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RESEARCH ARTICLE

# Cognitive-Behavioral Interventions and Assistive Technology-based Programs for Improving Adaptive Responding of Persons with Parkinson's Disease: A Literature Overview

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## Abstract

We provide the reader with a literature overview on the use and the implementation of the cognitive-behavioral interventions, and the assistive technology-based programs for improving adaptive responding of persons with Parkinson Disease. Three basic categories of studies were retained, namely (a) Gait and posture; (b) Leisure and occupation, and (c) Mental health. Twenty studies were reviewed and 3984 participants were involved. Assistive technology was primarily used for gait and posture, and leisure/occupation. Cognitive-behavioral interventions basically focused on mental problems. Results were largely positive, although few failures occurred. Clinical, psychological, and rehabilitative implications of the findings were critically discussed. Some useful guidelines for future research and practice were emphasized.

## Keywords

Parkinson disease, Cognitive-behavioral interventions, Assistive technology, Quality of life, Self-determination

## Introduction

Parkinson disease (PD) is a neurodegenerative disorder that has a commonly asymmetric onset and is characterized by muscular rigidity, resting tremor, bradykinesia, loss of postural reflexes. Gait and balance difficulties are usually included. Stopped posture, shuffling steps, falling are additionally observed. The first affected arm may not swing fully when walking, and the foot of the same side may scrape the floor. Over the time, the axial posture becomes gradually flexed and strides becomes shorter. Among the non-motor symptoms, cognitive impairments, bradyphrenia, tip-of-the-tongue (i.e., word finding), depression, apathy, anhedonia, behavioral and psychiatric problems, anosmia, abnormal sweating, urinary and sexual dysfunction, weight loss, and sleep disorders are usually reported. Dementia, obsessive-compulsive behaviors, craving, examining, sorting, and arranging objects are also described. PD patients may encounter a relevant olfactory function reduction (i.e., smell). Additionally, they may exhibit rapid eye movements during REM sleep, frequently described as hitting or kicking. Constipation and/or excessive daytime sleeping may be noticed [1-3].

PD is diagnosed on clinical criteria. Although there is no definitive test for its diagnosis, pathological confirmation of the hall-mark Lewy body on autopsy is considered the standard criterion. In clinical practice, the diagnosis is typically based on the presence of the combination of specific motor features, associated with exclusionary symptoms, and response to levodopa. The diagnosis is straightforward with a classical presentation. However, differentiating forms of PD can be evinced early in the course of the disease, when symptoms overlap with other syndromes [4,5].

Beside pharmacological treatments, cognitive-behavioral interventions, and assistive technology-based programs (AT) may be envisaged to reduce the negative outcomes of the disease. Cognitive-behavioral interventions have been successfully used for non-motor

Perilli et al. Int J Psychol Psychoanal 2018, 4:038

• Page 1 of 7 •

symptoms, while AT have been efficiently implemented for overcoming postural and gait abnormalities, and for occupational purposes. Both could be merged and matched for promoting the independence and self-determination of patients with PD, based on learning principles (i.e., causal association between behavioral responses and environmental consequences) [6-8]. The literature on the use of both rehabilitative approaches separately is substantial [9-12]. However, no review papers are available on their matching.

Accordingly, the goal of the current review paper is to provide the reader with the newest empirical contributions available on the implementation of cognitive-behavioral interventions, and AT-based programs for enhancing the adaptive responding of patients with PD. The effects of such rehabilitative strategies on the participants' quality of life and the reduction of the caregivers' burden will be outlined. Strengths and weaknesses of the reviewed studies will be emphasized. Implications of the findings will be critically discussed. Finally, some useful guidelines for future research and practice will be proposed.

## Method

A computerized search was performed in Scopus. A manual search was merged as completion. Parkinson disease, cognitive-behavioral interventions, assistive technology-based programs, quality of life, adaptive skills, dementia, social validation, independence, and self-determination were used as keywords. Eligibility criteria were (a) An empirical contribution with at least a participant with PD; (b) At least a cognitive-behavioral intervention and/or an AT-based program; (c) English language of the reviewed papers, and (d) 2008-2018 as range publication years (i.e., last decade). Accordingly, three main categories were identified, namely (a) Gait and/or postural problems; (b) Leisure and occupation activities, and (c) Mental problems/health care (i.e., including cognitive impairments, personality disorders, and sleep difficulties). Overall, twenty studies were reviewed, and 3984 participants were involved. For practical reasons, three studies for each category were concisely described. Synoptic tabs were additionally included as completion, with the authors of the papers, the participants involved, their chronological ages, the implemented interventions, and the outcomes.

