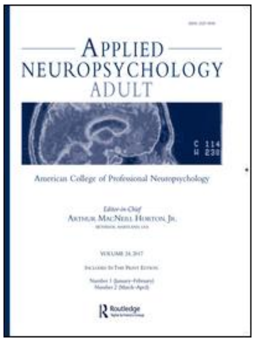

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Rehabilitation of limb apraxia in patients following stroke: a systematic review

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ABSTRACT

Apraxia is widely used to describe one of the more disabling deficits following left strokes. The role of rehabilitation in treating apraxic stroke patients remains unclear. This systematic review was conducted to study the impacts of various rehabilitation interventions on the limb apraxia post-stroke. PubMed, SCOPUS, PEDro, CINAHL, MEDLINE, REHABDATA, and Web of Science were searched for the experimental studies that investigated the effects of the rehabilitation interventions on apraxia in patients with stroke. The methodological quality was rated using the Physiotherapy Evidence Database scale (PEDro). Six studies met our inclusion criteria in this systematic review. Four were randomized controlled trials, pilot ($n=1$), and case study ($n=1$). The scores on the PEDro scale ranged from two to eight, with a median of seven. The results showed some evidence for the effects of strategy training and gesture training interventions on the cognitive functions, motor activities, and activities of daily livings outcomes poststroke. The preliminary findings showed that the effects of the strategy training and the gesture training on apraxia in patients with stroke are promising. Further randomized controlled trials with long-term follow-ups are strongly needed.

KEYWORDS
Rehabilitation; stroke; apraxia; therapy; limb

Introduction

Approximately 50% of the individuals with left stroke (Zwinkels et al., 2004) and about 35% of the individuals with Alzheimer's disease and corticobasal degeneration exhibit apraxia that persists following illness onset (Holl et al., 2011; Nelissen et al., 2010). Classically, apraxia is diagnosed when an individual exhibits an inability to execute gestures in response to the verbal commands or follow with various effectors (mouth, hand, or foot) (Petreska et al., 2007), including the movements that involving the non-hemiplegic limb ipsilateral to the lesion. Although apraxia mainly affects motor activities, studies describe that higher impairment levels may be associated with visuomotor integration (Nobusako et al., 2018).

Apraxia is a disorder of a purposeful movement that cannot be associated with comprehension deficiencies or sensorimotor dysfunction (Heilman & Valenstein, 2003). It may affect an individual's ability to conceptualize the determination of a goal, initiate and execute a movement, and assume its results (Hansen et al., 2009). The praxis system works to store motor information for later use, so motor planning is not needed every time an activity is initiated (Rothi et al., 1997). Functionally, the praxis system promotes skilled interaction with the environment (Rothi et al., 1997).

Evidence supports that apraxia affects skilled acts in the environment, opposes independent functioning, prevents daily activities, and influences the performance of routine self-care (Foundas et al., 1995; Hanna-Pladdy et al., 2003). The individuals with apraxia may have difficulty brushing teeth (Goldenberg & Hagmann, 1998), eating (Foundas et al., 1995), cooking food (van Heugten et al., 2000), and getting dressed (Sunderland et al., 2006). As a consequence, the individuals with apraxia can reveal anxiety and decreases in the spontaneous use of social gestures (Borod et al., 1989), leading to isolation and depression (Tabaki et al., 2009) and resulting delays in returning to work (Saeki et al., 1993).

Currently, different approaches were used to treat apraxia deficits, including strategy training (Donkervoort et al., 2001), gesture training (Smania et al., 2006), verbal (French et al., 2009), graphic facilitation (Smania et al., 2006), the practice of physical cues based on the repetitive behavioral-training programs with the gesture-production activities, and the errorless completion method (Buxbaum et al., 2008). However, to date, independence in the activities of daily living tends to be underestimated (Etcharry-Bouyx et al., 2017), and rehabilitation evidence remains insufficient due to the nature of disturbances to the automatic voluntary dissociations (Pazzaglia & Galli, 2019). A previous systematic review by Lindsten-McQueen et al. (2014) demonstrated the beneficial influences of the apraxia treatment in patients with various neurological disorders. However, it was not specified to stoke population and limited to occupational performance. This study aimed to investigate the effects of

