Sistematic review

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Evaluation of physiotherapy and speech therapy treatment in patients with apraxia: a systematic review and meta-analysis

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Abstract

Apraxia affects 20% of the right brain-damaged patients and 50% of the left brain-damaged patients. This disorder of motor programming reduces patients' independence and there are few guidelines on the rehabilitative treatment in the physiotherapy and speech therapy field.

The aim of this study was to assess which therapeutic interventions are the most effective in stroke patients with apraxia in considering the mentioned purviews.

Four databases were systematically searched in order to detect all available studies investigating the physical and speech rehabilitation of patients. The literature research produced five studies including 168 patients for the physiotherapy and 50 for speech therapy fields; two were eligible for meta-analysis. Quality was rated with Jadad, PEDro scale and Cochrane Risk Of Bias Tool. Both for physiotherapy and speech therapy fields, the RCTs interventions obtained statistically significant results for outcomes of interest. Despite this, it is still not possible to determine the best approach due to the low number of patients involved, the lack of maintenance of the results at follow up and the timing of the revaluation period being very short to confirm the efficacy of treatments. ***Clin Ter 2020; 171 (5):e454-465. doi: 10.7417/CT.2020.2257***

Key words: *apraxia, treatment, therapy, rehabilitation, physical therapy, speech therapy*

Introduction

Apraxia covers a wide spectrum of higher order motor disorders caused by acquired brain disease that affects the capacity required to carry out intentional, finalized and sequential action, with or without preservation of the ability to perform the same movement outside the clinical setting in the appropriate environment or situation. (1) Apraxia is not a well-localized disorder, and many different lesions can lead to apraxia, including parietal, frontal and subcortical lesions. It is almost always associated with injury to the left hemisphere or the corpus callosum, and has been described specifically in context of premotor cortex (preMC) and motor lesions. (2) Half of the patients affected by a stroke manifest apraxia (3) and this condition has important implications for recovery and rehabilitation.

The apraxic disorder is characterized by voluntary automatic dissociation, in which the same gesture performed correctly in response to contextual stresses or internal needs fails when it is required by the examiner, out of any internal or external motivation. Therefore, it was considered that voluntary automatic dissociation did not cause any consequences in conducting activities of daily living (ADLs), but several studies (4,5) described negative ecological implications (e.g. grooming, bathing, and toileting relative to age-matched control subjects). In addition, principal rehabilitation outcomes linked to ictus, such as the Functional Independence Measure (FIM) and the upper extremity section of the Fugl-Meyer Assessment (FMA), show a lower average score at discharge in apraxic patients than in non apraxics,(3) with difficulties in reintegrating patients with apraxia into their daily and working context.(6) Obstacles, as the difficulties in reproducing a significant rehabilitative setting, are well-known by physiotherapists and speech therapists, who have to treat disorders that compromise the functionality of the gesture in all forms: both the purpose of the voluntary motor act and the effectiveness of the communicative message.(7) The last stroke guidelines,(8) recommend starting a rehabilitation program, especially for those suffering from limb and buccofacial apraxia.In this review, authors focused on apraxia's forms that hinder the re-acquisition of autonomy for patients.

Limb Apraxia: planning deficit that obstructs the voluntary movement of the arms, hands, legs and feet (ideo-motor apraxia and ideative apraxia). (9)

Apraxia of speech (AOS) is a disorder of speech production characterized by sound distortions; increased durations within and between sounds, syllables, words and disturbed prosody. AOS is not related to language processing, as with aphasia but affects the planning and programming of speech. (10) AOS is an independent deficit affecting a processing level separate from phonological assembly and motor implementation.

Buccofacial apraxia (BFA) may be defined as the inability to perform voluntary movements of the larynx, pharynx, mandible, tongue, lips, and cheeks while maintaining the automatic or reflexive control of these structures.

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Recent studies (11,12) suggested that principles of motor learning may provide an improved means of treating a variety of apraxic disorders. The patients had to learn to use the damage motor system in a new way to accomplish an environmental goal. In this process, both physical and speech therapists act as a facilitator instructor, using techniques of the motor learning, such as providing instructions or verbal and physical guidance. (13)

According to the "scheme theory", (14) the patient don't learn specific movements, but a "generalized motor programs" and in this framework the motor rehabilitation proposed two main approaches. The *Restitution Approach*, whose goal is to bring the deficit function to the same pre-morbid efficiency and to reconstruct the compromised cognitive functions and the *Compensatory Approach*, in which the aim is to train the remaining functions to substitute for the deficit functions and find alternative compensation strategies. (15)

Speech and language therapists use many differing treatment techniques in clinical practice (16) yet there are no evidence from randomised trials to support or refute the therapeutic approach AOS after stroke. (17) In the 2006 AOS guidelines report, four general categories of treatment approaches were identified: *articulatory kinematic, rate/ rhythm control, intersystemic facilitation/reorganization and alternative/augmentative communication* (AAC). (18) The weight of evidence supports a strong effect for both articulatory kinematic and rate/ rhythm-based interventions. (19)

Currently, apraxia is still considered a rehabilitation problem (20) both for patients, that are compromised in everyday life and slowed down in the stroke recovery, and for therapists who have no guidelines and recommendations to follow. The latest systematic reviews, in exploring apraxia's interventions (21) have pointed to a lack of scientific evidence supporting the effectiveness of a therapeutic approach. The purpose of this systematic review is therefore to evaluate the current evidence regarding the available physiotherapy and speech treatment on the field of apraxia to make suggestions to rehabilitation therapists regarding how to approach them.