## Literature Overview

### Gait and posture difficulties

Freezing of gait (FOG), defined as an episodic inability to generate effective steps in absence of any known cause other than parkinsonism or high level gait disorders, is one of the most common feature of PD. Frequently, the patient has trouble during step initiation and turning but also when faced with obstacles, doorways, stress, and distraction. The FOG phenomenon is closely related in the striatum, the frontal lobe, and frontal basal ganglia projections. Effective treatment for gait difficulties in PD requires reliable and affordable tools for evaluating the severity of gait impairments, and the suitability of rehabilitative interventions. Two basic methods may be considered for that purposes. A first method relies on a standard gait laboratory by using specialized technology, and involves a full analysis of the motion of all body segments. It requires cumbersome equipment to be attached to the patient, although produces well-quantified and accurate outcomes over short distances. The second method, recently developed, implies the use of wearable sensors with a long-term monitoring system. The equipment included is light, small, inexpensive, and can easily be carried for long periods and distances to quantify gait parameters [13-15]. Seven studies were included in this section with 321 participants involved (see Table 1) [16-22].

For example, Bachlin, et al. [16] evaluated the concept of wearable device that could record real-time gait data, monitored them, and provided assistance based on pre-determined parameters. A real-time wearable FOG detection system, which automatically delivered a cueing sound when FOG was detected, and which stayed until the participant resumed walking was adopted. Ten PD patients were enrolled. The wearable AT-based equipment was assessed. Over eight hours of data was collected, and a questionnaire was filled out by each participant. Two hundred and thirty-seven FOG events were identified and analyzed by professional physiotherapists in a post-hoc video analysis. The device recorded the FOG events online with a sensitivity of 73% and a specificity of 82%, on a 0.5 sec frame-based evaluation. The wearable device seemed to be manageable, suitable and effective for profitably recording gait parameters.

**Table 1:** Reviewed studies on the use of AT for improving gait abilities.

| Authors | Participants | Mean age | Strategies | Outcomes |
|---|---|---|---|---|
| Bacchlin, et al. [16] | 10 | 66.2 | Wearable AT - Device | Ten positive |
| Buated, et al. [17] | 30 | 64.5 | Visual Cues + Laser Cane | Thirty positive |
| Mazilu, et al. [18] | 9 | 68.7 | Wearable System | One negative |
| Nilsson & Irwasson [19] | 160 | 72.3 | AT-Equipment | Two negative |
| Stummer, et al. [20] | 18 | 63 | Walk-Bicycle | Two negative |
| Uchitomi, et al. [21] | 32 | 70.4 | Interactive Rhythmic Cues | Two negative |
| Zhao, et al. [22] | 62 | 65.7 | Survey | Two negative |

Buated, Sriyudthsak, Sribunruangrit, and Bhidayasiri [17] assessed the difference in the impact of FOG with a group of PD patients receiving visual cues from an innovative "laser cane" and with a traditional cane with no cues. The study compared thirty participants with PD with both aforementioned canes, during "on" and "off" responses to medications. For each trial, participants were video-recorded walking two rounds on a 5-meter track and their footsteps were printed on paper tracking sheets. Results emphasized that the visual cues of the laser beam could significantly improve both stride length and the velocity during the "off" medication period in all the participants. Greater increasing of the gait parameters (i.e., balance, posture, body weight, and ambulation responses such as locomotion fluency) were found in PD patients who were at a moderate stage, than those at the mild level of the disease. Similarly, the biggest differences in reduced FOG and increased stride length were observed between both aforementioned groups. The laser cane emphasized relevant differences between groups.

Nilsson and Iwarsson [19] designed a longitudinal study (i.e., a cohort survey) that included a baseline data collection and a three-year follow-up. Both data collection involved self-administrated questionnaires, structured interviews, clinical assessments, and observations during home visits effectuated by research staff, with project-specific training. One hundred and sixty participants with PD were recruited. Data collection targeted environmental factors such as AT device, social support, physical environmental barriers, accessibility problems, and perceived features of home (i.e., assessed by the project administrators during structured home visits). A broad variety of instruments tapped PD-specific problems (e.g., FOG, fear of falling), and health-related issues such as general self-efficacy, body functions, activities, and participation. Knowledge to the benefit of the development of health care and societal planning that targeted people ageing with PD was provided, ultimately promoting activity and participation, an increase of the number of healthy life years for this specific sub-group of the population. The longitudinal study added relevant information for practitioners, parents, and caregivers while dealing with PD patients' care.