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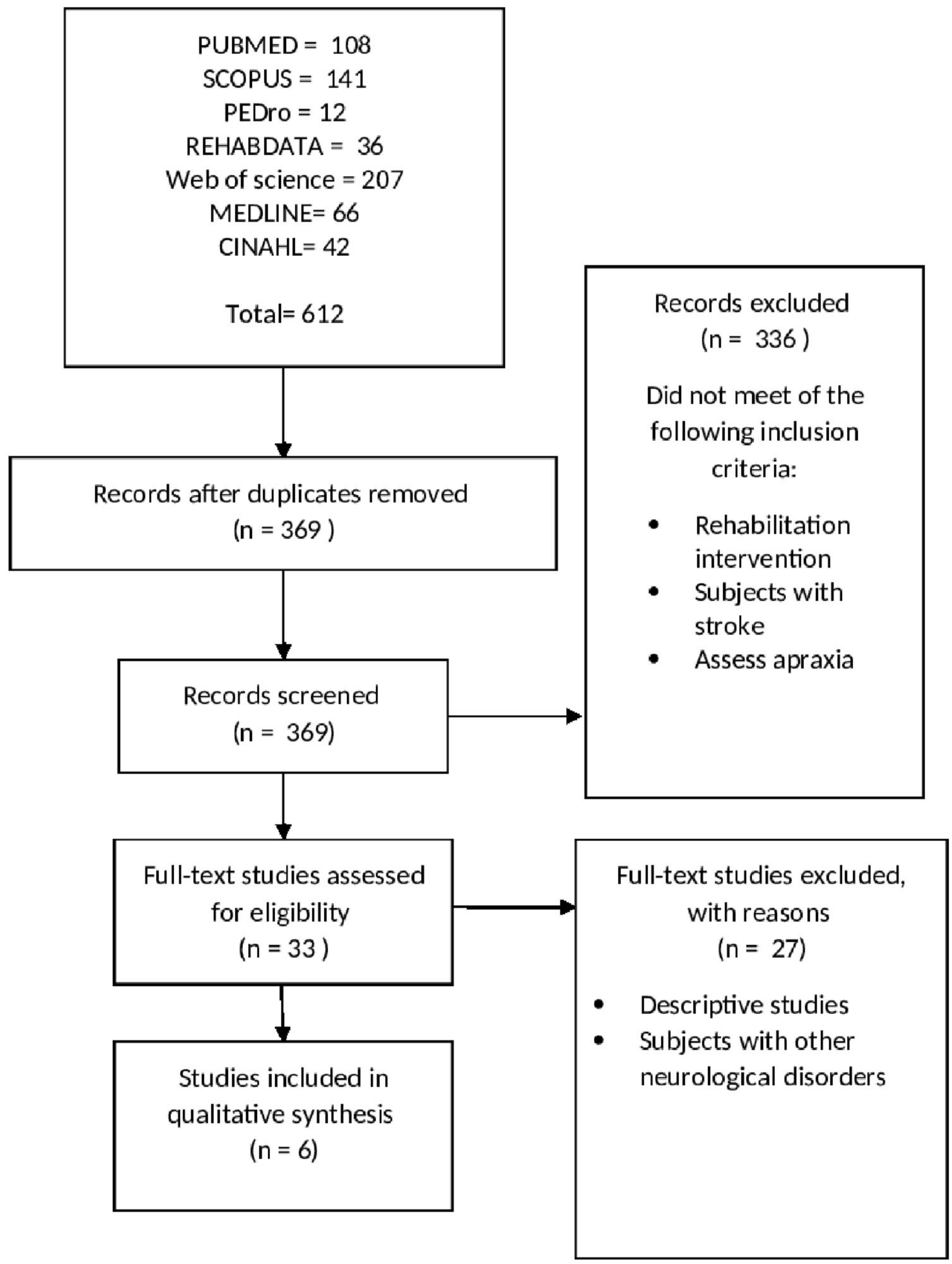

Figure 1. Summary of literature review process.

the existing rehabilitation interventions on limb apraxia in patients with stroke.

Materials and methods

Search strategy

We completed searches with PubMed, SCOPUS, PEDro, CINAHL, MEDLINE, REHABDATA, and Web of Science from inception to September 2020. The keywords used to search the databases were (apraxia OR action disorganization syndrome) AND (rehabilitation OR physiotherapy OR occupational therapy OR non-pharmacological intervention) AND (stroke OR cerebrovascular disease OR CVA OR brain injury OR transient ischemic attack OR TIA) (Figure 1).

Eligibility criteria

The current review followed all PRISMA guidelines. We followed the PICOS approach (P: participants; I: intervention; C: comparison; O: Outcomes; S: study design) (Liberati et al., 2009). Studies were included if they: (a) assessed stroke survivors, (b) used rehabilitation interventions, (c) evaluated limb apraxia, (d) classified as an experimental study published in English, and (e) compared with active/passive control group or no control. Studies were excluded if they: (a) assessed patients with other neurological disorders (e.g., traumatic brain injury), (c) considered descriptive studies, and (d) applied the intervention on animal models.