Methods

This study was conducted by a research group composed by medical doctors and rehabilitation professionals from the "Sapienza" University of Rome and from "Rehabilitation & Outcome Measure Assessment" (R.O.M.A.) association. R.O. M.A. association in the last few years has dealt with several systematic reviews and the validation of many outcome measures in Italy. (22-32)

Protocol and registration. Methods of analysis and inclusion criteria were documented in the protocol registered on Prospero and can be consulted on the site https://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42017065429

Study Design. Randomised controlled trials were included. Group comparisons, pre-post comparison designs, book sections and single-case study designs evidence were excluded. There were no language or year of publication restrictions. All studies considered had at least one outcome of interest in the evaluation of apraxia as the presence or absence of apraxia, the alteration of imitative abilities, transitive or intransitive gestures, temporal and spatial sequence errors, buccofacial motor control and accuracy of speech articulation. Moreover, we considered the level of impairment in daily life activity. Studies measured the outcome of interest with both validated and unvalidated scales.

Participants. The inclusion criteria were as follows: randomised control trials of apraxia with enrolled patients of age > 19 with limb, ideomotor, ideational, buccofacial and apraxia of speech due to neurological lesions, such as unilateral vascular lesions, developed after a stroke. No exclusion criteria were applied.

Interventions. Eligible studies investigating physiotherapy and speech therapy interventions in the treatment of apraxia in adult stroke survivors, specifically with limb, ideomotor, ideational, buccofacial and apraxia of speech. Studies investigating the effectiveness of apraxia rehabilitation treatment using medications or procedural interventions, such as surgery and implanted electrical stimulation, are excluded.

Comparisons. Sham therapy, standard care/other treatments were considered control interventions. In this review, we refered to sham interventions as all interventions mimicking the specific treatment for the one aspect of apraxia, but modifying at least one aspect of the traditional treatment.

Outcome measures. The physiotherapy field should consider the following outcomes: the apraxic limb functions and the difficulty in carrying out transitive and intransitive gestures generally evaluated with these scales: the 'Test of upper limb apraxia, Tulia', (33) the 'Apraxia test by De Renzi and colleagues', (34) 'Cologne apraxia screening, (35) (CAS)', the 'Van Heugten apraxia test', (36) 'Kertesz and Ferro apraxia test' (37) and the level of independence in carrying out ADLs, which is generally evaluated through 'Barthel ADL Index'. (38) While speech therapy field should consider the articulation' s accuracy and buccofacial performing movements that generally are evaluated through validated scales such as the 'ABA-2: Apraxia Battery for Adults–Second Edition' by Tafiadis et al. (39) and not validated scales.

Search methods. All literature published until March 2017 was retrieved through a comprehensive systematic search on the following databases: PubMed, MEDLINE, CINAHL and PEDRO. No relative limitations were applied to the language of publication, and foreign language (as English) articles were translated. The last bibliographic search was performed on 20 July, 2017.

The database searching was performed manually and the duplicates were also manually excluded by an independent analysis performed by two reviewers. Records were examined and evaluated according to the inclusion criteria: those that didn't correspond to the inclusion criteria for age, pathology or manifestation of the type of apraxia were excluded. The details on the search strategy are provided in the Supplementary Material.

Data collection and evaluation. Data extraction was carried out independently by two reviewers. Extracted data included the type of interventions, number of patients, study results and all other descriptive characteristics reported in

the included trials. Where reported details were missing or insufficient, the authors were contacted. All data were stored in a specific hard disk, managed only by the two reviewers. Disagreements were discussed and resolved by consensus or by a third reviewer.

Data extraction (selection and coding). The following aspects of the included studies are analysed: type of interventions and comparison, number of patients and age's average, study results, follow-up (schedule), outcome measurements and all other descriptive characteristics reported in the included trials. Where reported details were missing or insufficient, authors were contacted. All data were stored in a specific hard disk, managed only by the two reviewers. Disagreements were discussed and resolved by consensus.

Risk of bias (quality) assessment. The risk of bias was assessed in accordance with Cochrane Collaboration's risk of bias methods. (40) Figures are generated using RevMan 5.3 to provide summary assessments of the bias risk. The PEDro an Jadad scores are specifically designed to assess the quality of trials and include specific questions for the identification of potential methodological issues/biases. The Jadad score includes three items: allocation, blinding, and description of withdrawals and dropouts. One point is assigned for each item if an accurate and detailed description is provided, while if the item is judged inadequate or incomplete, the point is withdrawn. The highest possible score is five points, and studies scoring less than three points are usually considered as being of low methodological quality. The "PEDro Rating Scale," consisting of 11 criteria including, for example, allocation concealment, blinding of partecipants and therapists, intention to treat analysis and dropouts. The rating scale is a checklist of "yes or no" answers to each criteria that totals the "yes" answers. The highest score is therefore an 11, which would make that trial of particular interest and more than 7 for the PEDro score considered of high methodological quality. For the Cochrane Risk of Bias tools, five domains are included: sequence generation, allocation concealment, blinding to personnel, blinding to outcome analysis and incomplete outcome bias. RoB was assessed for each domain according to a three-point scale: low RoB, unclear RoB and high RoB. (41)Two authors independently assess the bias risk in the included trials. Any disagreements are resolved by reaching a consensus or consulting a third reviewer.