### Leisure and occupation

To prevent isolation, passivity and withdrawal, AT-based programs focused on leisure and occupation ac-

tivities for promoting self-determination, independence and an active role of people with PD. The main concept, which should be closely associated to leisure and occupation activities for enhancing constructive engagement and positive participation of individuals with PD is the cognitive reserve (CR). CR has been formulated to explain the gap between the degree of brain injury or pathological changes and clinical observations. According to the CR hypothesis, differences of patients with PD in the task processing can be explained by their CR against brain pathology. CR has been divided in active and passive forms. Passive reserve, also defined brain reserve, includes long standing inter-individual variations in the brain. That is, it allows some people to cope better. Active reserve, also called CR, the brain actively enlists pre-existing cognitive programs and compensatory strategies. Both constitute the CR [23]. Specifically, the active reserve requires a constructive and behavioral (i.e., which may be directly observed) engagement of the individual involved, while the passive reserve refers to the coping strategies, which may not always directly observed. Five studies were included in this section, with 3109 participants involved (see Table 2) [24-28].

For instance, Cieza, et al. [24] identified a set of psychosocial difficulties closely linked with short term changes in health outcomes across a heterogeneous set of brain disorders, neurological and psychiatric impairments. A longitudinal observational study, which lasted approximately 12 weeks was carried out, with three time points of assessment and 741 participants with bipolar disorders, depression, migraine, multiple sclerosis, PD, stroke, and traumatic brain injury was carried out. Data on the disability were collected with the checklist of the International Classification of Functioning, Disability and Health [29,30]. The selected health outcomes were the Short Form 36 and the World Health Organization Disability Assessment Schedule Multilevel models for change were applied controlling for age, gender, and disease severity. Results evinced that psychosocial difficulties which explained the variability and change over time of the selected health outcomes were energy and drive, sleep and emotional functions, and a broad of activities and participation demands, such as problem solving, conversation, areas of mobility and self-care, relationships, community life and recreation, and leisure. Significant data were collected through the longitudinal study as to improve PD patients' well-being.

Lancioni, et al. [26] investigated whether simple

**Table 2:** Reviewed studies on AT-based interventions for leisure and occupation.

| Authors | Participants | Mean age | Strategies | Outcomes |
|---------|--------------|----------|------------|----------|
| Cieza, et al. [24] | 741 | 54.5 | Longitudinal study | One negative |
| Goldman, et al. [25] | 99 | 61.7 | Epidemiologic design | Nine negative |
| Lancioni, et al. [26] | 3 | 72.5 | Microswitches + Computer | Three positive |
| Shih, et al. [27] | 1909 | 68.7 | Job exposure matrix | Nine negative |
| Shih, et al. [28] | 357 | 65.5 | Self-reports | Seven negative |

**Table 3:** Reviewed studies on health problems.

| Authors | Participants | Mean age | Strategies | Outcomes |
|---|---|---|---|---|
| Berardelli, et al. [33] | 20 | 66.5 | CBT | Twenty positive |
| Connor, et al. [34] | 347 | 68.8 | Multi-faceted Program | Seven negative |
| Dissanayaka, et al. [35] | 17 | 70 | CBT | Five negative |
| Freund, et al. [36] | 1 | 71 | Deep-brain-stimulation | One positive |
| Lawson, et al. [37] | 66 | 56.2 | Neuropsychological approach | Six negative |
| Mulders, et al. [38] | 60 | 71.2 | CBT | Sixty positive |
| Shinmei, et al. [39] | 19 | 70 | CBT | Nineteen positive |
| Valldeoriola, et al. [40] | 24 | 69.6 | Brain stimulation | Two negative |

technology-aided programs could be adopted to support leisure and communication opportunities in three elderly with advanced PD. The program included music and video options, which were combined with (a) Text messaging and telephone calls for the first participant; (b) Verbal statements/requests, text messaging, and reading for the second participant, and (c) Verbal statements/requests and prayers for the third participant. The participants could activate those options through hand movement or vocal emission and related micro switches. All three participants successfully used the technology for activating the available options. The technology was helpful for promoting participants' self-determination and independence towards their environment.

