A Standardized Approach to Performing the Action Research Arm Test

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The study of stroke and its treatment in human subjects requires accurate measurement of behavioral status. Arm motor deficits are among the most common sequelae after stroke. The Action Research Arm Test (ARAT) is a reliable, valid measure of arm motor status after stroke. This test has established value for characterizing clinical state and for measuring spontaneous and therapy-induced recovery; however, sufficient details have not been previously published to allow for performance of this scale in a standardized manner over time and across sites. Such an approach to ARAT scoring would likely reduce variance between investigators and sites. This report therefore includes a manual that provides a highly detailed and standardized approach for assigning ARAT scores. Intrarater reliability and interrater reliability, as well as validity, with this approach were measured and are excellent. The ARAT, when performed in a standardized manner, is a useful tool for assessment of arm motor deficits after stroke.

Key Words: *Stroke—Recovery—Measurement—Motor System.*

A number of therapies are in development to improve motor outcome in human subjects with stroke.[1] Evaluation of such interventions, as well as the natural course of recovery after stroke, is highly reliant on the performance of the outcome measures employed.[2-5] The utility of an outcome measure to detect change in neurologic status is influenced by its clinimetric properties such as validity and reliability, as well as by the extent to which test administration is standardized, an issue that is the focus of this report.

Arm motor deficits are common after stroke.[5] Several measures are available for the study of arm motor function after stroke, including the Action Research Arm Test (ARAT). This test, first described by Lyle,[6] evaluates 19 tests of arm motor function, both distally and proximally. Each test is given an ordinal score of 0, 1, 2, or 3, with higher values indicating better arm motor status. The total ARAT score is the sum of the 19 tests, and thus the maximum score is 57.

The ARAT has been found useful in prior studies evaluating stroke patients across a wide spectrum of impairments.[7-14] The test shows good validity,[7,8] as well as sensitivity to spontaneous[7,9-11] and therapy-related[12-15] gains after stroke. Interrater and intrarater reliability have been reported to be high[6,8,16]; however, each of these values represents reliability as assessed within a single institution. Increasingly, multisite trials of acute stroke have embraced the importance of reducing the intersite variance that is present when assigning a score for outcome assessments.

The ARAT, like most motor assessments, requires a human examiner to transform observations of a patient's movement into a score. Reliance on a human examiner leaves room for variability in scoring, particularly given the innumerable patterns of motor exam abnormality that arise after stroke. Reliance on a human examiner also emphasizes the need for clear methods for testing and rules for scoring; however, little information is available to guide ARAT administration and scoring, although some strides have been made in this regard.[17]

This report therefore includes a manual that provides a detailed, standardized approach to scoring the ARAT. Most studies using the ARAT cite Lyle's original article that introduced the scale,[6] but many operational definitions and critical details are either absent or incompletely presented in this report. For example, for each of the 19 tests evaluated in the ARAT, the subject receives a score of 3 for a normal performance and a score of 2 if the subject "can complete the test but takes abnormally long or has great difficulty." Few specifics are available to define "abnormally long" or "great difficulty." This report addresses this need by rigorously defining such details. The definitions, materials, administration techniques, and scoring approaches suggested herein represent the final refinements from several years of experience with the ARAT. The reliability and validity of this suggested method are reported.

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METHODS

Subjects and Procedure

In order to assess the reliability and validity of the currently presented method of ARAT scoring (see Appendix), 12 subjects with stroke were examined. Inclusion criteria were (1) chronic stroke, defined as more than 3 months prior; (2) moderate right hemiparesis, defined by a more than 10-degree range of motion at index finger metacarpophalangeal joint but 9-hole pegboard score on right less than 75% of score on the left; (3) age of more than 18 years; and (4) right-hand dominant.[18] All subjects gave informed consent as approved by the local institutional review board.

Three properties of ARAT were studied. First, for interrater reliability, 2 different therapists, each blinded to the other, scored ARAT during the same session in the 9 patients available for this assessment. Second, for intrarater reliability, the same therapist repeated the ARAT for each patient within a 1-week interval in the 8 patients available for this assessment. Third, the validity of the current ARAT method was assessed by having a single therapist compare the ARAT score with a valid, reliable, sensitive, often-used measure of arm motor function after stroke, the arm motor Fugl-Meyer score,[10,19,20] in 12 patients.

Statistics

Validity measures were evaluated using the Pearson correlation coefficient. Interrater reliability and intrarater reliability were estimated in 2 ways, first via the intraclass correlation coefficient, and second, via the Spearman rank correlation coefficient. For all tests, significance was set at .05. All statistical procedures were performed with the JMP5 (SAS, Cary, NC).

RESULTS

The 12 stroke patients examined had a mean age of 61 ± 15 years (mean ± SD; range, 39-86), with 6 males/6 females, and mean time after stroke of 34 ± 59 months (range, 4-217). Baseline ARAT total score and Fugl-Meyer arm motor scores were 34 ± 20 and 45 ± 11, respectively. Mild-moderate aphasia (score on National Institutes of Health Stroke Scale question 9 = 1) was present in 4 of 12, and mild to moderate neglect (score on NIHSS question 11 = 1) was present in 3 of 12 patients.

Interrater reliability (Table 1) and intrarater reliability (Table 2) were each excellent, with high values for Spearman's ρ and intraclass correlation coefficient measured for each, for both total and subscale scores. Validity was also excellent, with ARAT and arm motor Fugl-Meyer score showing a high correlation ($r = .94$, $P < .01$).

DISCUSSION

The ARAT was first described by Lyle[6] as an adaptation to Carroll's Upper Extremity Function test.[21] Wagenaar et al[11] suggested a time cutoff for "abnormally long." Platz et al[16] provided some suggestions for size of test materials and general guidelines for scoring. An instructional DVD, ARAT box vendor, and corresponding website (http://www.aratest.eu/) have been of additional value; however, the need existed for defining several operational definitions and critical details on administration and scoring of ARAT. These details are provided herein (see Appendix), with excellent reliability and validity demonstrated using the proposed method.

The ARAT has been found to be valid,[7,8] reliable,[6,8,16] and sensitive to change[7,9-15] in patients with stroke; however, these reports provided little or no detail as to how testing was performed and scored, although 1 recent publication made some strides in this regard.[17] These issues are addressed in this report and the manual (see Appendix).