Methodological quality

Two authors evaluated the methodological quality of the included studies using the Physiotherapy Evidence Database scale (PEDro). It presents an overview of the internal and external validity of the studies (Maher et al., 2003). Four points of the PEDro scale have been validated, while the other items have face validity (Moher et al., 1999). Further, acceptable inter-rater reliability has been proved (Foley et al., 2006; Maher et al., 2003). The outcome of the included studies with a higher PEDro score was given more attention (>6 High quality). Methodological quality scores for the included studies were displayed in Table 1.

Data extraction and analysis

The data were extracted by two authors subsequently checked by the third author. The data were extracted separately: (1) study design and participants, (2) treatment intervention details, (3) experimental intervention, and (4) control group intervention (Table 2). Table 3 displays the outcome measures details (i.e., outcome measure, time of assessment, experimental group outcomes, control group outcomes, and the results). After reviewing the included studies, we decided that the meta-analysis was not appropriate due to the significant heterogeneity of the treatment protocols and outcome measures.

Results

Study selection

A systematic search of PubMed (yielding 108 articles), SCOPUS (141), CINAHL (42), PEDro (12), REHABDATA (36), MEDLINE (66), and Web of Science (207) produced a total of 612 articles. After removing duplicates, 369 articles were reviewed. Out of those, 336 articles were excluded because they did not match our inclusion criteria. Thirty-three articles were subjected to a more detailed analysis. Twenty-seven articles were eliminated because they were classified as descriptive studies and assessed patients with other neurological disorders (e.g., traumatic brain injury). A total of six articles were identified for the inclusion criteria in this systematic review. The process of the study selection was displayed in Figure 1.

Methodological quality

Four of the selected studies were RCTs (Donkervoort et al., 2001; Geusgens et al., 2006; Smania et al., 2000), pilot studies ($n = 1$) (Geusgens et al., 2007), and case study ($n = 1$) (Code & Gaunt, 1986). The score on the PEDro scale ranged from two to eight, with a median of seven. Overall, one study met eight criteria (Donkervoort et al., 2001), three

Table 1. Methodological quality scores.

Reference	Randome allocation	Concealed allocation	Groups similar at baseline	Participant blinding	Therapist blinding	Assessor blinding	<15% dropouts	Intention to treat analysis	Between-group differences reported	Point estimate and variability reported	Total (0–10)
Code & Gaunt, 1986							*	*			2
Donkervoort et al., 2001	*	*	*			*	*	*	*	*	8
Geusgens et al., 2006	*		*			*	*	*	*	*	7
Geusgens et al., 2007							*	*		*	3
Smania et al., 2000	*		*			*	*	*	*	*	7
Smania et al., 2006	*		*			*	*	*	*	*	7
Median = 7											

*Low risk of bias.

Table 2. Study characteristics.

Reference	Study design and participants	Treatment details	Experimental group	Control group
Code & Gaunt, 1986	Study design: Case study Sample: 1 Age: 71 Gender (M/F): 1/0 Diagnosis: Left stroke Duration of injury (Months): 20	45 min session weekly for 8 months (with breaks totaling 7 weeks)	Six stages of hierarchical gesture Training	NA
Donkervoort et al., 2001	Study design: RCT Sample: 113 Age: 64.2 Gender (M/F): 64/49 Diagnosis: Left stroke Duration of injury (Months): 3	8 weeks (25 sessions, 15 h)	Strategy Training + Usual Occupational Therapy	Occupational Therapy alone
Geusgens et al., 2006	Study design: RCT Sample: 113 Age: 64.2 Gender (M/F): 64/49 Diagnosis: Left stroke Duration of injury (Months): 3	8 weeks (25 sessions, 15 h)	Strategy Training	Occupational Therapy alone
Geusgens et al., 2007	Study design: Pilot Sample: 29 Age: 60.5 Gender (M/F): 22/7 Diagnosis: Left stroke Duration of injury (Months): 3	8 weeks (25 sessions, 15 h)	Strategy training	NA
Smania et al., 2000	Study design: RCT Sample: 13 Age: 65.4 Gender (M/F): 10/3 Diagnosis: Left stroke Duration of injury (Months): >12	3 × 50 min sessions per week up to 35 sessions	Gesture training	Aphasia therapy: language skills training
Smania et al., 2006	Study design: RCT Sample: 33 Age: 65.5 Gender (M/F): 23/10 Diagnosis: Left stroke Duration of injury (Months): 10–17	3 × 50 min sessions per week up to 35 sessions	Gesture training	Aphasia therapy: language skills training

CCT: Clinical Controlled Trial; RCT: Randomized Controlled Trial.