Measures of treatment effect. When available, data for continuous variables were reported as MDs (Mean Difference), along with their 95% CIs (confidence interval), while dichotomous outcomes were reported as RRs (relative risk) along with their 95% CIs. In the case of missing data, the authors of the studies were contacted for further information.

Assessment of heterogeneity. Mean interrater reliability in the qualitative assessment using the Jadad score resulted in a kappa value of 0.74, while the kappa value for the qualitative assessment using the Cochrane RoB tool was 0.68.

Data synthesis. Data from the review were reported according to the PRISMA statement. A meta-analysis of either dichotomous outcomes or continuous outcomes was carried out whenever possible; when a meta-analysis was not possible, results were presented using summary and descriptive statistics. Meta-analyses were carried out using Review Manager version 5.2.6 and the p-value was considered statistically significant at <0.05.

Results

Results of the search. A total of 87 records have been id

entified corresponding to the selection criteria applied through database searches and manually searching for other sources. The 68 duplicates were manually excluded by an independent analysis performed by two reviewers. The remaining 19 records were screened and another 12 of those were excluded, due to the age of the patients (<19 years), the apraxia linked to another pathology, as Multiple Sclerosis (MS) and Alzhaimer and for the manifestation of another type of apraxia different from those investigated, as Gait Apraxia (loss of ability to walk correctly) or Costructional Apraxia (inability to draw or construct configurations).

The 7 studies were found to be suitable for inclusion criteria, but two of them were pilot studies.

The full texts of the 5 remaining studies were included and assessed for qualitative synthesis.

Only two studies were included for the quantitative synthesis.The full texts of the 5 remaining studies were retrieved and assessed for inclusion and were qualitatively assessed. All included studies were in English. Two trials have been conducted in Italy, one was carried out in Dutch and two in England. All the included studies except for one were published before 2006 and were RCTs with a parallel-group among which speech therapy study used a crossover design. (Fig. 1).

Interventions and comparisons. The articles included in the qualitative analysis correspond to the criteria of inclusions applied: all five articles were RCTs with patients over the age of 19 and the lesions that caused the disease were attributable to the onset of unilateral right or left stroke. All trials considered motor and speech treatment for apraxia as their primary intervention. *(Data extraction, Table 1)* In this review, authors included all the RCTs that concerned the treatment of apraxia to obtain strong evidence-based results for guiding therapists' behaviour who interfere with pathology.

Physiotherapy studies. It should be emphasized that the rehabilitation of apraxia is very cross-cutting and non-sectoral. For this reason, with reference to the latest evidence of the physiotherapy rehabilitation for strokes and treatment for apraxia. (42,43) we decided to also include studies in which the intervention of interest was provided by other figures to avoid missing those relevant the aim of our research. In both Smania' s studies, (44,45) the study groups underwent on a transitive/intransitive gesture training programme with production exercises, while the control groups received aphasia therapy.

The experimental treatment is divided into three parts: the first is related to transitive gestures, requiring the demonstration of the use of an object, the recognition of the action with the object and the execution of the pantomime related to the use of the object; the second, the intransitive-symbolic part entails performing gestural activities with meaning (such as "waving bye bye") in different contexts