Based on the interrater reliability data (Table 1), the ARAT is capable of detecting changes that are in the range of clinically significant values. This assertion is based on the fact that a test is capable of detecting a difference that is equal to the mean ± 2 SDs of the difference between 2 ratings of the same subject.[10] For ARAT, based on the data in Table 1, this value is from −2.4 to 2.8, a range that is less than the minimum clinically important difference defined by van der Lee et al as 5.7 points (10% of the maximum score).[10] This increases confidence that clinically significant changes detected by ARAT are not a result of measurement error.

The use of a standardized method can reduce variance in testing scores. This is particularly important in motor assessments after stroke, where the challenges of converting subjective observations into a score are heightened by the innumerable patterns of motor exam abnormalities that can arise. Details of testing can each influence findings, for example, use of a specific time limit to define upper limit of normal,[22] positioning of trunk and extremities,[23-25] and choice of testing object weight, material, and texture.[26] These issues are of particular importance for a multisite investigation. Although

Table 1. ARAT Interrater Reliability

	Grasp Subscale		Grip Subscale		Pinch Subscale		Gross Movement Subscale		ARAT Total	
Examiner	1	2	1	2	1	2	1	2	1	2
Mean	11.22	11.33	7.22	7.22	8.11	8.22	6.77	6.77	33.33	33.55
SD	8.15	8.06	5.11	5.17	7.84	7.74	2.22	2.22	22.49	22.35
Range	0-18	0-18	1-12	0-12	0-18	0-18	3-9	3-9	6-56	5-56
Spearman's r	1.0	1.0	.99	.99	0.98	0.98	.93	.93	.96	.96
Spearman's p	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001	.0003	.0003	< .0001	< .0001
ICC	.9992	.9992	.996	.996	.997	.997	.978	.978	.9986	.9986

ICC = intraclass correlation coefficient

Table 2. ARAT Intrarater Reliability

	Grasp Subscale		Grip Subscale		Pinch Subscale		Gross Movement Subscale		ARAT Total	
Exam	1	2	1	2	1	2	1	2	1	2
Mean	12.25	11.75	8.08	7.85	7.75	7.54	6.75	6.61	34.33	34.33
SD	7.43	7.78	4.46	4.35	7.21	6.95	2.13	2.1	20.29	20.46
Range	0-18	0-12	0-12	0-12	0-18	0-18	3-9	3-9	5-57	5-57
Spearman's r	.93	.93	.93	.93	.98	.98	.91	.91	.99	.99
Spearman p	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001
ICC	.98	.98	.97	.97	.99	.99	.93	.93	.99	.99

ICC = intraclass correlation coefficient

this report is from a single center, extensive information is provided in order to generate a standardized method for ARAT administration that is expected to be useful for future multisite trials.

APPENDIX
Manual for Performing and Scoring the ARAT

OVERVIEW OF THE ACTION RESEARCH ARM TEST

The final Action Research Arm Test (ARAT) score is the sum of the scores from 19 tests spread across each of 4 subscales[6]: grasp, grip, pinch, and gross movement. Items in each subscale are arranged in a hierarchical order of difficulty, with the most difficult item in the subscale tested first, followed by the easiest tested second. This approach, outlined by Lyle, can increase efficiency of subject assessment, as normal performance on the most difficult subscale item predicts success for all of the remaining items in that subscale, which are easier tasks. Similarly, complete failure on performance of the easiest item predicts failure with all of the remaining items, which are more difficult tasks. With this approach, the ARAT takes about 5 to 15 minutes to administer.

The quality of movement for each of the 19 tests examined in the ARAT is scored on an ordinal 4-point scale, with 0 = no movement, 1 = the movement task is partially performed, 2 = the movement task is completed but takes abnormally long, and 3 = the movement is performed normally (see Table A1). These are Lyle's original terms, clarification of which could improve standardization of ARAT testing.

Another aspect of the ARAT that could be improved is specification of the amount of time used to define "abnormally long," which distinguishes a score of 2 versus 3. Another aspect of the ARAT that requires greater standardization is the source, material, weight, and size of the materials used for examining subjects, variability in which likely influences ARAT scores. In addition, many of the fine details of test administration are not stated in the original report and are open to interpretation, such as body position/posture, test item positioning, and a maximum time allowed to complete each ARAT test item. This could be an additional source of score variance across centers and time. These are among the issues considered herein.

ARAT MATERIALS

The basic testing materials, as originally outlined by Lyle,[6] are a chair without armrests, a table, various sized wooden blocks, a cricket ball, a sharpening stone, alloy tubes, a washer and bolt, 2 glasses, marbles, and ball bearings. Also required are 2 planks for placing the alloy tubes, 1 plank to place the washer, 2 tobacco tin lids, and a 37-cm-high shelf. Suggested standards for these materials appear in Table A2.

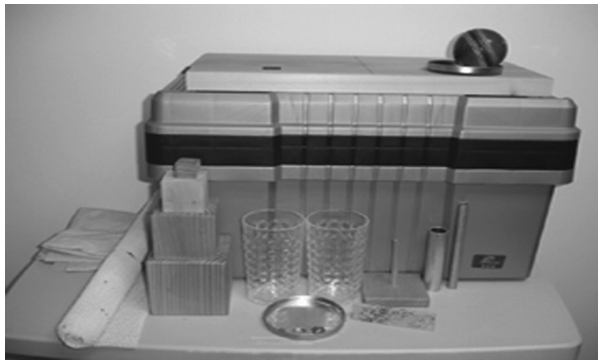


Figure 1. The complete ARAT kit is displayed.

Each material can be purchased at a large hardware store or together from vendors such as http://www.aratest.eu/. The wooden blocks are cut to appropriate sizes and are sanded and finished. We recommend fabricating these from pine, which is widely available, and has a consistent and light density. The cricket ball (The Pavilion, Dreamcricket, Hillsborough, NJ; www.dreamcricket.com), sharpening stone (Smith's Medium Arkansas Stone Knife Sharpener, Hot Springs, AR, CAT#MP4L; www.smithabrasives.com), marbles (widely available), ball bearings (made of steel, widely available), and plastic tumblers (widely available) are standard items that can be bought prefabricated. The alloy tubes are fabricated from aluminum tubing and are cut down to appropriate size with rough edges sanded down. A plastic toolbox (56 cm in length × 32 cm in width × 34 cm in height; Plano, Grab'n Go style, Part # 823-002, Plano, IL, http://www.planomolding.com) can be used for 2 purposes: first, to house/carry all materials, and second, as part of the 37-cm shelf employed during testing. To create the final shelf used in testing, a wood plank (3 cm in height) is placed on top of the box and is affixed with Velcro (Figure 1). If this plank is 23 cm in width × 46 cm in length, it will fit in the box with other materials during storage and affix to the top of the box snugly to create the needed 37-cm shelf. This system allows for ease of portability.

