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# Influence of Task-Oriented Training Content on Skilled Arm–Hand Performance in Stroke: A Systematic Review

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**Abstract**

*Objective*. This review evaluates the underlying training components currently used in task-oriented training and assesses the effects of these components on skilled arm–hand performance in patients after a stroke. *Methods*. A computerized systematic literature search in 5 databases (PubMed, CINAHL, EMBASE, PEDro, and Cochrane) identified randomized clinical trials, published through March 2009, evaluating the effects of task-oriented training. Relevant article references listed in publications included were also screened. The methodological quality of the selected studies was assessed with the Van Tulder Checklist. For each functional outcome measure used, the effect size (bias corrected Hedges's *g*) was calculated. *Results*. The intervention results in 528 patients (16 studies) were studied. From these, 15 components were identified to characterize task-oriented training. An average of 7.8 (standard deviation = 2.1) components were used in the included trials. There was no correlation between the number of task-oriented training components used in a study and the treatment effect size. "Distributed practice" and "feedback" were associated with the largest postintervention effect sizes. "Random practice" and "use of clear functional goals" were associated with the largest follow-up effect sizes. *Conclusion*. The task-oriented training was operationalized with 15 components. The number of components used in an intervention aimed at improving arm–hand performance after stroke was not associated with the posttreatment effect size. Certain components, which optimize storage of learned motor performance in the long-term memory, occurred more in studies with larger treatment effects.

**Keywords**

stroke, upper extremity, rehabilitation, motor skills, motor learning, systematic review

## Introduction

Stroke leaves approximately 50% of its survivors disabled with regard to arm–hand performance, often for the rest of their lives.[1,2] With increasing stroke incidence and prevalence,[3] arm–hand performance problems are likely to occur more frequently and increase the burden on the health system substantially in the coming decades.

Rehabilitation after stroke has evolved in the past 15 years from analytical training approaches to task-oriented training approaches that involve training of "basic functions," "skills," and "endurance" (at muscular and cardiovascular levels).[4] The task-oriented training approach matches patient training preferences[5] and has been proven to be effective for the improvement of skilled arm–hand performance after stroke.[6,7] However, French et al[8] did not find supporting evidence for repetitive task training of the paretic upper limb.

"Task-oriented training" is, to date, a poorly defined concept. For occupational therapy, Legg et al[9] mention that the exact nature of a successful intervention is vague and the same holds for task-oriented training specifically. Studies reporting on "task training" of the upper extremity after stroke use different intervention durations and intensities and include

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different kinds of interventions that makes comparison of their treatment effects difficult. Some studies consider the instruction of single-joint and/or single-plane movements to be task-oriented training (eg, reaching, pointing),[10] whereas other studies consider task-oriented training to focus on meaningful complex movements with real-life object manipulation in a real-life environment.[11] This finding emphasizes the need for an operationalization of task-oriented training to define its key characteristics.

Training may consist of different training components, used in several unique combinations. In this article, a "training component" refers to a task-oriented training characteristic with a specific effect on motor learning. For example, "random practice" is a training component that has proven to have positive effects on retention of learned motor actions.[12,13]

To optimize training programs, it is important that components of task-oriented training are identified and their importance for task-oriented training effects known so that they can be used in evidence-based therapies by clinicians and patients. Although the merit of most training components for motor learning has been scientifically investigated in isolated studies, the relative importance of the components for postintervention and follow-up effect sizes is unknown. The authors of this article hypothesize that the success of task-oriented training may, next to factors such as intensity[14-16] and duration of training,[17] depend on the use of specific "training components."

For future interventions, it will be interesting to know if training effects are larger if more components are used in an intervention. It is possible that "more is better" because training effects caused by individual components add up.

The main objective of this review is to (1) identify task-oriented components that have been used for task-oriented training in randomized clinical trials, (2) investigate if a relationship exists between the number of task-oriented components used in a training intervention and the treatment effect size (ES) of the training intervention, and (3) investigate the influence of each task-oriented arm training component on the functional outcome, that is, skill or activity level.

## Methods

### Literature Search Strategy

The systematic review is based on articles published until March 2009 and that were selected after a computerized search strategy in the following databases: PubMed, EMBASE, CINAHL, PEDro, and Cochrane. The following Medical Subject Headings (MeSH) were used: ("stroke") AND ("exercise movement techniques" OR "occupational therapy" OR "task performance and analysis" OR "exercise therapy" OR "exercise") AND ("clinical trial") AND ("upper extremity" OR ("activities of daily living" NOT "lower extremity") OR ("motor skills" OR "motor skill disorders"). The abstracts were screened by 2 independent reviewers (AT and AS). In case of disagreement, the opinion of a third reviewer (MM) was asked. Only references that fulfilled inclusion criteria were selected for further analysis and use in this review.

In addition to the database search, articles in the selected papers' reference list that were found to be relevant were checked.

### Eligible Studies

Inclusion criteria were the following: (1) The study described should be a randomized clinical trial. (2) At least 1 condition of the trial had to include active task-oriented arm–hand training in (hemorrhagic or ischemic) stroke patients. Constraint-induced movement therapy (CIMT) trials were not considered for the present systematic review because of the lack of comparability with the included trials, because CIMT is characterized by constraining the nonparetic arm and focuses on practice by the affected arm only (the nonaffected arm may serve as a support). Much of the CIMT practice can, however, be considered task oriented[18] and, for activities that are important to the patient, can induce cortical reorganization.[19] (3) The task-oriented training should be well described in the article (general descriptions such as "occupational therapy" and "physiotherapy" were not included as they could not be used for training component identification). (4) The studies should use outcome measures at activity level by means of (*a*) registration of kinematic parameters measured during skilled arm–hand performance or (*b*) arm–hand performance tests on activity level. (5) Articles had to be written in Dutch, French, English, or German. (6) A minimum of 10 stroke patients had to be included.