Table 3. Outcome measures.

Reference	Outcome measure	Time of assessment	Experimental group (mean ± SD)	Control group (mean ± SD)	Results
Code & Gaunt, 1986	Limb Apraxia Screening Test (Cognitive functioning)	At baseline, during, and post intervention	To Command **Pre:22 (52.2%) **Post: 25 (59.5 %) To Imitation **Pre:32 (75.2%) **Post: 35 (83.3 %)	NA	Small improvements in producing 10 trained Makaton signs
Donkervoort et al., 2001	Motricity Index (Motor functioning)	At baseline, post intervention, and 5-month follow-up	Pre: 50.8 (31.3) *Post: 2.61 (–0.26, 5.49) *Follow-up: 3.30 (0.01, 6.59)	Pre: 40.9 (30.1) *Post: 2.98 (0.09, 5.87) *Follow-up: 3.74 (0.66, 6.82)	No significant differences between the two intervention groups post intervention and at follow-up
	Functional Motricity Test (Motor functioning)	At baseline, post intervention, and 5-month follow-up	Pre: 6.5 (3.9) *Post:0.60 (0.16, 1.04) *Follow-up:0.51 (0.04, 0.98)	Pre: 5.3 (3.5) *Post: 0.33 (0.06, 0.59) *Follow-up: 0.48 (0.15, 0.80)	No significant differences between the two intervention groups post intervention and at follow-up
	Apraxia test (Cognitive functioning)	At baseline, post intervention, and 5-month follow-up	Pre:57.3 (21.2) *Post: 4.20 (1.69, 6.72) *Follow-up: 6.26 (2.76, 9.77)	Pre:62.0 (17.9) *Post: 2.21 (–0.32, 4.74) *Follow-up: 4.02 (0.84, 7.21)	No significant differences between the two intervention groups post intervention and at follow-up
	Barthel Index (ADL functioning)	At baseline, post intervention, and 5-month follow-up	Pre:10.7 (4.9) *Post: 2.44 (1.70, 3.19) *Follow-up: 0.21 (0.09, 0.33)	Pre:11.2 (5.0) *Post:1.15 (0.55, 1.74) *Follow-up: 0.22 (0.10, 0.33)	Significant improvement post experimental intervention. No significant differences between the two intervention groups at follow-up
	ADL observations (ADL functioning)	At baseline, post intervention, and 5-month follow-up	Pre:2.2 (0.5) *Post:0.24 (0.15, 0.34) *Follow-up:3.00 (1.97, 4.03)	Pre:2.3 (0.4) *Post:0.12 (0.03, 0.21) *Follow-up: 2.83 (2.00, 3.65)	Significant improvement post experimental intervention. No significant differences between the two intervention groups at follow-up
	ADL judgment (OT)(ADL functioning)	At baseline, post intervention, and 5-month follow-up	Pre:3.2 (1.3) *Post: 0.90 (0.65, 1.25) *Follow-up: 1.20 (0.79, 1.62)	Pre:3.1 (1.4) *Post: 1.04 (0.78, 1.31) *Follow-up: 1.48 (1.11, 1.85)	Significant improvement post experimental intervention. No significant differences between the two intervention groups at follow-up
	ADL judgment (PT) (ADL functioning)	At baseline, post intervention, and 5-month follow-up	Pre:4.1 (1.5) *Post: 0.65 (0.35, 0.95) *Follow-up: 0.72 (0.27, 1.18)	Pre:4.4 (1.6) *Post: 0.54 (0.27, 0.82) *Follow-up: 0.56 (0.28, 0.85)	Significant improvement post experimental intervention. No significant differences between the two intervention groups at follow-up
Geusgens et al., 2006	Action Research Arm Test (Motor functioning)	At baseline, post intervention, and 5-month follow-up	NA	NA	Significant improvement in the experimental group.
	Apraxia test (Cognitive functioning)	At baseline, post intervention, and 5-month follow-up	NA	NA	Significant improvement in the experimental group.
	Barthel (ADL functioning)	At baseline, post intervention, and 5-month follow-up	NA	NA	Both interventions were associated with improvement on untrained as well as trained tasks but gains were larger in the Strategy training group.
	ADL observations (ADL functioning)	At baseline, post intervention, and 5-month follow-up	NA	NA	Both interventions were associated with improvement on untrained as well as trained tasks but gains were larger in the Strategy training group.
Geusgens et al., 2007	Apraxia test (Cognitive functioning)	At baseline and post-intervention	Pre: 56.9 (22.4) Post: 67.3 (19.6)	NA	Significant improvement
	Functional motor test (Motor functioning)	At baseline and post-intervention	Pre: 7.9 (4.4) Post: 7.9 (4.4)	NA	No significant difference
	Barthel (ADL functioning)	At baseline and post-intervention	Pre: 14.8 (5.2) Post: 16.8 (4.1)	NA	Significant improvement
	ADL observations (ADL functioning)	At baseline and post-intervention	Pre: 1.8 (0.6) Post: 2.4 (0.4)	NA	Significant improvement
Smania et al., 2000	Limb praxic function evaluation (Cognitive functioning)	At baseline and post-intervention	NA	NA	Significant improvement
Smania et al., 2006	Limb praxic function evaluation (Cognitive functioning)	At baseline, post intervention, and 2-month follow-up	NA	NA	Significant improvement
	ADL questionnaire	At baseline, post intervention, and 2-month follow-up	NA	NA	Significant improvement