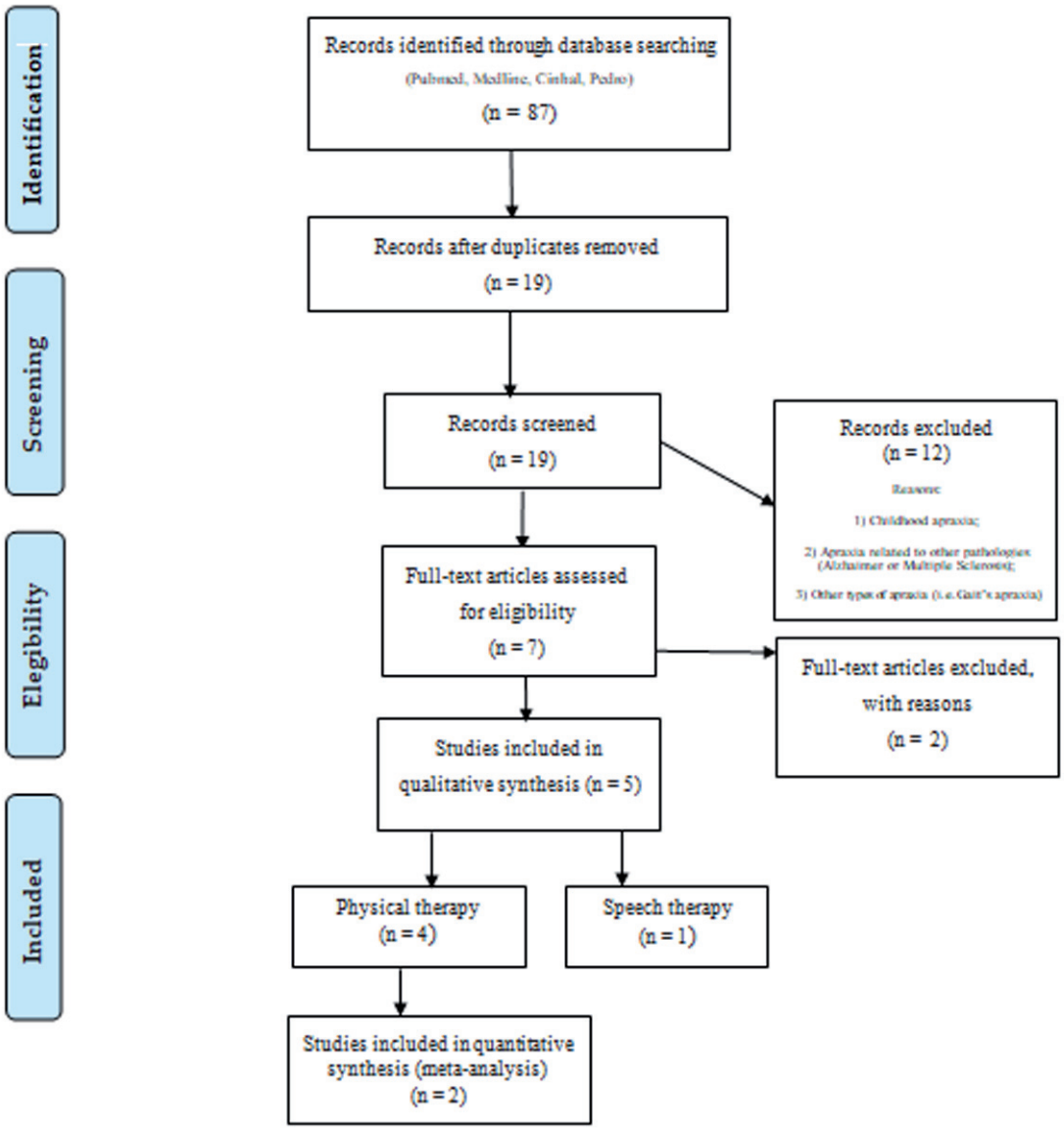

Fig. 1 Flow-chart
87 records have been identified through database searching.
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The remaining 19 records were screened and another 12 of those were excluded, due to the age of the subject (<19 years), the apraxia linked to another pathology, as Multiple Sclerosis and Alzhaimer and for the manifestation of another type of apraxia different from those investigated, as Gait Apraxia (loss of ability to walk correctly) or Costructional Apraxia (inability to draw or construct configurations).
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Only two studies were included for the quantitative synthesis.

and the third, the intransitive-non symbolic part, is based on the imitation of meaningless intransitive gestures previously shown by the examiner. The first study(45) enrolled 13 patients with ideomotor limb apraxia. Fifty-minute treatment sessions were administered three times per week for approximately 10 weeks, with the number of total treatment sessions ranging from 30–35. The second study (44) assessed whether rehabilitation program for LA may increase not only praxic ability, but also independence from caregivers during ADLs. Forty-one post-acute left hemisphere stroke patients with limb apraxia (either ideational or IMA – not defined) were assigned randomly to treatment or no-treatment groups. Patients attended 30 fifty-minute sessions over the course of 10 weeks.

In Donkevoort's study (46) the study group received the strategy training method developed for patients with ADL impairment secondary to apraxia. Patients trained on three ADLs, decided together with the therapist to choose activities that were carried out by the patient before the occurrence of the stroke; in this training the therapist can use internal or external compensatory strategies to improve the independence in doing the activity. Instead, the control

Author of the study	Design of study	Outcome Measure	Description of Intervention and Comparison	Objective	Schedule	Participants	Aetiology	Results	Pedro Scale	Ja-dad Sca-le
SPEECH THERAPY STUDY										
Varley et al., 2016.	Randomized control trial with crossover	Primary outcome: communicative adequacy of spoken naming. Secondary outcome: phonetic accuracy of words in repetition	GS: speech intervention based on self-administered computer therapy given for 1-2 times a day for 20min. GC: visuospatial sham program	To determine effectiveness of the speech intervention in improving communicative adequacy of word production	Two evaluations at baseline; FU: 6 weeks	50: GS (men: 17, women: 18); GC (men: 12; women: 13) Mean Age: GS: 63; GC: 68	Unilateral left hemisphere lesion	Improvements in both naming and repetition in speakers with AOS impairments; largely maintenance (>18wks)	8/10	3/5
PHYSICAL THERAPY STUDIES										
Smania et al., 2000.	Randomized controlled trial	Primary outcomes: A standard test for ideomotor apraxia (De Renzi E., et al.;1980), no standard test for ideational apraxia and gesture comprehension test. Secondary outcomes: Raven's Progressive Matrices (Lewis, H.K.;1962); Token Test by De Renzi and Faglioni (De Renzi, E.; Faglioni, P. 1978); Oral Apraxia test (De Renzi, E. et al.;1966) and Costructional Apraxia Tests (Arrigoni, G., De Renzi, E.; 1964)	GS: experimental rehabilitative training for limb apraxia; given for 35 sessions of 50 min. GC: conventional treatment for aphasia	To assess the effectiveness of a rehabilitative training program for patients with apraxia	At baseline and at the end of treatment, except the aphasia test; no FU	13: GS (men: 5, women: 1); GC (men: 5; women: 2) Mean Age: GS:69.3; GC: 62,1	Left hemisphere lesion	Significant improvement of performance in both IA (Z 2.06, p .039) and IMA (Z 2.02, p .043) tests.	4/10	2/5
Smania et al., 2006.	Randomized controlled trial	Primary outcomes: A standard test for ideomotor apraxia (De Renzi E., et al.;1980), no standard test for ideational apraxia, gesture comprehension test. and ADL questionnaire score. Secondary outcomes: Raven's Progressive Matrices (Lewis, H.K.;1962); Token Test by De Renzi and Faglioni (De Renzi, E.; Faglioni, P. 1978); Oral Apraxia test (De Renzi, E. et al.;1966) and Costructional Apraxia Tests (Arrigoni, G., De Renzi, E.; 1964) Secondary outcomes: Raven Test; Token Test; Oral Apraxia and Costructional Apraxia	GS: experimental rehabilitative training for limb apraxia given for 35 sessions of 50 min. GC: conventional treatment for aphasia	To assess the effectiveness of rehabilitative training program for patients with limb apraxia in increasing praxic ability and independence from caregivers during ADL	At baseline and at the end of treatment; FU: 2 months	33: GS (men: 12; women: 6); GC (men: 11; women: 4) Mean Age: GS: 65,7; GC: 65,7	Left-sided unilateral vascular lesion	Significant improvement in IA, IMA, gesture comprehension test and ADL questionnaire (ADL-IA: R 0.65, p 0.001; ADL-IMA: R 0.48, p 0.01; ADL-gesture comprehension: R 0.37, p 0.034). No maintenance at FU	8/10	2/5