### Identification of Task-Oriented Training Type

Two reviewers (AT and AS) independently identified 15 training components. Interrater reliability of individual components that were matched to a training intervention was tested with Cohen's κ statistic (SPSS). The results of both researchers were compared, and consensus was reached after discussion on the differences.

We agreed to use the following components to mark the interventions that were described in the included articles, namely, the exercises presented can be: (1) functional, (2) directed toward a clear functional or everyday life activity (activities of daily living [ADL]) goal,[20] (3) client centered,[21] (4) repeated frequently (overlearning[22] and overload[23] principle), (5) used with real-life object manipulation, (6) performed in a context-specific environment,[13] (7) performed in increasing difficulty levels (exercise progression),[24] (8) varied (within 1 task),[13] (9) followed by feedback on the exercise performance,[25] (10) exercised in multiple movement planes, (11) included total skill performance,[26] (12) patient customized for training load,[27] (13) offered in random practice,[13] (14) occurred through distributed practice,[22] and (15) composed of bimanual tasks.[28] A more extensive explanation of the categories can be found in the Appendix. These 15 components were selected because they were thought to contain the most important contributors to support motor learning during (and after) task-oriented training.

### Methodological Quality Assessment

The methodological quality of the studies was rated using Van Tulder's quality assessment system[29,30] and scored by 2 independent reviewers (AT and AS). The Van Tulder list consists of internal validity criteria, descriptive criteria, and statistical criteria. The internal validity criteria refer to characteristics of the study that might be related to selection bias, performance bias, attrition bias, and detection bias and should be used to define methodological quality in the meta-analysis. The descriptive criteria refer to the external validity of the study and may be used for the subgroup and sensitivity analyses. The statistical criteria indicate whether calculations can be made and conclusions can be drawn independently of the opinion of the authors of the original study.[29] Interrater reliability of individual items was tested with Cohen's $\kappa$ statistic (SPSS). In case of disagreement, a third reviewer (HS) made the final decision. Using the consensus method, the total Van Tulder score was calculated.

### Quantitative Analysis

Hedges's $g$[31] was chosen to calculate the ES of the different studies selected, because of its good properties for small samples when multiplied by a correction factor that adjusts for small sample bias.[32] Hedges's $g$ was established by calculating the difference between means of the baseline values and postintervention measurement divided by the pooled standard deviation (SD). In cases where means and SDs were not provided in the article, the respective authors of the articles were contacted by e-mail and data were requested.

Given the selected studies, a correlation coefficient (Spearman's $\rho$) was calculated between the number of task-oriented components that were used in the studies and the ES reported. In case multiple measurement instruments were used, the outcome measurement providing the largest ES after intervention administration was used. Choosing the largest ES allows components to be linked to their maximal possible treatment effect, which is also in line with the ultimate goal of each therapist.

An inventory was made of the highest ESs for each study in which the component was used. Subsequently, a *median effect size* (MES) across studies was calculated to enable comparison between components with regard to their relation to treatment outcome. Nonparametric descriptive values were used as the data were not normally distributed. The more a component was used in an intervention with a large ES, the larger the MES will be that is matched to a component.

Based on the classification of Cohen, ESs <0.2 were classified as small, between 0.2 and 0.5 as medium, and >0.5 as large.[33] According to this classification, we assessed whether training components were linked to small, moderate, or large ESs both for postintervention and follow-up.

As the first component "functional" was an inclusion criterion for this review, it was present in all included interventions. The median linked to this component therefore served as a reference value to which the median values of the other studies were compared. A *relative median effect size (RMES) per component* was calculated by subtracting the MES attributed to the component "functional" from the MES that was attributed to that component and by dividing this difference by the MES of the component "functional."

To assess the influence of poststroke time, training duration, and training intensity, categories were made and MESs of all interventions belonging to a category were calculated. In case of differences in MES between categories, we assessed whether components were spread over the categories (or not). To assess the influence of poststroke time on the conclusions drawn, poststroke time was categorized as follows: (1) acute (between 0 and 30 days poststroke), (2) subacute (between 30 days and 6 months poststroke), and (3) chronic (6+ months poststroke). To assess the influence of training duration on the results of this study, MESs of studies belonging to the following categories were calculated: (1) 3 to 4 weeks training, (2) 5 to 6 weeks training, and (3) 12+ weeks of training. To assess the influence of the training intensity on the results of this study, MESs of studies belonging to following categories were calculated: (1) training less than 3 hours per week, (2) training between 3 and 4 hours per week, and (3) training more than 5 hours per week.

## Results

### Selection of Studies

The article selection process and results are shown in Figure 1. From the 362 articles resulting from the literature search, 16 papers were finally selected and analyzed. In 2 articles,[34,35] both the control and intervention groups were offered task-oriented training. One article[16] reported the follow-up results from another included study[15]; both studies were further treated as a single study for data extraction. Therefore, a total of 17 interventions were analyzed with regard to task-oriented training type. Three studies (4 articles)[15,16,36,37] did not report the mean and SD information of the results that were needed for ES calculation. As a result, ES calculation could be performed from only 14 interventions.

