persons. Secondly, when compared with both healthy controls and MCI patients, AD patients show impairment in gross motor activity, which is reflected primarily in a slower performance of hand motor function.

Discussion

How the Assessment of the Hand Motor Function May Support the Diagnosis of (Preclinical) Dementia

The reviewed studies suggest that a relationship exists between higher-level hand motor function and higher-level cognitive status, similar to that observed between higher-level gait and higher-level cognitive functioning [4]. For example, a decline in fine and complex hand motor function, assessed by e.g. Grooved Pegboard and Assembly test of the Purdue Pegboard, respectively, was observed to a much greater extent in MCI patients than in elderly people with no cognitive impairment. However, the difference in fine hand motor function might disappear if MCI patients with a stroke were excluded from data analysis [24]. It also emerged that elderly people and MCI patients did not differ significantly in impairment of gross hand motor function, assessed by e.g. finger-tapping speed and hand muscle strength. The assessment of hand motor function can differentiate more reliably between AD and normal aging and between AD and MCI. AD patients showed the strongest impairment of fine, complex and gross hand motor function compared with healthy controls [28, 29] and MCI patients [27]. To the best of our knowledge, only one study compared the hand motor function in VaD patients with the hand motor function of MCI patients, AD patients, and elderly persons without dementia [32]. The results show that simple hand motor function, i.e. copying alternating hand-tapping performed by the examiner, did not differentiate between groups. The fact that this task did not involve alternating hand movements with a visuospatial component, strength, or speed might explain the absence of significant differences between groups. All things considered, no firm conclusions can as yet be drawn about the (in)effectiveness of hand motor function as a tool to differentiate between the various subtypes of (preclinical) dementia. However, the neuropathology underlying the various subtypes of (preclinical) dementia supports the notion that disturbances in higher-level hand motor function are indicative of cognitive impairment and vice versa.

Indeed, the clinical outcome described above parallels the neuropathological characteristics of aging, MCI and AD. Activity in the frontoparietal network has been observed during a precision-grip task and a sequence fist-edge-palm motor task [33, 34]. Frontoparietal connectivity is vulnerable in normal aging [35], MCI [36] and early AD [37]. A dysfunction of the frontostriatal network due to a decline in the dopaminergic striatal innervation might cause impairment in gross hand motor function, such as motor speed [38] (fig. 1). It should be stressed with respect to the findings currently available that, compared with normal aging, the striatum is more affected in AD patients, even at an early stage [39]. Both the frontoparietal and frontostriatal connectivities are involved in higher-level cognitive functioning [40, 41]. Finally, it is argued that the clinical outcome (i.e. the specific hand motor and cognitive function impairment) is determined by *where* the neuronal circuit is damaged.

Clinical Relevance of Studying the Relationship between Hand Motor Function, Procedural Learning and (I)ADL in (Preclinical) Dementia

It follows from the above-described neuropathological point of view and from the premise that, as in the case of gait, higher-level hand motor function should be considered as a higher-level cognitive function (fig. 1), the more impaired the hand motor function, and thus (I)ADL, the severer the cognitive impairment, and vice versa. Indeed, a positive relationship has been observed between the level of cognitive function and (I)ADL in particular, implying that the greater the cognitive impairment, the greater the decline in (I)ADL (e.g. money management and telephone use) [42]. However, as assessment of hand motor function was not included, the findings of McGuire et al. [42] do not automatically point to a positive relationship between hand motor function and (I)ADL in cognitively impaired elderly persons. Currently available data show that compared with controls, AD patients demonstrate impairment in fine, complex, and gross motor functions. Even so, AD patients can maintain (I)ADL to a certain extent as their capacity for procedural/implicit learning is relatively well preserved [43]. For example, procedural learning may enable AD patients to regain the use of a mobile phone [44].

As far as we know, only one study compares procedural learning in patients with ischemic vascular dementia with AD patients [45]. Although global cognitive functioning was similar in both groups, patients with ischemic vascular dementia performed worse on procedural learning tasks than AD patients, implying that (I)ADL might be more severely damaged in the former group. However, neither (I)ADL nor hand motor function was specifically examined in that study [45]. There are no available studies that examine the relationship between hand motor function, procedural learning, and (I)ADL in other subtypes of dementia such as FTD.

Although the study of McGuire et al. [42] shows that hand motor function and (I)ADL need not be related, studying the relationship between the two is of clinical relevance, as the level of (I)ADL might be maintained or improved by training hand motor function itself. It is argued that hand motor function should be trained at a stage at which impairment and thus a decline in (I)ADL might still be redressed. In healthy aging persons, training for pinch force, hand steadiness and moving small objects has proven successful [13, 46]. This is an important finding since many (I)ADL tasks involve hand manipulation, and improvements in these areas could enhance quality of life [46]. That said, not all aspects of hand motor function are easy to train. For example, elderly people have more problems with releasing grip force – which is one aspect of the hand motor function that is not easy to exercise [12]. This is unfortunate, since a decrease in releasing grip force plays a particularly important role in the impairment of hand function in elderly persons [12].

Since AD patients are also able to implicitly learn fine and gross hand motor function, such as rotary pursuit and tossing, respectively [47, 48], it is of clinical importance to examine whether implicit learning of hand motor function is possible in other subtypes of (preclinical) dementia as well. In addition, it would be worthwhile to ascertain whether a rehabilitation program consisting of a combination of implicit learning of (I)ADL and implicit learning of fine, complex and gross hand motor function would have a more beneficial effect on (I)ADL than each type of implicit learning applied separately. The question of whether such a program might postpone or even prevent institutionalization is a challenge for future research.

Conclusion

Future studies should focus on higher-level hand motor function in cognitively impaired patients and explore its relationship with (I)ADL and the risk of institutionalization. The results of these studies might show that each subtype of (preclinical) dementia has its own pattern of higher-level hand motor function impairment and therefore requires its own specific program of rehabilitation.

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