Shih, Liew, Krause, and Ritz [28] examined physical activities across the lifespan and risk of PD. Three hundred and fifty-seven patients with PD were involved, with 341 controls. Physical activity levels via self-report of (a) Overall physical activity (PA) over 4 age periods; (b) Competitive sports, and (c) Occupational histories. Results outlined that PD risks were lower comparing the overall PA highest quartile (i.e., moderate to vigorous activities), with the lowest quartile in age period 18-24 years. Individuals who consistently engaged in overall PA at high levels (before 65 years of age) had a 51% lower risk of PD than those with low levels. Additionally, having participated in competitive sports prior to age of 25 was inversely linked with PD. However, no association was found between occupational physical activities and PD risks. It was unclear whether the PD risk was associated to a reduction of physical activity years before the motor symptoms onset and PD was diagnosed. Nevertheless, sports activities and high levels of general PA in youth seemed to be protective unless they were markers for biologic or genetic factors that lower PD risk. The study provided further suggestions and recommendations on the physical activities which may be useful for preventing PD.

### Health problems

Next to gait difficulties, isolation, withdrawal, and passivity, PD may have a negative impact on several health areas (e.g., emotional well-being, sleep disorders, depression, dementia) and on participation in daily activities. To minimize the negative outcomes on the patient's quality of life, self-management skills should be enhanced. Thus, independence and self-determination should be pursued. Self-management includes having knowledge, skills, and confidence to manage daily tasks and live well with a chronic condition. These skills involve monitoring progress and problems, problem-solving, and goal attainment. Caregivers can influence self-management skills of their patients adopting a comprehensive approach that provides education and supportive interventions to improve patients' skills and confidence in positively solving their health problems. Self-management may be viewed as crucial feature to significantly reducing the negative effects of the disease. That is, it may contribute to slowed disease progression, decreased complications, and lowered costs. Both AT-based programs and cognitive-behavioral interventions may be helpful for that objectives [31,32]. Eight studies were included in this section, with 554 participants involved (see Table 3) [33-40].

An illustrative example is represented by Connor, et al. [34] who developed indicators to measure the quality of care delivered to patients with PD, and identified gaps in delivering evidence-based interventions for this population. Accordingly, a multi-faceted proactive implementation program, called Care Coordination for Health Promotion and Activities in PD (CHAPS), was designed. Three hundred and forty-six patients were enrolled. The program consisted of telephone assessments, evidence-based protocols, and tools to enhance patient self-management, care planning, and coordination of care across providers, including an electronic database to support and track care coordination. A randomized, controlled trial design was adopted to test whether CHAPS intervention improved the participants' performance. Thirty-eight quality measures were categorized into overarching areas of communication, education, and continuity. Additionally, regulatory reporting, diagnosis, periodic assessment, medication use, management of motor and non-motor symptoms, use of non-pharmacological therapies, palliative care, and health maintenance were considered. Secondary outcomes were participant health-related quality of life, self-efficacy, and perception of care quality. Outcomes were assessed by interviewer-administered surveys collected at baseline, and 6, 12, and 18 months, and by medical record chart abstractions. The examined indicators revealed how the delivered care could be helpful for improving PD patients' quality of life.

Freund, et al. [36] described a deep brain stimulation-based program (DBS) for the modification of cognitive functions in an elderly with severe PD-dementia syndrome, who were aged of 71 years. A prospective study with double-blinded sham stimulation period was carried out. Two electrodes into the nucleus basalis of Meynert and two electrodes in the sub-thalamic nucleus were inserted. Results emphasized that by turning on the sub-thalamic nucleus electrodes improved motor symptoms but left cognitive functions unchanged. By turning on the electrical stimulation of the nucleus basalis of Meynert, a markedly improved cognitive function was observed. Improved attention, concentration, alertness, drive, and spontaneity were recorded. Additionally, a renewed enjoyment of former interests and enhanced social communication were evinced. This study demonstrated how such approach could facilitate the recovery of a patient with PD.

Mulders, et al. [38] assessed a randomized controlled trial (RCT) aimed at analyzing the effectiveness, alterations in brain circuitry, and cost-effectiveness of a cognitive-behavioral therapy (CBT) for anxiety in PD. Sixty participants were recruited. A prospective investigation, two-centre RCT with a randomization of the CBT and clinical monitoring (i.e., intervention group) was conducted. Patients underwent standardized clinical, cognitive, and behavioral assessment at baseline, and at two follow-up assessments, as well as fMRI scanning before and after the intervention. The primary outcome measure was changes in severity of anxiety symptoms. Secondary outcome measure included long-term changes in anxiety symptoms, changes in functional and structural connectivity between limbic and frontal cortices, and cost-effectiveness of the treatment. This contribution outlined the role of a CBT-based therapy for preventing and/or reducing anxiety in PD patients.