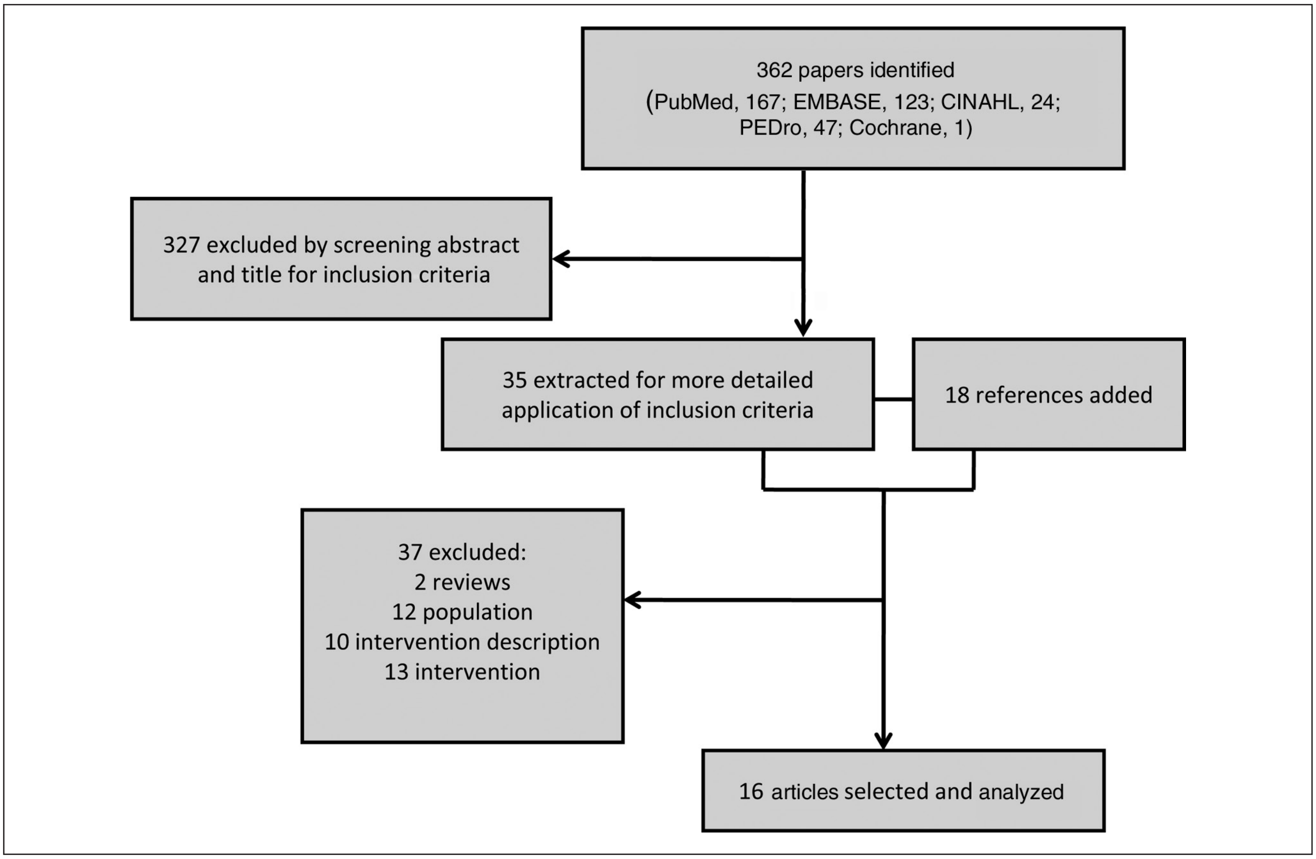


**Figure 1.** Process of article selection.

## *Patient Characteristics of Included Studies*

In total, the intervention results of 528 patients were studied. All patients had suffered from ischemic or hemorrhagic stroke. The average age of the patients was 68.9 years (range = 38.4-95.1 years). The number of days since stroke on inclusion to the study varied between 5 and 546 days (average = 71.63 days). The average sample size of the group studied was 31 persons (SD = 15.8). More detailed information about the characteristics of the patients who participated in the included studies is provided in Table 1.

## *Methodological Quality Judgment*

In Table 2, the Van Tulder scores are presented for the 15 studies that are included in this review.

The 2 coders disagreed on 20 of the 204 Van Tulder items, resulting in a mean Cohen's κ score of .79, which was considered good.[38] After obtaining consensus on the differences in Van Tulder scores, the mean Van Tulder score of all included studies was 13.6 (SD = 1.7).

All studies were of acceptable methodological quality, as the lowest Van Tulder score equaled 11, which is well above the Van Tulder suggested cutoff point of 50% (=9.5).[29]

The mean internal validity score for all studies was 7.2 (out of 10; SD = 1.4). The mean descriptive score for all studies was 4.6 (out of 6; SD = 0.8). Twelve out of the 15 studies had full scores for statistical criteria. The mean statistical score was 1.8 (SD = 0.4).

## *Use of Components in Task-Oriented Training Intervention and Their Relation to Intervention Effect Size*

The two coders disagreed on 12 of the 255 components rated (255 = 17 interventions × 15 components), resulting in a mean Cohen's κ score of .88 (SD = .15), which was considered excellent.[38]

The articles included in this study used between 3[15,16] and 11[34] training components. The average number of training components used was 7.8 (SD = 2.1). An overview of the training components that were used in each study is provided in Table 3.

Six components, that is, "training that was functional," "use of a clear ADL goal," "use of real object manipulation," "use of exercise progression," "involving multiple movement planes," and "total skill practice" were included in at least 12 of the 17 interventions.

Two components were included in between 9 and 11 of the 17 interventions: "use of a patient customized training load" and "inclusion of bimanual task practice."