POSITIONING

Positioning of the Subject

Appropriate body posture for ARAT testing has the subject seated upright in a standard chair that has a firm back and no armrests. The assessor may provide foam padding to the back of the chair to ensure that upright position is maintained. The trunk must remain in contact with the back of the chair throughout testing. In this regard, the subject is instructed and regularly reminded not to lean forward, stand up, or move sideways, although we do not recommend that the subject's trunk be strapped to the chair. The head is held in a neutral upright position. The subject's legs are in front of the chair, with feet in contact with floor throughout testing.

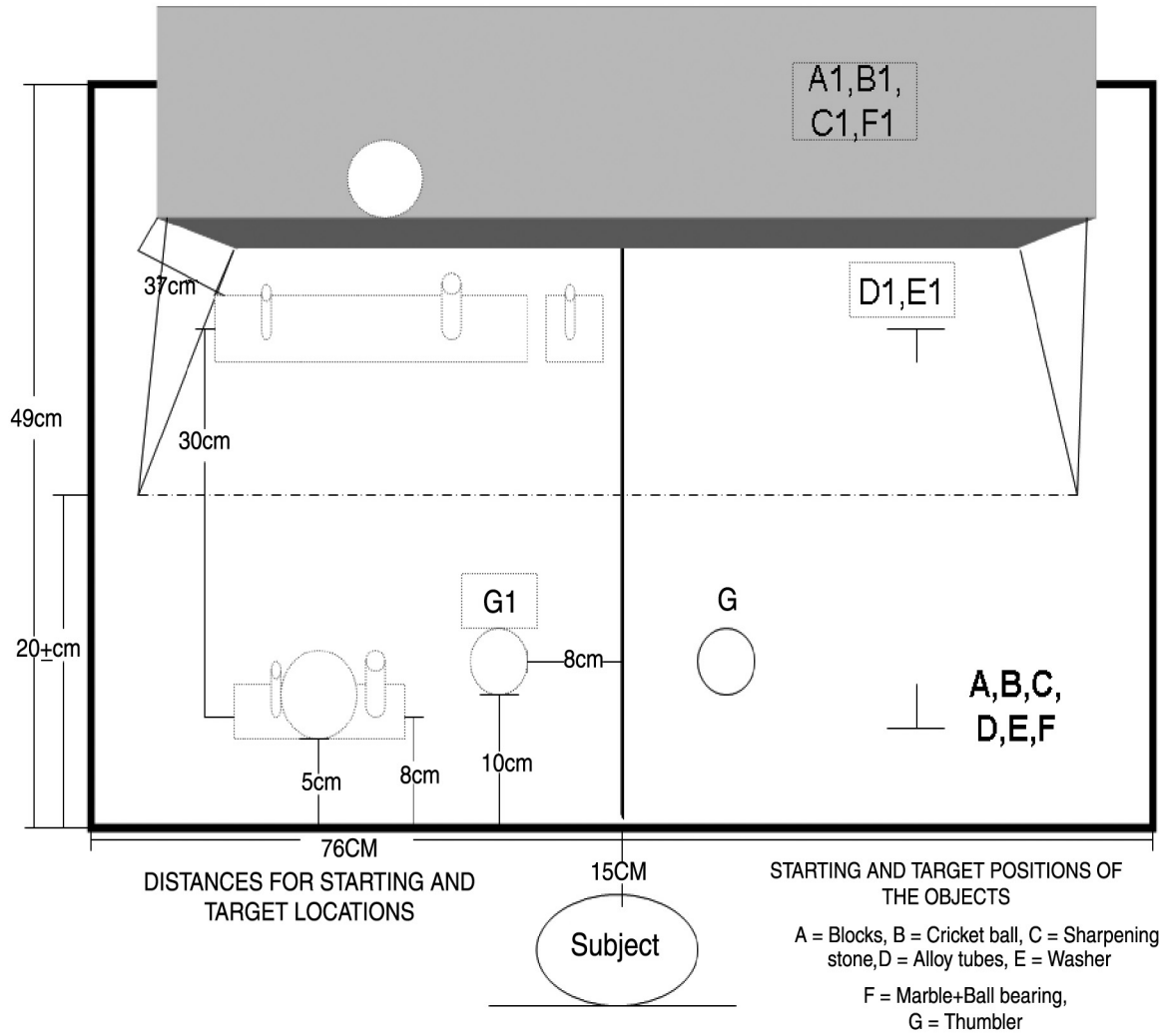


Figure 2. Mat dimensions and object placement positions are indicated for ARAT testing.

All ARAT tasks are performed unilaterally. To promote this and keep the nontested hand in view, the subject is always asked to start with both hands in pronated position on the table, except for the "gross movement" subscale, which requires starting with both hands pronated on the lap. Suggested chair and testing-table dimensions are provided in Table A2. The testing-table level should approximate the subject's midabdomen, with the difference in chair-table height of about 30 cm considered optimal.

Positioning of the Materials for Each Task

The subject sits close to the table, with a 15-cm distance from the anterior torso to the front edge of table. In our experience, this distance allows enough upper-extremity mobility for the subject to be able to reach the top of the shelf, but maintains emphasis on the required body posture during testing. The use of a nonslip mat that is placed over the table is highly recommended. We have found it useful to draw prestated positions for each test object on this mat (Figure 2).

Further specifications for position of testing materials are specified under the instructions for each subscale.

SCORING

General Scoring Instructions

Instructions for each task are read aloud to the subject; however, if the subject has any difficulty understanding instructions, such as in the presence of aphasia, the assessor has the option of also providing a visual demonstration of the requested task. The subject is allowed to practice the task repeatedly to insure that instructions are fully understood.

Both upper extremities are separately assessed. For each of the 4 ARAT subscales, the subject starts with the nonaffected (or less affected) arm, and then the affected arm is assessed for that subscale. Thus, the order of testing is the nonaffected arm grasp subscale, the affected arm grasp subscale, the nonaffected arm grip subscale, the affected arm grip subscale, and so forth. The use of this order, combined with verbal and visual instruction, improves test instruction comprehension. We have found this method useful in patients with mild to moderate aphasia or neglect.

The 19 tests of the ARAT are distributed across 4 subscales, with 3 to 6 tasks each. Each task runs until the subject completes the task or until reaching a time limit that we have defined as 60 seconds. The quality of the task is rated on an ordinal 4 point-scale, that is, from 0 to 3. The maximum score for the ARAT is 57 for each arm, with a higher score indicating better arm motor status. A general scoring outline follows, with further specifics provided in each task's section.