## Discussion

Data of the reviewed studies were widely positive, and confirmed the effectiveness and the suitability of both strategies. Occasional failures occurred (i.e., 1.4%). AT-based programs and cognitive-behavioral interventions were helpful for promoting independence, self-determination, and self-management of daily activities by patients with PD. The isolation, withdrawal, and passivity were prevented. The progression of the disease was arrested, and the participants' active role, constructive engagement, and positive occupation were fostered. The families and caregivers burden was reduced. These beneficial effects had positive outcomes on the participants' quality of life. The learning process was consolidated over the time. The health problems significantly decreased. Conversely to the pharmacological approach, which should be administrated along the life once the disease emerged, the AT-based solutions seemed to be more effective for independence and self-determination of the participants involved. The re-sults were consistent with previous findings [41-44] and suggested the following considerations.

First, AT-based intervention may be useful for preventing gait and posture difficulties. The reviewed studies of the first category emphasized the reliability of the technological solutions for preventing FOG phenomenon. Locomotion fluency was enhanced and step responses increased during the intervention accordingly. AT may be considered as a great psychological and rehabilitative resource for promoting high motivation, self-determination, and independence of the participants. Thus, patients with PD were constantly and contingently rewarding by performing forward steps. One may argue that their active role was relevantly improved during the intervention sessions, with positive outcomes on their social image and status [45,46].

Second, AT-based programs may be viewed as critical for increasing leisure and occupation. Daily activities were promoted and the participants' positive involvement was critically supported. The participants were constructively engaged and their independent capacities of achieving their daily goals was emphasized. By adopting individualized solutions, the learning process was consolidated, with beneficial consequences on them-selves, their families, and caregivers. The participants profitably used their cognitive reserve for leisure and occupational purposes. Data of reviewed studies demonstrated that their adaptive responding during the sessions was purposeful [47,48].

Third, the cognitive-behavioral interventions were successful for reducing health problems. Thus, the adaptive responding was encouraged and the challenging behaviors disappeared. Two basic explanation could be putted forward. On one hand, patients with PD were no longer engaged in health problems. That is, the positive stimulation, the therapies, and the activities proposed were adequately rewarded and the participants no more needed to deal with health difficulties, because sufficiently motivated externally (i.e., extrinsic motivation). Otherwise, one may argue that they redirected their anxiety, depression, and/or health problems, into newest and favorable adaptive responding, with beneficial outcomes for their quality of life [49,50].

Fourth, the learning process was corroborated and consolidated over the time. Even if the intervention was suspended, the participants maintained their performance during follow-up phases. This specific data evinced the quality of the intervention. Thus, the suggested activities, the targeted behaviors, and the stimulation retained constituted tailored solutions strictly adapted for their participants. In other words, the causal association between behavioral responses at low costs for the participants, and the positive stimulation highly motivating was demonstrated to be very

strong, with relevant consequences on the participants' well-being [51,52]. The combined cognitive-behavioral intervention with an AT-based program may be considered for individualized solutions, responding to both financial and human resources on the patients, parents, and caregivers involved.

## Limitations and Future Directions

Despite the positive outcomes, some crucial features still remain to be investigated. For example, one may envisage social validation assessment involving external experts (e.g., caregivers, families of patients with neurological disorders other than PD, psychologists, neurologists) as raters. The intervention's clinical and social validity could be confirmed accordingly. Furthermore, one can consider preference check assessments between two different strategies (e.g., AT and CBT) for the participants involved as to assert whether both are considered valid and/or one is preferable to the other. Additionally, one could extend and compare the use of such strategies to other neurological disorders (e.g., Alzheimer disease) [53,54]. Furthermore, we reviewed only twenty studies as an overview of the literature. Further empirical contributions as part of a systematic review on this specific topic should be examined. Moreover, the pharmacological treatments along the current review were substantially ignored. Finally, the combination of the cognitive-behavioral interventions, the AT-based programs, and the pharmacological therapies were not emphasized.

Concluding, in light of the above, new research perspectives should deal with the following topics. First, new extensions of both strategies to new participants with PD and/or other neurological disorders. Second, further enlargement of the AT options, which should be affordable for both families and caregivers, and suitable (i.e., individualized) for the participants involved. Third, the considerations of social validation procedures, as above argued. Fourth, further data collection of indices of positive participation as outcome measure of participants' constructive engagement and improved quality of life. Fifth, systematic reviews which should consider (a) A significant higher number of empirical studies; (b) The combination of the cognitive behavioral interventions with the AT-based programs, and the pharmacological therapies, and (c) Strengths and weaknesses of each approach considered.

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Perilli et al. Int J Psychol Psychoanal 2018, 4:038

• Page 7 of 7 •