Seven components were included in less than 9 of the 17 interventions studied: "client-centered training," "use of frequent repetitions," "training in a context-specific environment," "exercise variety," "feedback on motor performance," "random," and "distributed practice."

No relation was found between the number of components used in a training intervention for improving arm–hand performance after stroke and the postintervention ES ($r = .12$).

All but 3 components were associated with large postintervention and follow-up MESs (Cohen > 0.5[33]). Only client-centered training, bimanual training, and total skill training were associated with medium ESs (Cohen 0.2-0.5[33]).

As explained earlier, the component "functional" (MES = 0.9) can be considered as a measure of comparison for the MESs of the other components. The components that were associated with the largest postintervention ES are (nonrelative values) "distributed practice" (MES = 2.39) and "feedback" (MES = 1.95). Also scoring high were "within task exercise variability" (MES = 1.72) and "random practice" (MES = 1.72). An overview of the RMES per component is given in Figure 2 for postintervention and in Figure 3 for follow-up.

For follow-up ES the median value of the component "functional" equals 1.24. The components that scored highest on follow-up ES (compared to baseline values) were "use of clear functional goals" (MES = 4.01) and "random practice" (MES = 2.95). Also scoring high were "context-specific environment" (MES = 2.03), "frequent movement repetition" (MES = 1.4), and "feedback" (MES = 1.4).

The studies that were training with acute stroke patients were associated with an MES (MES = 4.19) that was almost 4 times larger than the MES associated with studies that were training subacute (MES = 1.04) and chronic (MES = 1.17) stroke patients. However, 3 components that were linked to large ESs (feedback, random practice, and use of clear functional goals) were linked to studies with acute, subacute, and chronic patients. Therefore, it can be concluded that poststroke time did not influence the results presented for these components in this study. The component "distributed practice" only occurred in the category of acute stroke patients.

The following MES values were found for the training duration categories: (1) 3 to 4 weeks training (MES = 0.93, SD = 2.17), (2) 5 to 6 weeks training (MES = 1.17, SD = 0.62), and (3) 12+ weeks of training (MES = 2.99, SD = 1.8). Longer intervention duration does influence the MES, which is consistent with earlier results found in other task-oriented training interventions.[6] However, 3 out of 4 components were well distributed over the different categories. The result for the component "distributed practice" may have been influenced by training duration as it only occurred in the category training of 12 weeks.

The MES values of the training intensity categories were (1) training less than 3 hours per week (MES = 1.1, SD = 0.8), (2) training between 3 and 4 hours per week (MES = 1.02, SD = 0.2), and (3) training more than 5 hours per week (MES = 1.6, SD = 1.9). One study[39] left the training intensity up to the patient and could therefore not contribute to this analysis. The components "clear functional goal," "feedback," and "random practice" were equally distributed along the different categories. However, the component "distributed practice" did only occur in the highest intensity category and may therefore have been influenced by this factor.

## Discussion

The aim of this systematic review was (1) to identify task-oriented training components and (2) to assess whether the number of task-oriented components that were used in a training intervention is related to the treatment ES, and (3) to assess the possible influence of task-oriented training components on the treatment ES.

Although the use of more task-oriented training components did not lead to higher treatment ESs, several components could be identified that were used more frequently in interventions with a larger treatment ES than other components, namely, "feedback" and "distributed practice" (postintervention) and "clear functional goal" and "random practice" (follow-up). Substantial evidence exists for the positive effects of distributed practice,[40] random practice,[12] feedback,[10,41] and clear functional goals[6,42] for motor skill learning after stroke. However, there has been no research to date that compares their importance for training outcome. It is good to raise awareness for the importance of these components in a task-oriented training program as especially feedback, random, and distributed practice were reported in very few of the included studies (in only 6, 3, and 1 out of the 17 studies, respectively; Table 3).

The finding that *distributed* practice improves postintervention performance and *random practice* is linked to high follow-up outcome is supported by previous research.[13,22] Distributed practice has been shown to result in better motor learning than massing practice sessions.[40] Possible explanations for the distributed practice benefit are that (1) less fatigue occurs than in mass practice, (2) the amount of cognitive effort that one is prepared to put is higher, and (3) there is more opportunity for memory consolidation