A score of 3 is given when the task is performed normally. This requires the task be completed in less than 5 seconds, appropriate body posture, normal hand movement components, and normal arm movement components (see Table A3).

A score of 2 is given when the task is completed but either "with great difficulty or takes abnormally long." We define "great difficulty" as task completion in the setting of either (1) abnormal hand movement components (eg, use of wrong grasp), (2) abnormal arm movement components (eg, the elbow does not flex as required), or (3) abnormal body posture (eg, used as a substitute for impaired arm movements).

The amount of time used to distinguish a score of 2 versus 3 was not specified by Lyle.[6] A specific time limit was first suggested by Wagenaar et al,[11] who advocated using the mean ± 2 SDs, as determined from age-matched healthy control subjects. As an extension of this, we define "takes abnormally long" as 5 to 60 seconds.

A score of 1 is given when the subject only partially completes the task within the 60 seconds allotted for examining each task, regardless of the quality of hand and arm movement components or posture requirements. For grasp, grip, and pinch subscales, the subject cannot achieve a score of 1 for arm movements only. In order to attain a score of 1, the subject must initiate some form of hand movement, abnormal or normal, that achieves holding and lifting the object—simply pushing an object across the table with the dorsum of the hand does not constitute partial completion of the true task.

A score of 0 is given when the subject is unable to complete any part of the hand or arm movement components within the 60 seconds allotted for examining each task.

The score is based on the best performance. A subject is not penalized if a testing object is dropped and relifted. All performances must be performed with only 1 hand.

For subjects who have any finger amputations, scoring is as usual except for the pinch subscale. For any task that requires movement of an amputated body part, such as opposition of an amputated finger, the subject scores 0, and the assessor notes "task not done secondary to amputation."

Specific Scoring Instructions for the Grasp Subscale (ARAT Test Items 1 Through 6)

Object positioning. The nonslippery mat is placed over the table, and then the shelf and testing objects are placed in their predrawn positions (Figure 2). This approach has the shelf placed lengthwise, 20 ± 5 cm away from the proximal edge of the table on the mat; however, if the subject does not have sufficient range of motion for the fingertips to reach the top of shelf, such as due to contractures or increased tone, then the examiner can adjust this distance as needed.

The items are placed, one at a time during the appropriate test, halfway between the subject's midsagittal line and the axillary line of the arm being tested. The hand being tested should be placed pronated, immediately lateral to the testing object, with the other hand also pronated atop the table. For all of the blocks, the assessor should not stabilize the object, nor can the subject stabilize the object with the nontested hand. For the sharpening-stone task, the stone has to be placed on its narrow long side in a slightly diagonal position (parallel to the axis of the palmar creases) for ease of grasping. If the sharpening stone falls to its side during grasping attempts, it can be repositioned onto its narrow long side by the examiner for up to 60 seconds. The 2 tin lids are used as the initial and final sites for the cricket ball. The distance between the proximal edge of the lower tin lid and the proximal edge of the table is 5 cm, whereas the proximal edge of the upper tin lid is the same as the proximal edge of the shelf. If desired, the upper tin lid can be attached to the top of the shelf using Velcro, in order to maintain stability, while the lower lid can be stabilized by the assessor as needed during task performance.

Instructions to subject. The subject is asked to grasp, lift vertically, place, and then release each object (block, ball, or stone) onto the top of the shelf. The instructions spoken to the subject are to "grasp the block [cricket ball, sharpening stone] that I have placed here, lift it up, and place then release it on top of that shelf."

Scoring. Start with the task of grasping the 10-cm block (the most difficult task in this subscale); if the score is 3, then the total score for this subscale is 18 for the arm being tested, and no further tasks need be tested for this arm on this subscale. If the score is 0 to 2, then continue to the task of grasping the 2.5-cm block (the easiest task in this subscale). If the score is 0, then the total score for this subscale is 0, and no further testing is required for this arm on this skip to subscale. If the score for the 2.5-cm block task is 1-3, however, continue with scoring all tasks in this subscale.

Score 3 indicates normal, complete, timely task completion. The subject must grasp the object, lift it up, and release it onto the shelf, all within 5 seconds, to obtain a score of 3. Appropriate hand movement components and arm movement components (Table A3) must be used, as well as posture requirements. The subject should not have the score reduced if the object falls off the shelf after successful task completion. The subject may release the object on any place on the shelf (Figure 3a-f).

Score 2 is given when the subject completes the task but does so "with great difficulty and/or takes abnormally long time." The subject can display great difficulty when (1) not using