*Mean (90% CI), **Mean (%), NA: not applicable.

met seven criteria (Geusgens et al., 2006; Smania et al., 2000), one met three criteria (Geusgens et al., 2007), and one met two criteria (Code & Gaunt, 1986) for low risk of bias. Table 1 displays the methodological quality scores for the included studies.

Study characteristics

Participants

A total of 302 left stroke patients (right hemiplegia), 39.10% of whom were females. The mean age for all participants was 64.10 years. Concerning the duration of a stroke, three studies included patients with stroke in a sub-acute stage (2 weeks – 6 months) (Donkervoort et al., 2001; Geusgens et al., 2006, 2007), while other three studies included chronic stroke patients (>6 months) (Code & Gaunt, 1986; Smania et al., 2000).

Study design

Strategy training. Two randomized controlled trials (Donkervoort et al., 2001; Geusgens et al., 2006) and one pilot study (Geusgens et al., 2007) applied the strategy training on the patients with sub-acute stroke that was established by van Heugten et al. (1998). In the study by Donkervoort et al. (2001), the patients in the experimental group received strategy training plus usual occupational therapy compared with the usual occupational therapy control group, while the patients in the study by Geusgens et al. (2006) underwent strategy training alone compared with the usual occupational therapy control group. Moreover, another study by Geusgens et al. (2007) applied strategy training as an experimental intervention without including a control group.

Strategy training consisted of the treatment program for left hemisphere stroke individuals with apraxia, developed in a prior study (van Heugten et al., 1998). The main principle of this treatment program is the use of strategies to compensate for apraxic impairment during the performance of ADLs. Individuals are taught strategies to compensate internally or, if necessary, externally for the impairment (Donkervoort et al., 2001). In terms of the strategy training intervention in the included studies, the specific interventions applied during treatment matched with the particular problems that were estimated during the standardized activities of daily living (ADL) observations. The ADLs are conceptualized as being formed of three consecutive events, according to the framework of information processing (i.e., phases of initiation, execution, and control). The proper plan of action and the correct objects have to be selected (initiation of an activity) followed by the adequate performance of the plan (executing the activity), which has to be assessed in terms of the result (controlling, and if necessary correcting the activity). A patient with apraxia who, for example, cannot use objects appropriately may have a deficit in any one of the stages of which the activity consists. By assessing the various aspects of the activity, the nature of the deficit can be recognized, and the treatment plans can be formed accordingly. When a patient exhibited problems with initiating an activity, the emphasis during treatment was placed upon instructions. The instructions were varied depending on the individual's level of functioning, which means that verbal instructions were provided when minimal problems occurred. If, however, the patient could not initiate the activity, the therapist could, for instance, hand the objects to the patient one at a time. Specific assistance (i.e., verbal or physical) was provided when the performance of the activity caused problems. Finally, the therapist administered feedback when the patient did not detect or correct performance errors. The feedback could be verbal by telling the patient what went wrong, or the therapist could use a mirror to the patient to show the result. All forms of the intervention (instructions, assistance, and feedback) could be varied depending on the individual's functioning (Stehmann-Saris et al., 1996). Concerning the usual occupational therapy control interventions (Donkervoort et al., 2001; Geusgens et al., 2006), the main focus of therapy in each study is on motor impairments (i.e., muscle tone, reflexes, controlled movements, muscle strength, contractures). The treatment intervention in the studies (Donkervoort et al., 2001; Geusgens et al., 2006, 2007) lasts for 8 weeks (In a total; 25 sessions, 15 h).

Gesture training. Two randomized controlled trials (Smania et al., 2000, 2006) and one case study (Code & Gaunt, 1986) applied the gesture training intervention on chronic stroke patients compared with aphasia therapy (i.e., language skills training) in the control groups (Smania et al., 2000, 2006). The study by Code and Gaunt (1986) did not include control comparison.