**Table 1:** Overview of Patient Characteristics, Training Content, Measurement Instruments and Effect Size

| | Patients | | | Intervention | | | | | Measurement | Results | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Reference | Mean Age (SD) | Days Since Stroke (SD) | Sample Size | Training | Duration (Weeks) | Frequency/ Week | Frequency/ Day | Minutes/ Session | Instruments | PI-ES | FU-ES |
| Alon 2008[54] | 66.46 | 23.8 (10.9) | 13 | Task-specific training: grasping, holding, moving and placing objects | 12 | 5 | 2 | 30 | BBT, JTT, FM | 4.19 | |
| Baskett 1999[11] | 67.8 | 38.6 (28.1) | 50 | Individual home exercise program instructed by therapist, but patient trained by himself (no daily supervision of therapists at home) | 12 | 7 | Try several | Choice Patient | MAS, MBI, NHPT, FAT, grip strength (JAMAR) | 0.59 | |
| Blennerhasset 2004[55] | 56.3 | 50.1 (49.2) | 15 | Circuit of 10 five-minute workstations (under supervision) including warm-up, functional tasks to improve reach, grasp, hand-eye coordination, stretches (if needed therapist assisted exercises) | 4 | 5 | 1 | 60 | JTT, MAS | 1.07 | 1.09 |
| Chan 2006[34] | 53.8 (15.4) | 117.7 | 33 | Program in 4 steps: (1) identification missing performance components, (2) training using remedial exercises, (3) training using functional tasks components, (4) training functional skills | 6 | 3 | 1 | 120 | FIM, IADL, CIQ | 2.19 | |
| | 54.4 (13.7) | 88.8 | 33 | No identification of missing components, training remedial tasks and training functional task without reinforcement of missing components | | | | | | 0.46 | |
| Desrosiers 2005[35] | 72.2 | 34.2 (34.4) | 20 | Symmetrical and asymmetrical bilateral tasks, unilateral task of affected and less affected side | 5 | 3-4 | 1 | 45 | BBT, PPT, TEMPA, FIM, AMPS, grip strength (Martin Vigorometer) | 1.02 | |
| | | 35.4 (33.7) | 21 | Functional activities and exercise to enhance strength, active, assisted and passive movements and sensorimotor skills of the arm | | | | | | 0.78 | |
| Duncan 2003[36] | 68.5 | 77.5 (28.7) | 44 | Exercise program to improve strength, balance, endurance and to encourage use of affected extremity | 12 | 3 | | 90 | WMFT, FM, grip strength (JAMAR) | NA | |

*(continued)*

**Table 1 (Continued)**

| | Patients | | | Intervention | | | | | Measurement | Results | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Reference | Mean Age (SD) | Days Since Stroke (SD) | Sample Size | Training | Duration (Weeks) | Frequency/ Week | Frequency/ Day | Minutes/ Session | Instruments | PI-ES | FU-ES |
| Higgins 2006[56] | 73 | 217 | 47 | Therapy session + home program: training tasks based on daily problems including manipulating playing cards, clothespins, writing | 6 | 3 (home ex 7) | 1 | 90 (+15 home ex) | BBT, NHPT, TEMPA, BI, IADL, SF-36, grip strength (JAMAR) | 0.18 | |
| Holmqvist 1998[37] | 70.8 (7.6) | 5 | 41 | Individual tailor-made therapy at home with therapist | 12-16 | | | | BI, NHPT, LMC, Katz, FAI, SIP | NA | |
| Kwakkel 1999-2002[15,16] | 69 (9.8) | 7.2 (2.8) | 33 | Functional exercises that facilitated forced arm and hand activities such as leaning, punching a ball, grasping and moving objects | 20 | 5 | | 30 | BI, ARAT, FAI, NTHP, SIP | NA | |
| Liu 2004[57] | 72.7 (9.4) | 15.4 (12.2) | 20 | 3 sets of daily tasks with 5 tasks in each set (eg folding laundry, shopping, taking transportation) | 3 | 5 | | 60 | Performance of tasks, FM | 0.59 | |
| McDonnell 2007[58] | 60.1 (10.5) | 138 (78) | 10 | Identification of impairment; strategies to reduce these impairments implemented; task specific training including reaching, wrist extension against resistance, performing fine motor skills | 3 | 3 | 1 | 60 | Grip-Lift Task, ARAT, FM, MAL, Pinch Grip, Tapping speed | 0.79 | 4.01 |
| Michaelsen 2006[59] | 69.4 (10.8) | 546 (321) | 15 | Object-related reach-to-grasp training | 5 | 3 | 1 | 30 | Tempa, BBT, kinematic outcomes, FM | 0.58 | 0.71 |
| Morris 2008[60] | 67.8 (9.9) | 47 (9-284) | 50 | Bilateral training including 4 core tasks: move a doweling peg, move a block from the table, grasp and empty glass, point at targets | 6 | 5 | | 20 | BI, ARAT, NHPT, RMA, NTHP | 1.72 | 1.4 |
| Sackley 2006[39] | 88.6 (6.5) | ? | 63 | Targeted towards ADL activities, eg feeding, dressing, bathing, transferring, and mobilizing | 12 | | Choice Patient | | BI, RMA | 2.99 | 0.05 |
| Winstein 2004[46] | 95% 35-75 | 15.5 (6.0) | 20 | Standard care such as muscle facilitation, stretching, self-care; plus task-specific functional training such as pointing, grasping, stirring | 4 | | | 60 | FTHUE, FIM, FM, muscle strength arm-hand (Chatillon force gauge) | 5.15 | 4.51 |

**Abbreviations**: SD: Standard deviation; PI-ES: Post-intervention effect size; FU-ES: Follow-up effect size; BBT: Box and Block Test; JJT: Jebsen–Taylor Test; MAS: Motor Assessment Scale; MBI: Modified Barthel Index of activities of daily living; NHPT: Nine-Hole Peg Test; NTHP: Nottingham Health Profile; FAT: Frenchay Arm Test; FAI: Frenchay Arm Index; FIM: Functional Independence Measure; IADL: Instrumental Activities of Daily Living; PPT: Purdue Pegboard Test; AMPS: The Assessment of Motor and Process Skills; WMFT: Wolf Motor Function Test; LMCA: Lindmark Motor Capacity Assessment; ARAT: Action Research Arm Test; RMA: Rivermead Motor Assessment upper-limb scale; FTHUE: Functional Test for hemiparetic upper extremity; FM: Fugl Meyer Assessment; CIQ: Community Integration Questionnaire; SIP: Sickness Impact Profile