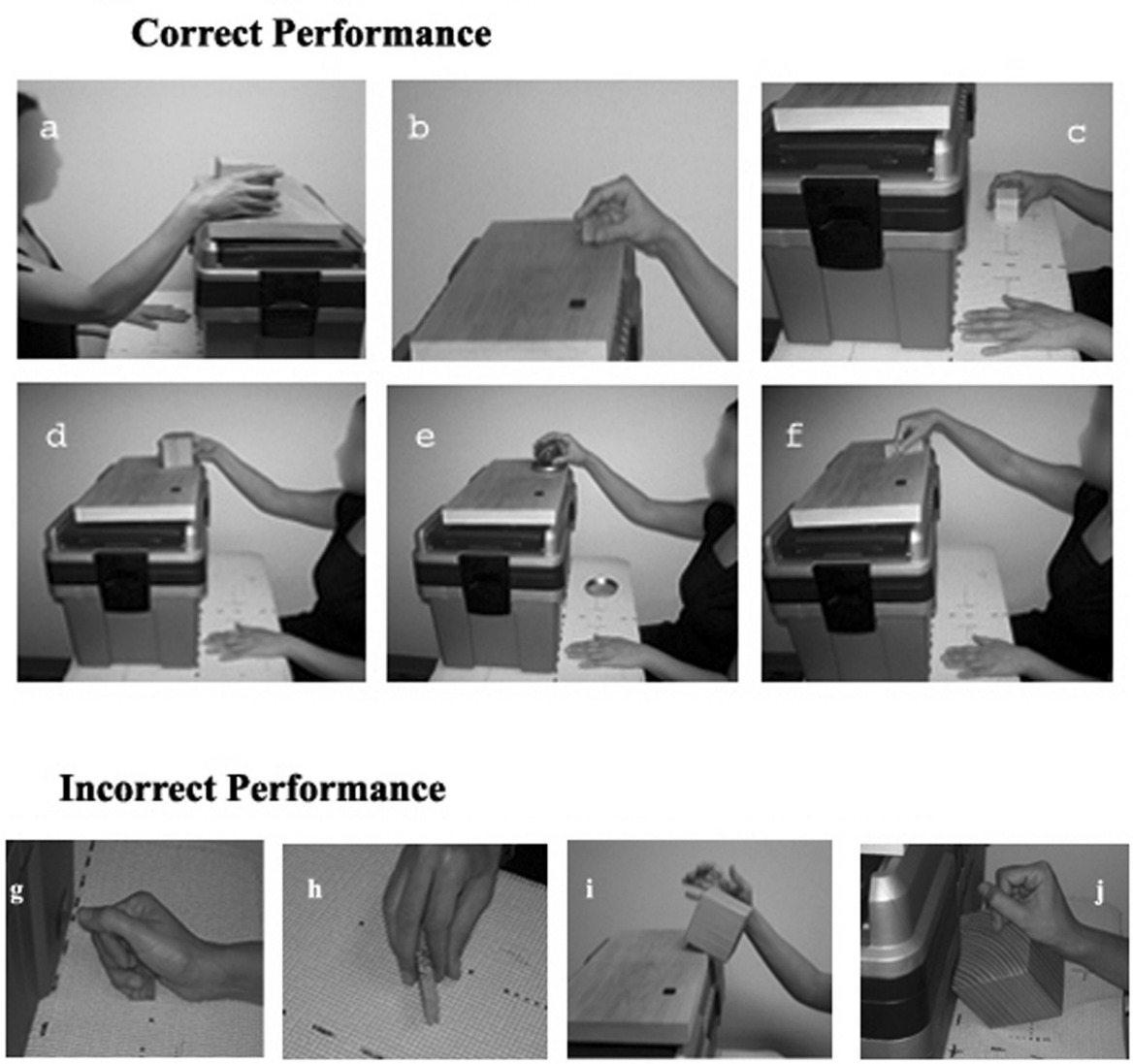


Figure 3. Grasp subscale. Correct performances are shown (a-f). Examples of incorrect performance: (g) thumb is not involved while grasping the 2.5 cm^3 block, (h) incorrect grasp for lateral pinch, (i) block falls off the shelf before release is completed, (j) object is held only via pushing it against the box.

appropriate hand movement components (Table A3), even if the task is otherwise completed (Figure 3g-h); (2) the subject displays abnormal arm movement components, such as abnormal object release when the object is brought to the shelf (Figure 3i); or (3) abnormal posture is evident (eg, if subject's trunk completely loses contact with the back of the chair). A score of 2 is also assigned if task completion takes 5 to 60 seconds.

For score 1, there are several possible means by which the subject can partially perform the task and thus receive a score of 1. For example, if the subject grasps and lifts the object, but does not reach the level of the shelf within the 60 seconds. A subject who can hold and lift the object—even with abnormal hand movement components and arm movement components —and lift it off the table any distance would score a 1 (Figure 3g and 3h). The subject must initiate some form of hand movement component to hold and lift the object, in order to attain a score of 1.

Score 0 indicates that the subject is unable to perform any part of the task within 60 seconds. A score of 0 would apply, for example, if the subject cannot open the hand to grasp the object, cannot extend and/or abduct the fingers or thumb to the size of object, at all within 60 seconds and/or the subject attempts to manipulate the object into the hand on the side being tested by stabilizing the object against the shelf or against the nontested hand, and/or moves the object across the table without any voluntary hand opening (Figure 3j). These are all permitted but provide no points and cannot be used to achieve a hold and lift hand movement component.

Specific Scoring Instructions for the Grip Subscale (ARAT Test Items 7-10)

Object positioning. The objects being tested are placed in their positions on the mat (Figure 2). For the pouring task, the cups are placed 8 cm apart on each side of the midline of the subject and 10 cm away from the proximal edge of the table. For alloy tube displacement, the starting plank is placed on the table so that the first peg is 8 cm away from the front edge of the table and the target plank is placed perpendicular to the proximal table edge so that the second peg is 30 cm distal to the first one. For washer displacement, the tin lid with the washer in it is placed 5 cm from the proximal edge of table and on the side being tested, whereas the washer's target peg is placed 30 cm distal to the middle of the tin lid. For the pouring task, the tumbler is filled with 4 ounces of water as indicated by a predrawn line on the cup. A water-resistant cover can be placed over the test subject's torso during task performance to protect from spills if desired.

Instructions to subject. The subject is asked to pour water from one cup to the other or to horizontally displace 2 different sized alloy tubes from a starting peg on a plank to a target peg on a plank and to horizontally displace a washer from a tin to a peg or bolt on a plank. The instructions spoken to the subject are to "pour the water from this cup to that other cup" or "grasp this tube [washer] and place it here [onto the peg on the plank]."

Scoring. Start with the task of pouring water from one glass to the other, which is the most difficult task in this subscale; if the score is 3, then the total score for the arm being tested on this subscale is 12, and no further testing on this subscale is required for that arm. If the score is 0 to 2 for the pouring task, then continue to the task of displacing the 2.25-cm alloy tube, which is the easiest task in this subscale. If the score on the 2.25-cm tube task is a 0, then the total score for this subscale is 0, and no further testing on this subscale is required for this arm. If the 2.25-cm tube task score is 1 to 3, continue with scoring all tasks in this subscale.

To score a 3, for the pouring task, the subject grasps the cup, lifts it, pours all of the water from 1 cup to the other without spilling, and releases the cup on the table. For the other 3 tasks, the subject must grasp the tube/washer, lift it off the plank/out of the tin, and displace it horizontally to the target plank peg and release. For all tasks, the effort must be completed within 5 seconds of starting the task (Figure 4a-d). The subject must complete the task with the appropriate hand movement components, arm movement components (Table A3), and posture.

A score of 2 is given when a subject completes the task (1) without the appropriate hand movement components, for example, uses alternative hand movement components as shown in Figures 4e-f; (2) with abnormal quality of arm movements, for example, for pouring task: subject grasps the cup, lifts it, pours water from 1 cup to the other with adequate forearm pronation, but spills some water; for tubes/washer: subject grasps the tube/washer, lifts it off the plank/out of the container, displaces it horizontally, places it in its target position, but is unable to release the object; or (3) without maintaining proper posture (eg, if subject's trunk completely loses contact with the back of the chair). A score of 2 is also given if task completion takes 5 to 60 seconds.