Table 1 Data extraction

Donkervoort et al.,2001.	Randomized, single blind, controlled trial	Primary outcomes: standardised ADL observations (Van Heugten et al., 1999a, 2000a); general ADL measures: the Barthel ADL Index (Wade and Collin, 1988); an extended ADL judgement list filled by the OT and a list filled in by the patient; the Apraxia Test (De Renzi, 1989; Van Heugten et al., 1999b); the Motricity Index (Demeurisse et al., 1980) and the Functional Motor Test (Lyle, 1981). Additional measures not mentioned in the table were used to monitor the patients' general cognitive functioning during the study.	GS: Strategy training and occupational therapy given for 8 weeks. GC: occupational therapy only.	To determine the efficacy of strategy training in Patients with apraxia	At baseline, at 8 weeks and FU: 5 months	113: GS (men: 29; women:27); GC (men: 35; women:22). Mean Age: GS: 67,6; GC: 63.3	Left hemisphere lesion	Improvement on the ADL observations: F(1, 81) = 3.52, p = .03. Barthel ADL index showed significant, effect in favour of strategy training: F(1, 92) = 7.31, p < .01. No significative improvement in apraxia. No maintenance at FU	8/10	3/5
Edmans et al., 2000.	Randomized, single blind, controlled trial	Primary outcomes: Rivermead Perceptual Assessment Battery (Whiting, S. et al; 1985) for perceptual ability; for ADL ability the Barthel ADL Index (Mahoney, FI et al., 1965) using the scoring by Collin et al. (1988) and Edmans ADL Index (Edmans et al., 1997). Secondary outcomes: Gross Function scale (Lincoln, NB., and Leadbitter, D., 1979)	GS: transfer of training, given for 2.5 hours per week for 6 weeks GC: functional approach.	To compare the effectiveness of the transfer of training and functional approaches in improving perceptual and functional abilities	At baseline ; FU at 6 weeks	9: GS: 6 (gender has not been specified); GC: 3 (gender has not been specified) Mean Age: GS: 70; GC:69	Left unilateral lesion	No significant difference was found in the amount of improvement in perceptual ability after six weeks treatment following either the transfer of training or functional approach	6/10	2/5

Abbreviations: AOS = Apraxia Of Speech; GS = study group; GC = control group; FU = follow-up; IA= ideational apraxia; IMA= ideomotor apraxia; OT= occupational therapist

group received occupational therapy only, and the duration of both treatment was an eight-week period, but the intensity was not specified.

Edmans's study (47) compares the effectiveness of the transfer of training and functional approaches in patients with difficulties in perceptual and functional abilities after left and right hemiplegic strokes. The transfer of training approach is concerned with treating the cause of the perceptual problem and the functional approach is the repetitive practise of particular tasks, usually ADLs to make the patient more independent. Nine patients with apraxia were treated with these two approaches, and perceptual treatment was administered for one half-hour per week for six weeks, in addition to their general OT treatment. (Table1)

As far as physiotherapy studies are concerned, encouraging results have been achieved in the improvement of ideomotor, ideational apraxia and in gestural understanding in both Smania studies. (44,45) The strategy training proposed by Donkervoort (46) has led to an improvement in the ADL performed by patients with apraxia. As for Edmans, (47) the improvements recorded were relevant for perceptual skills, not relevant for the improvement of the level of apraxia. Overall, in the follow up, (44,46,47) the results were not maintained. For more detailed information, refer to the discussion section.

Speech therapy study. The Varley's study (48) used a parallel-group, two-period, crossover design for 50 patients with chronic post-stroke apraxia of speech. They underwent a self-administered computer therapy based on speech content (intervention group) and visuospatial activities (sham group). The intervention group (25 patients) was involved on software therapy divided into a perceptual stage, (multimodality sensory stimulation), a production stage (trials requiriring imagined word production and repetition tasks) a final stage (use of trained words in sentence frames followed by independent word recapture). All patients were loaned a laptop once or twice a day for at least 20 minutes for 6 weeks, and the intensity of treatment was self-determined by the patient (Table1). For the speech therapy study, the results provide evidence that self administered computer therapy can improve word production in patients with chronic apraxia of speech. Even if treatment effects were generally specific to trained words, they were largely maintained when interventions were withdrawn.