**Table 2.** Van Tulder Score

| Reference | Internal Validity Score | Descriptive Score | Statistical Score | Total Score |
|---|---|---|---|---|
| Alon 2008[54] | 4 | 5 | 2 | 11 |
| Baskett 1999[11] | 8 | 4 | 1 | 13 |
| Blennerhassett 2004[55] | 7 | 4 | 2 | 13 |
| Chan 2006[34] | 6 | 4 | 2 | 12 |
| Desrosiers 2005[35] | 7 | 4 | 2 | 13 |
| Duncan 2003[36] | 9 | 5 | 2 | 16 |
| Higgins 2006[56] | 8 | 4 | 2 | 14 |
| Holmqvist 1998[37] | 6 | 6 | 1 | 13 |
| Kwakkel 1999-2002[15,16] | 10 | 6 | 2 | 18 |
| Liu 2004[57] | 6 | 4 | 2 | 12 |
| McDonnell 2007[58] | 8 | 4 | 1 | 13 |
| Michaelsen 2006[59] | 7 | 4 | 2 | 13 |
| Morris 2008[60] | 8 | 4 | 2 | 14 |
| Sackley 2006[39] | 8 | 5 | 2 | 15 |
| Winstein 2004[46] | 7 | 6 | 2 | 15 |

processes.[22] Random practice leads to better retention of learned motor performance through the contextual interference effect (memory and performance disruption that lead to a learning benefit[12]). *Feedback* is known to have positive effects on motor learning, although limited evidence is available for stroke patients.[41] The choice of appropriate and patient-customized feedback is very complex and depends on the location and type of the brain lesion[43,44] and the stage of learning the patient is in.[45] The way feedback was delivered was poorly described in many intervention reports. For example, it is known that progressively reducing feedback frequency leads to a better retention of learning effects and better transfer effects.[25,43,46] It was not clear at all if this strategy was used. A *clear functional goal* is identified as an important component for treatment outcome at follow-up. Working with a clear functional goal is a manner of goal setting that may increase the efficiency and the effectiveness of rehabilitation.[47] Even after finishing the training, patients are more likely to keep on doing these functional goals and therefore obtain better results at follow-up.

A common feature of the 4 components linked to the highest ES is that they all optimize the storage of learned "skilled" (clear functional goal) motor performance in the long-term memory (see reasons given in discussion above). This may be the reason for their contribution to high treatment outcome.

The ESs that were linked to "client-centered training" were lower than expected. It is known that client-centered training increases the level of "active" participation of the patient in the rehabilitation process.[48] This has a positive influence on patient motivation, which is an important factor for motor learning as attention during training is enhanced and exercise repetition and treatment compliance are stimulated.[25,49] The poor result for "client-centered training" in this review may be attributed to the fact that the aforementioned benefits could not be materialized during the clinical trial interventions, for example, because there was little control from therapists during home training, or by restricting the amount of repetitions or exercise duration to the one described in the exercise protocol or by not making use of the benefit from enhanced attention to "learn" (ie, store information in short- and long-term memory), for example, through very fast follow-up of exercises. Another cause for the poor result of this factor may be that client-centered treatment focuses on very specific goals (eg, progressions in the real-life objects used) that are not always measurable with the tests that were used in the included studies. This emphasizes the need for theoretical frameworks to formalize client-centered treatment and to guide the application of client-centered care into clinical practice.[50,51] Although there is not enough evidence for this component to be contributing to large treatment effects, it may be too early to dismiss it because of the early stage client-centered training is in with regard to its implementation in training interventions.

## *Methodological Considerations*

Studies could not be compared with regard to ESs because of differences in training duration, dosage of task practice, severity at inclusion, and time since stroke (Table 1). The authors chose to investigate which MES corresponded to each component. In this case the differences that occurred between studies were similar for all components, except for the results of the component "distributed practice," which may have been influenced by poststroke time, training duration, and training intensity. The ESs reported were not only influenced by the training content but also by the use of different measurement instruments (18 different outcome measures in 16 interventions). Although these effects are spread across the different studies, greater standardization of outcome measurements in the future would benefit the field.

The extent to which identified training components were used (and evaluated) in the study could not be assessed. For example, feedback was mentioned, but not which type (knowledge of performance or knowledge of results feedback, visual or auditory or haptic feedback), the frequency (after each exercise or summary feedback), or the schedule (fading frequency schedules, feedback delay).

Several studies were excluded from this systematic review because the task-oriented training was not well specified. Also, studies using constraint-induced movement therapy were not included in this review. In CIMT trials the patient inclusion criteria and the manner in which task practice is taught to the patient (shaping principles[52])

**Table 3.** Total Number of Components Used per Study and Frequency of Component Use

| Reference | Used to Calculate ES | Functional | Clear Functional Goal | Client-Centered | Over-load | Real Object | Context Specific | Exercise Progression | Exercise Variety | Feed-back | Multiple Movement Planes | Total Skill | Customized Training Load | Random Practice | Distributed Practice | Bimanual Tasks Included | Total Components |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alon 2008[54] | v | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 8 |
| Baskett 1999[11] | v | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 10 |
| Blennerhassett 2004[55] | v | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 4 |
| Chan 2006[34] (A) | v | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 11 |
| Chan 2006[34] (B) | v | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 9 |
| Desrosiers 2005 (A)[35] | v | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 10 |
| Desrosiers 2005 (B)[35] | v | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 7 |
| Duncan 2003[36] | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 8 |
| Higgins 2006[56] | v | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 9 |
| Holmqvist 1998[37] | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 7 |
| Kwakkel 1999[15] & 2002[16] | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 3 |
| Liu 2004[57] | v | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 8 |
| McDonnell 2007[58] | v | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 8 |
| Michaelsen 2006[59] | v | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 7 |
| Morris 2008[60] | v | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 9 |
| Sackley 2006[39] | v | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 10 |
| Winstein 2004[46] | v | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 6 |
| Frequency | | 17 | 12 | 4 | 7 | 13 | 6 | 12 | 5 | 6 | 16 | 12 | 9 | 3 | 1 | 11 | |

Note: In the second column, v denotes a study that was used to calculate ES; 0 denotes a study that was not used to calculate ES.
Abbreviation: ES, effect size.