In the studies by Smania et al. (2000) and Smania et al. (2006), the experimental intervention was made up of three sections, respectively devoted to transitive, intransitive-symbolic, and intransitive-nonsymbolic gestures. Transitive gesture training, this section was divided into phases A, B, and C. In phase A, the patient was asked to show the use of basic tools (i.e., a spoon). In phase B, the patient was shown a picture illustrating a transitive gesture (i.e., using a spoon) and then asked to produce a similar gestural pantomime. In phase C, the patient has presented a picture showing a basic tool (i.e., a spoon) and then asked to pantomime the use of that object. Each phase consisted of 20 items. When the patient was able to complete at least 17 of 20 items correctly, a phase was concluded, and the following one started. Subsequently, the intransitive-symbolic gesture training was divided into phases A, B, and C depending on the number of contextual cues used in the various conditions. In phase A, the patient was shown two pictures, one of which illustrated a given context (i.e., a man-eating a sandwich), and the other presenting a symbolic gesture related to that context (i.e., the gesture of eating). Following the presentation, the patient was asked to reproduce the symbolic gesture presented in the picture. In phase B, the task was to create the correct gesture (i.e., the gesture of eating) following the presentation of the context picture alone (i.e., a man-eating an apple). In phase C, the task was to create the correct gesture (i.e., the gesture of eating) after the presentation of a picture displaying a new, though similar to the previous one, contextual situation (i.e., a man-eating canned food with a fork). Each phase consisted of 20 items. The standard for passing from one phase to another was the same as for the transitive gesture section. Lastly, in the intransitive-non-symbolic gesture training, the patient was required to follow meaningless intransitive gestures previously presented by the examiner. Twelve gestures involving six proximal and six distal joints were delivered. Six of them were static, while the others were dynamic gestures. If the patient was not able to complete a gesture correctly, the examiner encouraged him to use verbal or any other kind of facilitation (e.g., presenting the exact gesture, passive positioning of the hand, passive achievement of the complete gesture). Each training session lasted approximately 50 min, three times per week. The apraxia treatment discontinued after the completion of all training sections was reached or after a maximum of 35 treatment sessions.

Moreover, in the study by Code and Gaunt (1986), the experimental intervention used the six stages of hierarchical gesture training that involved a gradual reduction of cues. First, the therapist and the patient produce a word and sign together. Second, the patient repeats the sign and a word after the therapist. Third, the therapist says a word, and the patient repeats the word with the sign. Forth, the therapist produces the sign, and the patient repeats the sign with the word. Fifth, the therapist shows the patient the picture of the sign and says a word, then the patient repeats the word at the same time. And sixth, the therapist shows the patient the picture of the sign, then the patient produces the sign and the word. The intervention includes a 45-min session delivered weekly for eight months (with breaks totaling 7 weeks).

Outcome measures

The cognitive functions were assessed using the limb apraxia screening test (Code & Gaunt, 1986), the apraxia test (Donkervoort et al., 2001; Geusgens et al., 2006, 2007), and the limb apraxic function evaluation (Smania et al., 2000, 2006). Moreover, the motor functions were evaluated using the motricity index (Donkervoort et al., 2001), the functional motricity index (Donkervoort et al., 2001), the action research arm test (Geusgens et al., 2006), and the functional motor test (Geusgens et al., 2007). Furthermore, the ADLs were assessed using the Barthel index (Donkervoort et al., 2001; Geusgens et al., 2006, 2007), the ADL observations (Donkervoort et al., 2001; Geusgens et al., 2006, 2007), the ADL judgment (subjective assessment by OT) (Donkervoort et al., 2001), the ADL judgment (subjective assessment by PT) (Donkervoort et al., 2001), and the ADL questionnaire (Smania et al., 2006).

Effectiveness rehabilitation on limb apraxia in patients with stroke

Strategy training

There was a significant improvement in the Barthel Index (ADL functioning), ADL observations (ADL functioning), ADL judgment (OT) (ADL functioning), and ADL judgment (PT) (ADL functioning) after the intervention; however, no significant differences between the two intervention groups at 5-week follow-up (Donkervoort et al., 2001). Moreover, there were no significant differences between groups in the Motricity Index (Motor functioning), Functional Motricity Test (Motor functioning), and Apraxia test (Cognitive functioning) after the intervention and at 5-week follow-up (Donkervoort et al., 2001). Another study by Geusgens et al. (2006) reported significant improvement after the experimental intervention in the Action Research Arm Test (Motor functioning) and Apraxia test after the intervention and at 5-week follow-up. As well, there was an improvement in the Barthel Index and ADL observations in both groups; however, the improvements were larger in the strategy training experimental group (Geusgens et al., 2006). Finally, a pilot study by Geusgens et al. (2007) demonstrated significant improvements in the Apraxia test, Barthel Index, and ADL observations after the intervention. Furthermore, there was no improvement in the Functional motor test (Motor functioning) after the intervention (Geusgens et al., 2007).