To score a 1, the subject partially completes the task and must initiate some type of hand movement that includes holding and lifting the object. For the pouring task, the subject might grasp the cup and lift it off the surface of the table but be unable to pour any water, or forearm pronation does not occur but is substituted, for example, by compensatory excessive lateral bending of the trunk (Figure 4g). For the other tasks, a score of 1 might be awarded if the subject extends the fingers sufficient to grasp the tube/ washer, lift it up off the plank/out of the tin, but is unable to make any horizontal movements or release the object within 60 seconds. As mentioned previously here, when scoring a 1, the subject must initiate some form of hand movement, abnormal or normal, that achieves holding and lifting the object; any type of hand movement is permitted (Figure 4e-f).

For a score of 0, the subject is unable to open the hand to grasp the cup/tube/washer (ie, extend and/or abduct the fingers or thumb to the size of the object) and/or takes greater than 60 seconds. A score of 0 is also given if the subject stabilizes the object in order to manipulate it into the hand and/or moves the object without any voluntary hand opening.

Specific Scoring Instructions for the Pinch Subscale (ARAT Test Items 11 Through 16)

Object positioning. The mat is placed over the table, with testing objects placed in their predrawn positions. The 2 tin lids are placed in the same positions as stated in the grasp subscale. Each marble or ball bearing is placed within the lower tin lid, and the subject is asked to grasp the object with the appropriate fingers, lift it up to the shelf, and release it into the target lid. Notes can be recorded in relationship to fingernail length as desired, but this does not change scoring.

Instructions to subject. The subject is asked to grasp a ball bearing or a marble from a tin lid, lift it up vertically, then place and release it into a target tin lid placed on the shelf. This requires that the subject independently move the fingers in opposition to the thumb with accompanying distal mobility and stabilization. The instructions spoken to the subject are to "grasp the ball bearing [marble] using these fingers, lift it up, and place it in the tin on top of the shelf."

Scoring. This subscale starts with the task of lifting the 6-mm ball bearing, the most difficult task; if score is 3, then the total score for the arm being tested on this subscale is 18, and no further testing is needed for this arm on this subscale. If the score is 0 to 2, then next is the task of lifting the marble with the first finger and thumb, that is, the easiest task in this subscale. If the score is a 0, then the total score for this arm on this subscale is 0, and no further testing is required for this arm on this subscale. If the score is 1 to 3, continue with scoring all tasks in this subscale.

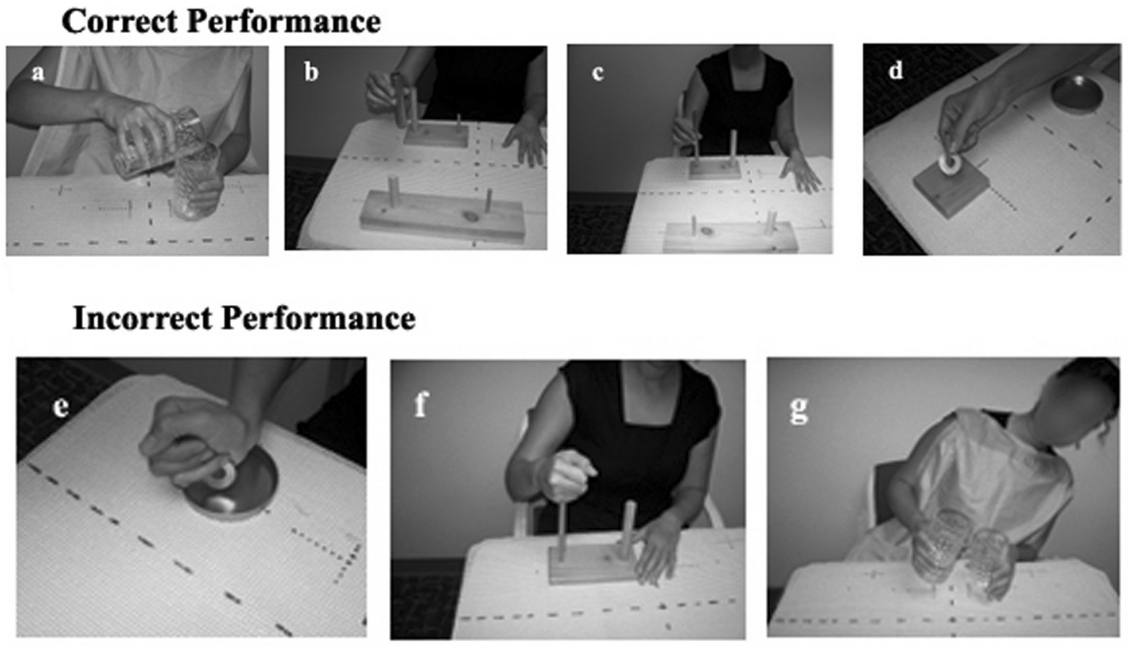


Figure 4. Grip subscale. Correct performances are shown (a-d). Examples of incorrect performance are as follows: (e) subject is unable to attempt to abduct and/or extend the fingers to the size of object, (f) subject uses wrong grasp to hold the alloy tube, and hand not being tested is being used to stabilize test materials, (g) forearm pronation is compensated by excessive lateral bending of the trunk.

An important note specific to pinch subscale tasks is that correct hand movement components (finger opposition; see Figure 5g) must be present to score more than 0. Thus, regardless of arm movement components, posture, and time used, the score can only be 0 if an incorrect finger opposition is employed, for example, holding the object in the palm with all 4 fingers flexed and thumb adducted/flexed (Figure 5h). As an extension of this note, task completion, necessary for a score of 2 or 3, is only deemed to be present if correct hand movement components are used. In addition, a score of 3 can only be generated if the finger opposition specifically uses the pads of the fingers.

A score of 3 is awarded for normal, complete, timely task completion. The subject grasps the marble or ball bearing from the tin, lifts the object up to the shelf, and releases it into the target tin, all within 5 seconds (Figure 5a-f). The task is completed using correct arm movement components, as well as hand movement components, including finger pads (Table A3), while maintaining proper posture. The score is not reduced if the object bounces off the shelf after successful task completion.

A score of 2 is awarded if (1) the quality of the arm movement component or the hand movement component is abnormal, as might occur for example with inability to release the object from the fingers into the target tin, or if the object falls out of the tin/off the shelf when attempting to release, or if the subject is unable to use the pads of the fingers to grasp the object (Figure 5g); (2) abnormal posture is displayed (eg, if subject's trunk completely loses contact with the back of the chair); or (3) performance takes 5 to 60 seconds.

A score of 1 is awarded if the subject partially completes the task, for example, grasps the object, lifts it up, but drops the object or is unable to reach the height of the shelf. The task must be completed within 60 seconds.