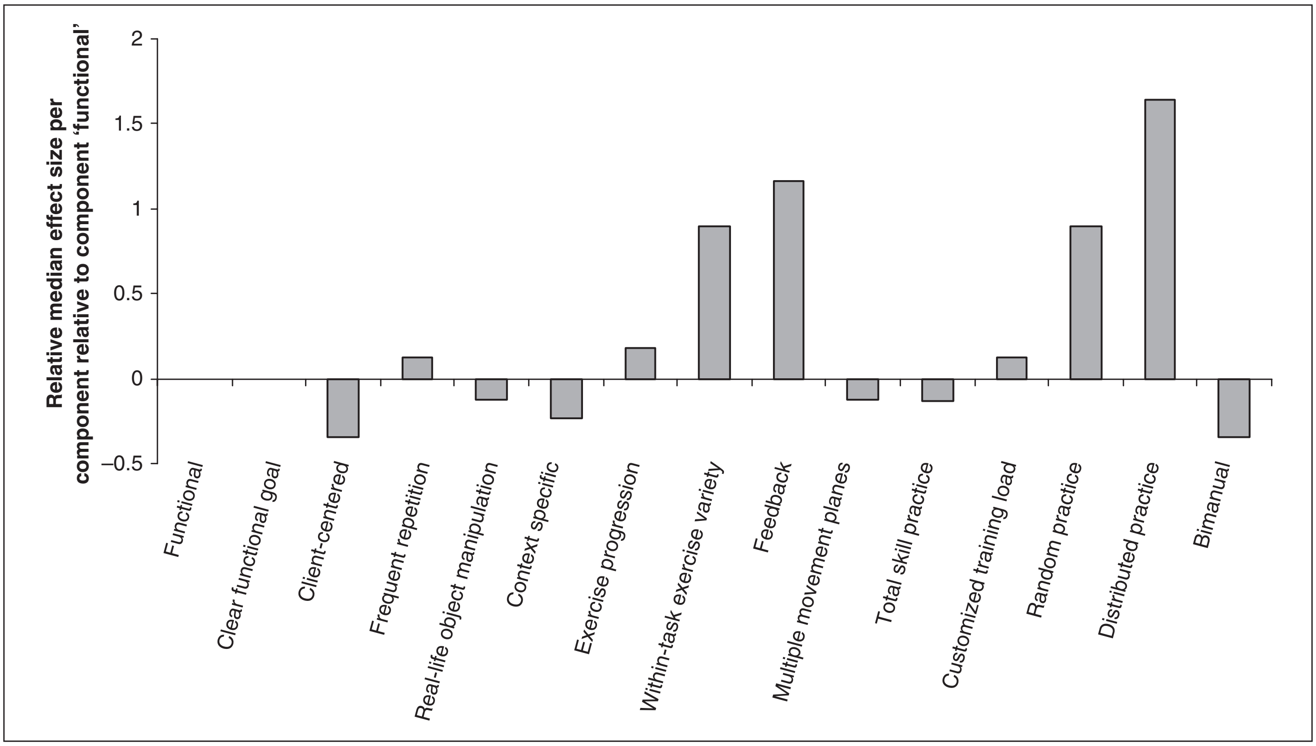


**Figure 2.** Relative median effect size per component (post-intervention).

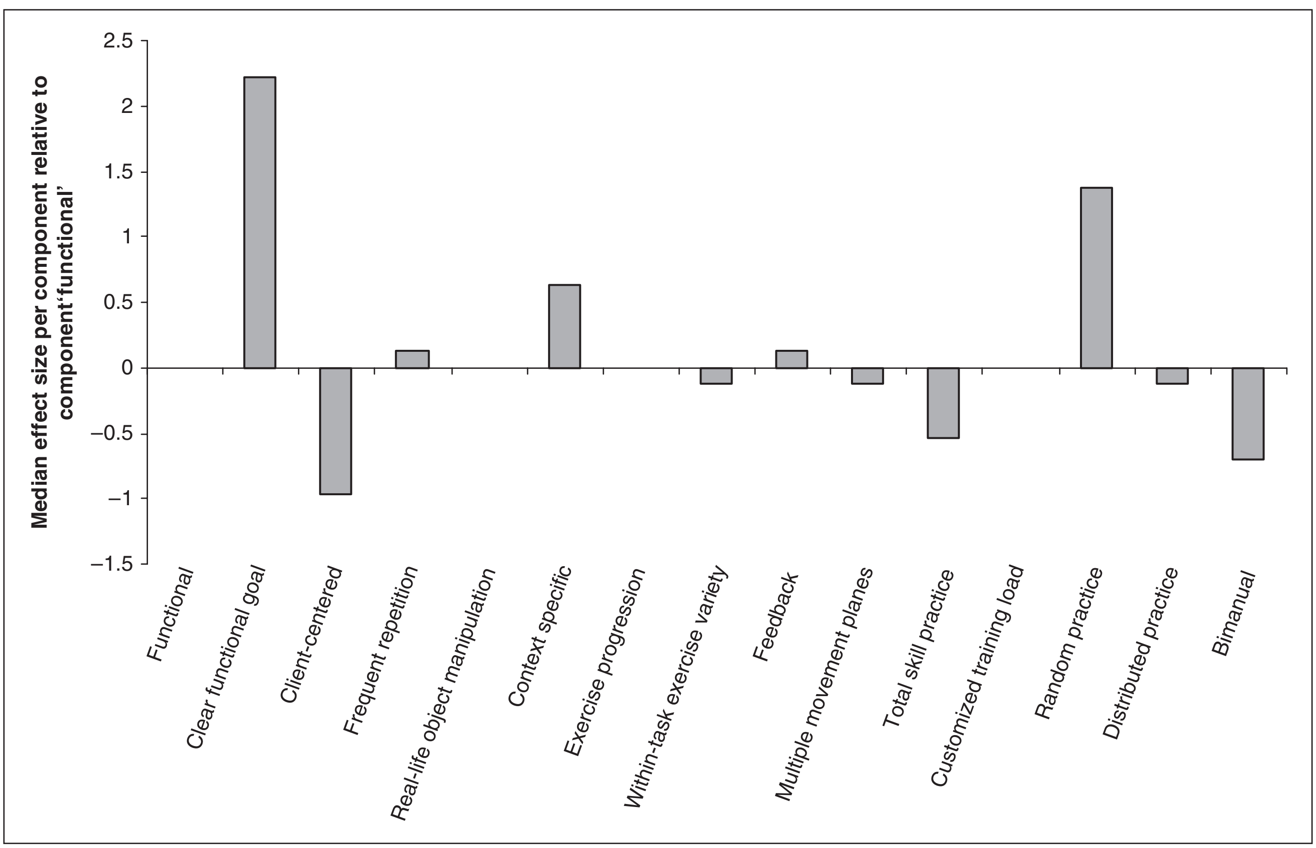


**Figure 3.** Relative median effect size per component (follow-up).

are highly specified. The baseline characteristics of the participants that were studied in the included trials of this review could not always be identified, especially with regard to impairment and activity levels. Also, the delivery of task training was generally not specified in relation to the problem-solving strategies that were stimulated. Because of the lack of comparability with the included trials, the CIMT randomized clinical trials were not included in this review.

Studies using technology-supported training (robotics, sensor technology) were not excluded from this systematic review. However, no publications of randomized clinical trials with technology-supported training were available that matched the inclusion criteria for this study. It will be very interesting to repeat this review when the results of ongoing research are published.[53]

It was not within the scope of this review to find out which training components lead to larger ESs for different patient groups, for example, with regard to degree of impairment in function/performance. This is an area for future research. The authors advocate for a detailed description of the training intervention, including a description of training content, training intensity, and training load for published trials.

This systematic review suggests that it is important to include random and distributed practice, feedback, and clear functional goals in task-oriented arm training for persons after stroke to augment outcomes of skilled arm–hand performance.

## Appendix

### *Brief Explanation of Task-Oriented Training Components*

1. *Functional movements:* A movement involving task execution that is not directed toward a clear activities of daily living goal (eg, moving blocks from one location to another, stacking rings over a cone) (as opposed to analytical movements, which are movements without a goal, usually occurring in one single movement plane and often occurring in single joints, eg, shoulder flexion).
2. *Clear functional goal:* A goal that is set during everyday-life activities, hobbies (eg, washing dishes, grooming activity, dressing oneself, playing golf).[20]
3. *Client-centered patient goal:* Therapy goals that are set through the involvement of the patient himself/herself in the therapy goal decision process. The goals respect patients' values, preferences, and expressed needs and recognize the clients' experience and knowledge.[21]