Gesture training

There were significant improvements in the Limb praxic function evaluation (Cognitive functioning) (Smania et al., 2000, 2006) and ADL questionnaire (Smania et al., 2006) after the intervention and at 2-month follow-up (Smania et al., 2006). Moreover, there was a small improvement in the Limb Apraxia Screening Test (Cognitive functioning) after the intervention (Code & Gaunt, 1986).

Adverse effects or side effects

No adverse effects or side effects were demonstrated after the strategy training or the gesture training interventions in the included studies.

Discussion

The current review aimed to examine the effectiveness of rehabilitation interventions on limb apraxia in stroke survivors. There is some evidence of the benefits of strategy training and gesture training interventions on limb apraxia in individuals with stroke. The previous systematic review by Lindsten-McQueen et al. (2014) reported beneficial effects of the apraxia treatment interventions (i.e., strategy training and gesture training) on occupational performance in apraxic patients. Moreover, Cicerone et al. (2005) recommended specific gestural or strategy training as a new standard treatment for apraxia as it was superior to the sensorimotor or aphasia therapies. Furthermore, Worthington (2016) reported that strategy training is the most promising intervention with no support for sensory and exploratory interventions and modest support for gestural training.

The current review included various experimental studies (i.e., four RCTs, one case study, and one pilot study) with a methodological quality ranged from two to eight, with a median of seven. Four studies were of high methodological quality (>6/10) on the PEDro scale (Donkervoort et al., 2001; Geusgens et al., 2006; Smania et al., 2000), while the remaining two studies were of low methodological quality (Code & Gaunt, 1986; Geusgens et al., 2007). We selected the case studies because of the paucity of experimental studies on the current subject. The case studies are beneficial in the study of humans; however, they are not an appropriate basis for generalization (Stake, 1978). On the other hand, two studies had a small sample size (Code & Gaunt, 1986; Smania et al., 2000). As the sample size was small, the significant difference was not allowed to calculate (Portney & Watkin, 2009).

Strategy training is considered a compensatory treatment intervention (Cantagallo et al., 2012). The strategy training intervention focuses not on training specific tasks but on encourage generalizable skills (Stehmann-Saris, 2020). Han et al. (2017) suggested that strategic-based brain training could modulate the cortical thickness and resting-state functional neural connectivity. One of the selected studies demonstrated a significant improvement in the ADLs, while no improvement in motor and cognitive functions was reported (Donkervoort et al., 2001). The authors explained that the patients who function rather independently before the treatment period cannot improve during treatment. This ceiling effect could conceal the results of strategy training. Similarly, van Heugten et al. (1998) reported that the improvement in ADL functioning was more evident than the recovery of cognitive function (i.e., apraxia) and motor impairments. The study by Donkervoort et al. (2001) was of high methodological quality and had a large sample size. So the meaningful effect of strategy training on the ADLs can be established. Moreover, in the study by Geusgens et al. (2006), there was an improvement in motor function, cognitive function, and ADL. The study was of high methodological quality and had a large sample size. So the scientific conclusion for clinical practice can be established. Lastly, the study by Geusgens et al. (2007) demonstrated a significant improvement in ADLs and cognitive function, while no improvement in motor function was reported. Although this study had a large sample size; however, it was of low methodological quality on the PEDro scale. So the clinical effects cannot be confirmed.

Gesture training is categorized as a restorative treatment approach (Worthington, 2016). The purpose of this type of intervention is to restore impaired processing to normal function, which has been attempted by trying to improve sensory integration, perceptuomotor performance, and selective attention (Worthington, 2016). Three studies used gesture training to treat apraxic stroke patients (Code & Gaunt, 1986; Smania et al., 2000, 2006). A significant improvement in cognitive functions (Smania et al., 2000, 2006) and ADLs (Smania et al., 2006). Although the study by Smania et al. (2000) was of high methodological quality; however, the sample size was small. Moreover, another study was of high methodological quality and had a large sample size (Smania et al., 2006). So the clinical meaning of reported effects can be established. Lastly, the study by Code and Gaunt (1986) demonstrated in his case study minimal improvement following the gesture training intervention. As the study type is a case study; thus, we cannot generalize the findings.