With a score of 0, the subject is unable to initiate the task within 60 seconds or, again for this subscale only, does not display the correct hand movement components, that is, finger opposition. The subject (1) is unable to open the hand to grasp the test object, that is, to extend and/or abduct the fingers or thumb to at least the size of the object; (2) attempts to manipulate the object into the fingers by stabilizing it with the nontested hand or some other object; (3) moves the object in the tin lid without any voluntary finger/thumb extension; or (4) attempts take greater than 60 seconds.

Specific Scoring Instructions for the Gross Movement Subscale (ARAT Test Items 17 Through 19)

Object positioning. The subject starts with both pronated hands on the lap. The assessor reminds the subject to keep the head still and in a neutral upright position. For item 17, the subject must touch the back of the head with the palmar side of the hand being tested; for 18, the subject must touch the top of the head, with the palmar side of the hand being tested, and for 19, the subject must touch the mouth with the palmar side of the hand being tested. The subject's hand can be in flexed posture if full finger extension/abduction cannot be maintained.

Instructions to subject. These tasks require the subject to move the shoulder and elbow across a wide range of motion, with

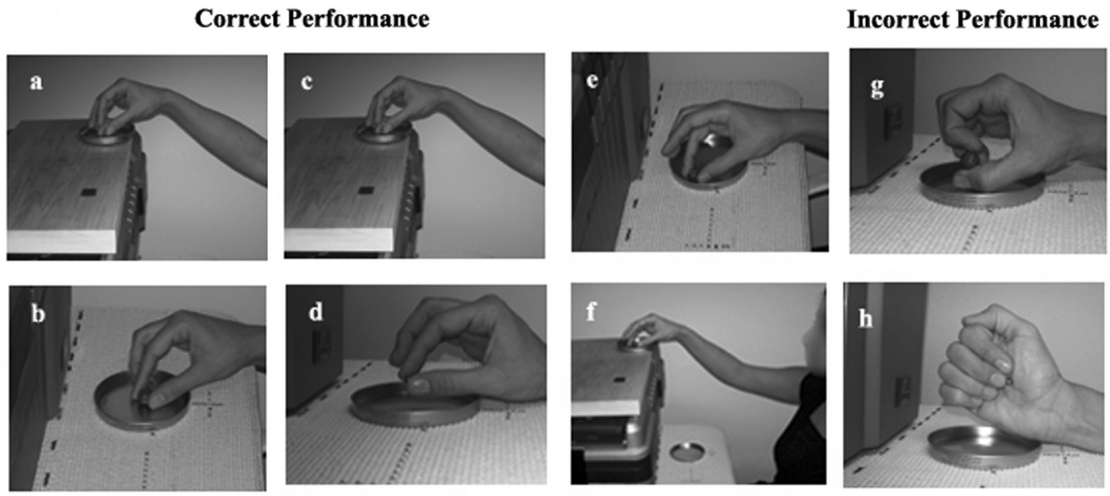


Figure 5. Pinch subscale. Correct performances are shown (a-f). Examples of incorrect performance: (g) subject is unable to use the pads of the appropriate fingers to grasp the marble, (h) uses palm to hold the ball bearing without any finger/thumb opposition.

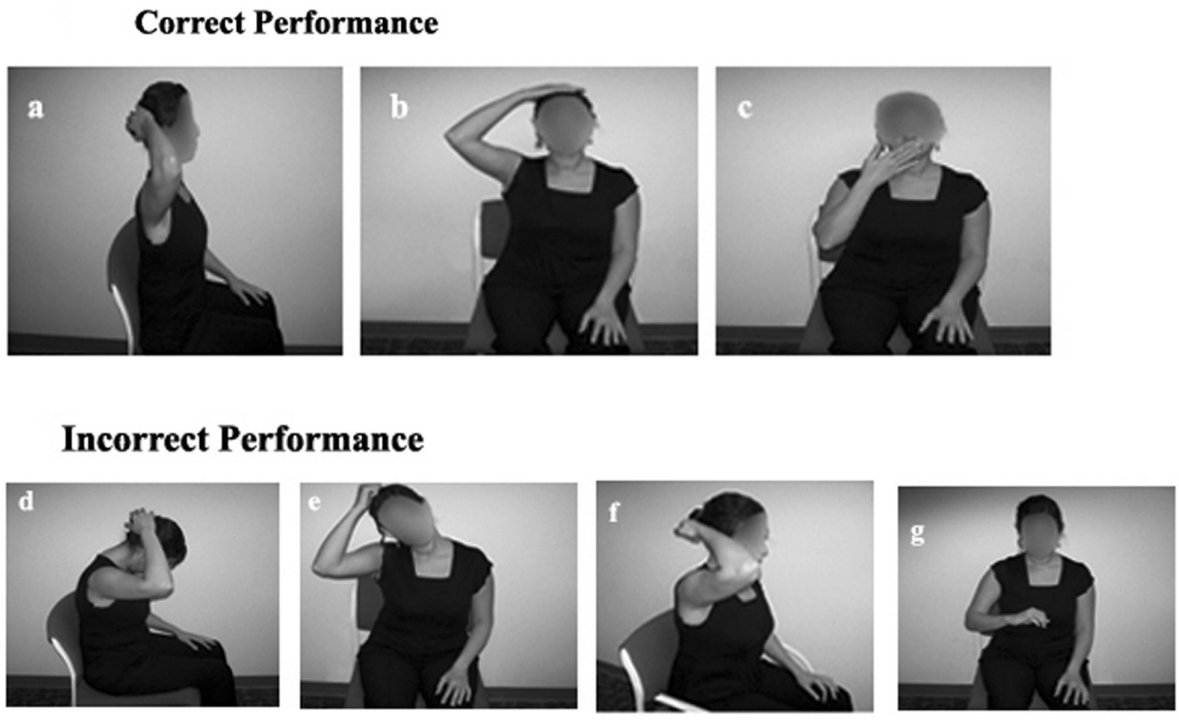


Figure 6. Gross movement subscale. Correct performances are shown (a-c). Examples of incorrect performance are as follows: compensation occurs via (d) neck flexion, (e) neck lateral flexion, (f) task completed with forearm in pronation, and (g) subject only partially completes the task.

accompanying forearm movement. The instructions spoken to the subject are to "touch the back of your head [top of your head, mouth] with the palm of your hand."

Scoring. Start with the task of placing the hand behind the head; if the score is 3, then the total score for this subscale is 9 for the arm being tested, and ARAT testing is completed. If the score is a 0, then the total score for the arm being tested is 0 on this subscale, and ARAT testing is completed. In this regard, the gross movement subscale is an exception in that the hardest and the easiest task have effectively been collapsed into a single task. If the score is 1 or 2, the arm being examined is then tested for the other tasks in this subscale.