Sample size and length of study. The included physiotherapy trials enrolled a total of 168 patients; for the speech therapy trial, the size was of 50 patients. All included patients were adults (age mean 67.54: range: 41–78). Three trials on five reported the length of follow-up, which ranged from six weeks to five months (Smania et al., 2006: two months; (44) Donkervoort et al., 2001: five months;(46) Varley et al., 2016: six weeks (48)). Smania et al., (2000) and Edmans et al,. (2000) (47) did not report any follow up. At the baseline, at least four out of five studies had comparable features and numbers of patients. Edmans's study had similar characteristics, but the sample size differed. Most of the treatments in these studies were carried out in stroke units, but in one case it was not specified.

Outcomes reported. In physiotherapy field, three studies have reported as outcome the impairment on transitive and intransitive gestures due to apraxia, and four studies have reported the level of disability in ADL; one has also reported levels of perceptual abilities. Smania et al., (2000) (45) focused principally on the level of ideational, ideomotor apraxia and understanding of the gesture. (49) Subsequently, Smania et al., (2006) (46) expanded their field of interest, not only to the aforementioned outcomes on the apraxia, but also to the consequences of disease on ADLs (not standardized ADL questionnaire, (Appendix E) (44). Donkervoort et al., (46) also assessed the level of impairment in ADLs related to apraxia and motor functioning, by a researcher and by the patient himself (ADL observation and ADL judgement. (50) Edmans et al., (47) instead, focused on perceptual problems after a stroke and assessed mainly perceptual and functional abilities (51), Barthel ADL Index (38) and Edmans ADL Index (52) and motor performance (RMA Gross Function scale, (53) but considered also the level of motor apraxia impairment. (37)

In speech therapy field, the study reported as a primary outcome the communicative adequacy of spoken naming and as a secondary outcome the phonetic accuracy of words in repetition. For measure both outcomes, three word sets were each containing 35 items. (Word sets are available in Table I – Supplemental Material). (48) In repetition task, patients had to repeat items after live presentation by an experimenter. Words were presented in a fixed pseudorandom order with no phonetically similar items appearing in sequence. Repetition responses were coded on a 0- to 7- scale based on accuracy's level. (Accuracy Scoring Protocol for the Speech Repetition Task is available in Table II - Supplemental Material). (48)

Naming performance was scored on 23 triplets words (strings of three); only triplets with good name agreement by healthy speakers were included and responses were scored as correct/incorrect (1/0). No cues were given in either task other than orientation cues to key elements of photographs in naming. Speech responses were audio recorded for subsequent analysis by an assessor blinded to allocation and period.

Other outcome measures were collected but not reported in the study (such as 'repetition word duration' , the average duration of the speech time).

Description of quality. The mean interrater reliability in the qualitative assessment using the Jadad score resulted in a kappa value of 0.74, while the kappa value for the qualitative assessment using the Cochrane RoB tool was 0.68.

Random sequence generation. In terms of the randomisation, the method was explicit in at least three studies: only one was generated on the computer, while other two studies used a restricted randomisation scheme, randomised permuted blocks (blocks of different sizes, where the size of the next block is randomly chosen from the available block sizes) and random number tables. In the article by Smania et al., (44) the randomisation method was not specified. Three group studies were judged to have a low risk of selection bias on the basis of having adequate random sequence generation. (45,46,48) Two studies were unclear in their explanation of random sequence generation, and thus the risk of bias was unclear (44,46).

Allocation. Concerning of the allocation concealment, three studies, Donkervoort et al., (46) Varley et al., (48)

and Edmans et al., (47)used seated envelops to keep the randomisation list secret, and these studies were judged to have low risk of bias. In both Smania et al., studies (44,45) the allocation concealment has not been described and for this reason have been judged as studies with unclear risk of bias.

Blinding of participants, personnel and of outcome assessors. In none of the studies included, therapists were blinded to the type of treatment they were going to administer and this factor determines a high risk of bias. Only in one study, (48) patients were blinded about the control treatment, being a sham treatment. In four studies, the risk of bias about the blinding of outcome assessment was considered low,(44,46-48) as the researchers were blind about the outcomes to be evaluated.

Incomplete outcome data. Two studies did not report intention to treat analysis (45,47) and the number of patients lost to follow up were considered to have a high risk of bias. (47) Other studies reported all outcome data and were considered to have a low risk of bias. (44,46,48)

Other bias. The quality of included studies was further evaluated by considering the presence/absence and adequacy of other reported information, such as informed consent, ethical approval, trial registration, data collection, data management, data monitoring committee, access to data, reporting funding source, conflict and declaration of interests and confidentiality. All studies reported having obtained ethical approval. Only two studies reported information on the source of funding, and the majority of included studies reported statements from authors declaring to have no conflicts of interests. None of the included studies reported information on confidentiality, data management, data monitoring committee and access to data.

Selective bias. When the study protocol was not available and all included studies not pre-specified all outcomes considered, selective bias could not to be assessed. Almost all studies showed a low risk of bias. (44-46.48) Only one study showed a high risk of bias. (47) (Table 2)

Description of heterogeneity. A high level of clinical heterogeneity was observed among the included studies, with wide variation across studies in the type of considered participants, interventions, and outcome, as shown in Table of Data Extraction. Enrolled patients differed in terms of age, disease severity at baseline, and comorbidities. The dose and frequency of administration, the length of treatment, the type of therapist performing the treatment, and the setting in which it was administered widely varied across studies. A wide variability was also observed in the type of comparisons used (sham or for another type of pathology), the type of therapist who administered it and the setting. Moreover, few of the included studies reported any information on concomitant treatments. High heterogeneity was also observed in the type of outcomes considered and in the length of follow-up.