4. *Overload:* Training that exceeds the patient's metabolic muscle capacity.[23] Overload is determined by the total time spent on therapeutic activity, the number of repetitions, the difficulty of the activity in terms of coordination, muscle activity type and resistance load, and the intensity, that is, number of repetitions per time unit.[23] In this review, we have scored a high amount of repetitions as a determining factor for the presence of overload, as the other factors are rarely described in intervention descriptions.
5. *Real-life object manipulation:* Manipulation that makes use of objects that are handled in normal everyday-life activities (eg, cutlery, hairbrush, etc).
6. *Context-specific environment:* A training environment (supporting surface, objects, people, room, etc) that equals or mimics the natural environment for a specific task execution, in order to include task characteristic sensory/perceptual information, task-specific context characteristics, and cognitive processes involved.[13]
7. *Exercise progression:* Exercises on offer have an increasing difficulty level that is in line with the increasing abilities of the patient, in order to keep the demands of the exercises and challenges optimal for motor learning.[24]
8. *Exercise variety:* A variety of exercises was offered to support motor skill learning of a certain task because of the person experiencing different movement and context characteristics (within task variety) and problem-solving strategies.[13]
9. *Feedback:* Specific information on the patient's motor performance that enhances motor learning and positively influences patient motivation (for more information, the authors refer to Kisner and Colby[23]).
10. *Multiple movement planes:* Movement that uses more than 1 degree of freedom of a joint, therefore occurring around multiple joint axes.
11. *Total skill practice:* The skill is practiced in total, with or without preceding skill component training (eg, via chaining).[26]
12. *Patient-customized training load:* A training load that suits the individualized treatment targets (eg, endurance, coordination, or strength training[27]) as well as the patient's capabilities (eg, 65% of 1 repetition maximum or 85% of 1 repetition maximum for the specific patient).
13. *Random practice:* In each practice session, the exercises are randomly ordered.[13]
14. *Distributed practice:* A practice schedule with relatively long rest periods.[22]
15. *Bimanual practice:* Tasks where both arms and hands are involved.[28]

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