Although a practice manual is available in Dutch from the authors of the strategy training method (Donkervoort et al., 2001; Geusgens et al., 2006, 2007), the manual is not readily available, and it remains unknown whether details are sufficient to implement the treatment program "out of the box." Each study reported general treatment approaches that are within occupational therapists' (OT) skill set, but without any details, it is unclear how these treatment interventions differ from standard treatment methods. If occupational therapists are to follow a more evidence-based structure, obtaining a manual to ensure similar practice among treating occupational therapists seems preferable. Additionally, time to conduct treatment was a limitation in many studies. Although the current research protocols were designed to assess efficacy (effect size under ideal conditions) rather than influences in everyday practice, the constraints of current outpatient and inpatient therapy need to be addressed when considering implementation in traditional clinics. The strategy training intervention is a 12-week program, and the gesture training intervention consisted of 30–35 50-min treatment sessions. Realistically, constraints such as insurance coverage and patients' motivation or willingness need to be acknowledged with the current protocols. We realize that these studies were undertaken to show that outcomes improve after patients undergo these interventions as described. Further work will need to be done to scale these treatment programs to a typical clinical setting and time frame and to decide whether that approach is effective. Furthermore, although gesture training produced improvement in measures of apraxia and caregiver report of ADL performance (Smania et al., 2000, 2006), actual observation of the performance of ADLs and IADLs was not assessed in the studies themselves. Further research is needed to determine whether training gestures improve performance in ADLs and IADLs. Only one study (Geusgens et al., 2007) reported outcomes within the natural context by assessing ADL performance in the participants' homes. We found this to be a limitation of the other studies, considering the importance of being able to function outside the structured environment of a rehabilitation facility.

The included studies did not afford sufficient information about the type of limb apraxia in the stroke population. Also, they included a stroke population in chronic and subacute stages; hence, the effect of the interventions on patients with acute stroke not understood. Moreover, some of the included studies did not present some of the treatment details adequately (e.g., session duration, frequency) make identifying the optimal treatment dosages are difficult. Furthermore, the majority of the studies included assessment at baseline and post-intervention, make the long term effects not clear.

As for the future development of apraxia treatment approaches, we suggest that descriptions of research participants enrolled in treatment studies be more clear so the therapists can define who may benefit from a treatment approach. Apraxic assessment tools used in future studies need to measure both the level of impairment and activity (WHO, 2001). Interventions should be explicitly described. Also, outcome measures need to include how apraxia influences everyday life. It is needed for decisions about whether results from the samples studied can be generalized to a typical heterogeneous clinical population. It is also crucial for future researchers to consider assessing their treatment in terms of the patients' opinions of the outcome. Finally, this systematic review points to the need for new treatment approaches to be established for the rehabilitation of individuals with apraxia. Concerning the cognitive function aspect of limb apraxia rehabilitation, recently, many rehabilitation interventions were found to be effective in improving cognitive functions through stimulating neuroplasticity, such as virtual reality (Alashram, Annino, et al., 2019). Moreover, in terms of the motor function aspect of limb apraxia rehabilitation, various rehabilitation interventions showed their effects on the motor function, such as focal muscle vibration (Alashram, Padua, et al., 2019; Annino et al., 2019), task-oriented interventions (Alashram et al., 2019a), and rhythmic auditory stimulation (Alashram et al., 2019b). Hence, combining these interventions with existing limb apraxia interventions (i.e., strategy training, gesture training) in future studies may show superior benefits than using strategy training or gesture training alone. Further high-quality studies with large sample sizes are strongly needed to detect functionally meaningful differences in the long-term outcome.

This review was limited in that we excluded articles not written in English. As the strategy search was limited by articles published in English, this can present bias because the articles with significant results are more probable to get published than the articles that fail to show significant results (Egger & Smith, 1998). Studies with significant results are also more likely to be published in English (Egger & Smith, 1998). Therefore, reviewing only studies published in English could lead to an overestimation of treatment effects (Higgins & Altman, 2008). Also, we excluded the descriptive studies that may contribute to the knowledge of the treatment of apraxia. Finally, the meta-analysis was not appropriate because only a few studies used the same outcome measures and the heterogeneity between the included studies. Further randomized controlled trials are strongly needed to be able to conduct a meta-analysis.

Conclusion

Despite no confirmed conclusion can be established; however, the initial findings for the short-term effects of strategy training and gesture training on apraxic sub-acute and chronic stroke patients are promising. The promising effects of treatment described in this review can be considered in planning treatment for people with limb apraxia to enhance the activities of daily livings; however, there is an outstanding need for more evidence to validate current treatment approaches. Further randomized controlled trials, with an adequate characterization of participants and measurement of long-term outcomes in naturalistic settings, are warranted.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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