Discussion

Results showed low evidence on apraxia's physiotherapy and speech therapy field. Below we list main conclusions obtained from five randomised controlled trials. One study (45) showed a significant improvement in performance in the study group, both ideational and ideomotor apraxia tests. There was also a significant reduction of praxic errors on ideational and ideomotor apraxia tests. In the gesture comprehension test there was a moderate improvement, while other outcome measures did not show any significant amelioration. Control patients did not show any significant change in performance.

The latest study of Smania et al., (44) showed a significant improvement in performance after the apraxia treatment in the IA, IMA, and gesture, comprehension tests and in the ADL questionnaire; no significant differences in performance in the intelligence, verbal comprehension or

Table 2. Cochrane Risk of Bias Tool for Randomized Controlled Trials (Higgins JPT, et al.; 2011).

COCHRANE RISK OF BIAS TOOL FOR RANDOMIZED CONTROLLED TRIALS	Smania et al., 2000.	Smania et al., 2006.	Donkervoort et al., 2001.	Edmans et al., 2000.	Varley et al., 2016.
Random sequence generation	L	U	L	U	L
Allocation concealment	U	U	L	L	L
Blinding of participants and personnel	H	H	H	H	H
Blinding of outcome assessment	U	L	L	L	H
Incomplete outcome data	H	H	L	H	L
Selective reporting	L	L	L	H	L
Other bias	H	L	L	H	H

H= High risk; U= Unclear risk; L=Low risk

oral apraxia tests were observed. After the aphasia treatment an important improvement was found in the intelligence and verbal comprehension tests. No significant changes were observed in the performance for the other outcome measures. In the follow-up evaluation, performance in the limb praxic functional tests and in the ADL questionnaire did not show any significant change in comparison with the post-treatment evaluation. The metanalysis of Smania's studies (2000, 2006) did not show any statistically significant results (Fig. 2-3), but a positive trend in the experimental group was found for the gesture comprehension. (Fig. 4). Donkevoort's trial (46) showed evidence for the short-term effectiveness of strategy training in left hemisphere stroke patients. After eight weeks of treatment, patients improved significantly more than patients in the usual treatment group on the ADL observations. No useful effects of strategy training were found after five months (at follow up). It is important that patients in the usual treatment group rather than in the strategy training group still received occupational therapy at follow-up. There was little detail regarding the treatment type used from occupational therapists.

Edmans's trial demonstrated no significant difference between the treatment groups before and after treatment on perceptual ability total scores, individual perceptual subtest scores or functional ability total scores and a significant improvement was found in both groups after treatment on perceptual and functional abilities.

The speech therapy study indicated for periods 1 and 2 a significant improvement in naming and repetition skills in the speech-first group and in the sham-first group after speech intervention. The improvement regarded above all the repetition and naming of treated words, with little generalization to structurally similar and not similar untreated words. (48)

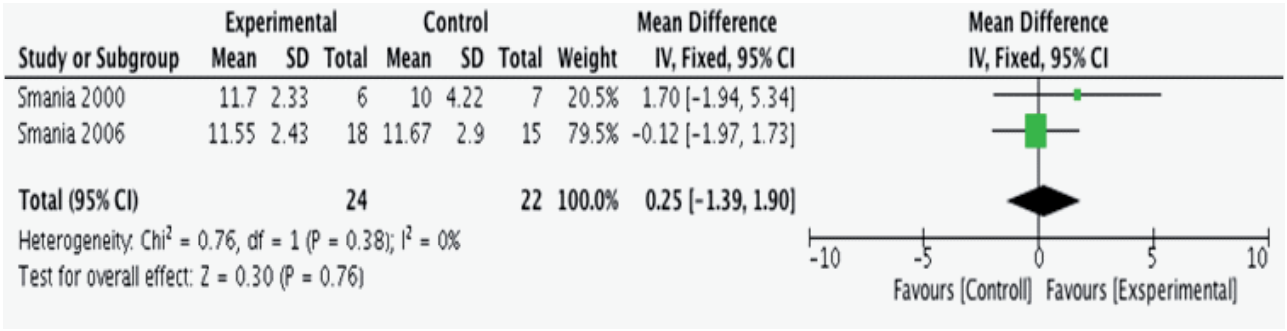

Fig. 2. Forest Plot Ideomotor Apraxia's (IMA) test

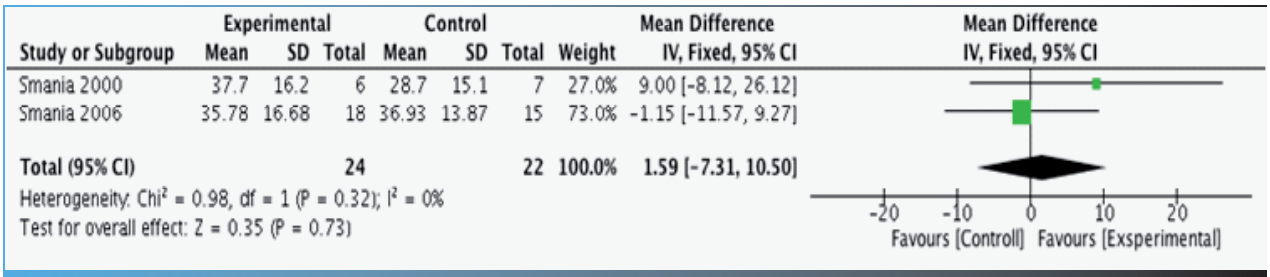

Fig. 3. Forest Plot Ideative Apraxia's (IA) test

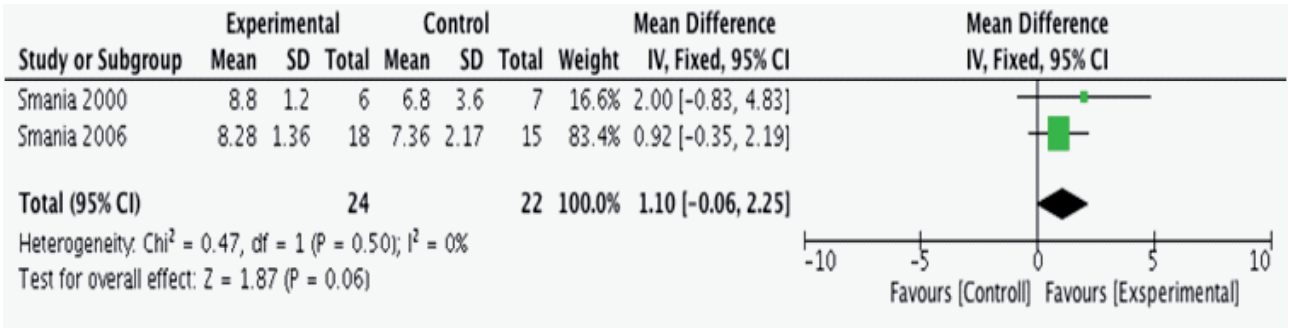

Fig. 4. Forest Plot Gesture Comprehension's test

In almost all mentioned studies who reported the follow-up, i.e., Donkervoort et al. (46) (five months), Smania et al., (44) (two months), improvements were not maintained after the withdrawal of intervention.

In particular, studies by Smania et al., (44,45) did not demonstrate the long-term maintenance of the treatment effect and capability to transfer it in apraxia patients' home setting. In fact, they gained not only in doing a wide range of gestures, but also in other outcome ratings. Donkervoort et al., (46) found little evidence regarding the transfer of his approach in daily life settings.

Among previous physiotherapic approaches listed, there was no better treatment approach: for example, Cappa et al. (43) awarded an evidence grade of A for the effectiveness of apraxia treatment with compensatory strategies, as there was ADL improvement, not correlated with the amelioration of apraxia. Otherwise, Cicerone et al. (54) strongly recommended treating apraxia in patients after left hemisphere stroke with specific gestural training.

For the speech treatment study, the maintenance phase showed that speech improvement was largely maintained after the withdrawal of intervention and a relationship was identified between treatment dose and response. The mean self-managed dose was moderate for both groups, and the duration of the revaluation period being very short makes the study not directly comparable with the other studies' follow-ups.

Therefore, studies show that apraxic patients participating in an intensive rehabilitation training program improve their gestural performance, both transitive and intransitive gestures, in different contextual situations. In addition, there is an amelioration of praxis functions generalized to ADL functioning with gains in functional independence from caregivers during ADLs. The specificity of the rehabilitation treatment is confirmed because patients in the control group did not show any change in either the ADLs or in limb praxic. On the other hand, perceptual abilities in stroke patients can benefit from both functional and transfer of training approaches, with a generalization of treatment to everyday activities.

Regarding speech treatment for apraxia, the results demonstrate that computer-therapy and other types of programs involving patients to self-manage interventions are effective both in naming and in repetition skills. In particular, the item-specific improvement in naming skills was observed because of top-down activation from the lexical level may enable access to motor plans. It depends on lexical facilitation rather than improvement specifically at the phonetic level.

Study limitations. Studies have been done investigating the comparative effectiveness of different strategies and therapeutic programs, but the results should be cautiously considered when planning interventions aimed at the management of apraxia.

A further limitation in all studies included was in considering the small sample of patients and in conducting a single-centre study. On the other hand, the maintenance phase was not sufficiently long, and in some studies, there was an absence of standardised scales to evaluate functional outcomes. Specifically, the physiotherapy studies considered training gestures less meaningful than training occupations themselves, although gesture training seems to produce improvements in measures of apraxia and in ADL performance. (44,45)

Moreover, in none of the studies examined, the results were maintained in the long term.

In the case of speech therapy research, in particular for buccofacial apraxia, there is a lack of studies, representing a limit for speech therapists who interface with this manifestation of apraxia.

Conclusions

Apraxia is a condition with a range of manifestations and severities, and research continues to address theoretical questions about its nature and subsequent impairments.

Further work will need to be done to test these treatment programs not only in clinical settings, but also in post-discharge setting (homes, nursing homes) to define the length of the rehabilitation time. Both physiotherapists and speech therapists should consider telerehab a valid and reliable vehicle for delivering speech and motor rehabilitation service for the maintenance of treatment gains after stopping intervention. (55,56) In addition, mental imagery (57) has demonstrate positive effects on patients' relearning of lost functions and performance post stroke, such us in the case of apraxia and hemiparesis. (58) Moreover, the concept of affordance by Gibson (59) can be explored with the recent model of interactive behaviour termed the "affordance competition hypothesis" , where is postulated that the interactive behaviour arises by a process of competition between possible actions elicited by the environment.

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