For a score of 3, the subject places the hand behind the head

(not the neck), on top of the head (not the forehead), or to the mouth (not the chin) with the palmar side of the hand while maintaining the head in an upright, neutral position (Table A3), and the task is completed within 5 seconds (Figure 6a-c).

A subject scores 2 if the movement is completed abnormally (eg, the subject completes the task by flexing the neck [Figure 6d-f], or the trunk loses contact with the back of the chair, or the task takes 5 to 60 seconds to complete).

For a score of 1, the subject only partially completes the task (eg, starts shoulder/elbow flexion but the hand does not reach the target position within 60 seconds) (Figure 6g).

For a score of 0, the subject is unable to initiate any part of the task within 60 seconds.

Table A1. Action Research Arm Test Scoring Sheet

Test Number	Item	Score	
	Grasp subscale	Left	Right
1	Block, 10 cm^3	0 1 2 3	0 1 2 3
2	Block, 2.5 cm^3	0 1 2 3	0 1 2 3
3	Block, 5 cm^3	0 1 2 3	0 1 2 3
4	Block, 7.5 cm^3	0 1 2 3	0 1 2 3
5	Cricket ball	0 1 2 3	0 1 2 3
6	Sharpening stone	0 1 2 3	0 1 2 3
		Subtotal ____/18	____/18
	Grip subscale		
7	Pour water from one glass to another	0 1 2 3	0 1 2 3
8	Displace 2.25-cm alloy tube from one side of table to the other	0 1 2 3	0 1 2 3
9	Displace 1-cm alloy tube from one side of table to the other	0 1 2 3	0 1 2 3
10	Put washer over bolt	0 1 2 3	0 1 2 3
		Subtotal ____/12	____/12
	Pinch subscale		
11	Ball bearing, held between ring finger and thumb	0 1 2 3	0 1 2 3
12	Marble, held between index finger and thumb	0 1 2 3	0 1 2 3
13	Ball bearing, held between middle finger and thumb	0 1 2 3	0 1 2 3
14	Ball bearing, held between index finger and thumb	0 1 2 3	0 1 2 3
15	Marble, held between ring finger and thumb	0 1 2 3	0 1 2 3
16	Marble, held between middle finger and thumb	0 1 2 3	0 1 2 3
		Subtotal ____/18	____/18
	Gross movement subscale		
17	Hand to behind the head	0 1 2 3	0 1 2 3
18	Hand to top of head	0 1 2 3	0 1 2 3
19	Hand to mouth	0 1 2 3	0 1 2 3
		Subtotal ____/18	____/9
		Total ____/57	____/57

There are 4 subscales. The tests in each are ordered so that if subject scores 3 on the first test, no more tests need to be administered in that subscale, and the subject automatically scores top marks (all 3s) for all tests in that subscale. If subject fails the first test (score 0) and fails the second test (score 0) of the subscale, the subject automatically scores zero for all tests in that subscale, and again no more tests needed to be performed in that subscale; and (3) otherwise the subject needs to complete all tasks within the subtest

Score: 3 = subject performed the test normally within 5 seconds; 2 = subject could complete the test but took abnormally long (5 to 60 seconds) or had great difficulty; 1 = subject could only partially perform the test within 60 seconds; and 0 = subject could not perform any part of the test within 60 seconds.

Table A2. Suggested Test Materials Used in Performing the Action Research Arm Test

Task Material	Dimensions	Weight of Test Items Lifted During Testing (g)
Table	Height, 75 cm; width, 76 cm; depth, 49 cm	
Chair	Height of seat 46 cm from floor; no arm rests	
Shelf (or box on the table)	37 cm above level of table	
Four wooden blocks	10.0, 7.5, 5, and 2.5 cm^3, respectively	492, 196, 55, and 6.5, respectively
Large alloy tube	Diameter, 2.5 cm; length, 11.5 cm	38.5
Small alloy tube	Diameter, 1 cm; length, 16 cm	14.2
Cricket ball	Diameter, 7.1 cm	159
Marble	Diameter, 1.6 cm	5.4
Sharpening stone	10.0 × 2.5 × 1 cm	60.3
Ball bearing	6-mm diameter	1.1
Two plastic tumblers	Upper diameter, 7 to 8 cm; lower diameter, 6 to 7 cm; height, 12 to 15 cm	125.4 (empty)
Washer	Outer diameter, 3.5 cm; inner diameter, 1.5 cm	16
Plank for the tubes		
Starting point	1.5 × 8.5 × 8.5 cm	
Target point	3.5 × 8.5 × 34 cm	
Bolt for the large alloy tube		
Starting position	Round wooden peg; diameter, 2.0 cm; height, 13.5 cm	
Target position	Round wooden peg; diameter, 2.0 cm; height, 8.0 cm	
Bolt for the small alloy tube		
Starting position	Round wooden peg; diameter, 0.8 cm; height, 6.0 cm	
Target position	Round wooden peg; diameter, 0.8 cm; height, 6.0 cm	
Plank for the washer	1.5 × 8.5 × 8.5 cm	
Bolt for the washer	Round wooden peg; diameter, 0.8 cm; height, 8.5 cm	
Tin lid	Diameter, 9 cm; rim height, 1 cm	

Table A3. Specific Details for Action Research Arm Test Tasks

Task Number	Task Materials and Details	Hand Movement Components	Arm Movement Components
1-4	Blocks: displace vertically to shelf	Hand voluntarily opens to the size of the block. Any type of grasp involving the thumb and fingers in opposition is acceptable.	a. Forearm is between midposition and pronation. b. Elbow flexed when first grasping object and then extends to reach top of shelf. c. Shoulder flexion to reach top of the shelf, and shoulder stabilization to maintain position as object is released onto shelf. d. Thumb and finger extension to release the object.
5	Cricket ball: displace vertically to shelf	Spherical grasp; fingers and thumb slightly flexed and abducted to the size of the ball.	
6	Sharpening stone: displace vertically to shelf	Lateral grip; sharpening stone is between the pad of thumb and the radial side of the index finger at or near interphalangeal joints.	
7	2 cups: pour water from one cup to another	Cylindrical grasp around cup	a. Forearm pronation to pour, then forearm supination to return cup to table. b. Thumb and finger extension to release the cup.
8-9	Alloy tubes: displace from starting plank to target plank	Any type of grasp, such as 3 jaw-chuck pinch, involving the pads of the thumb opposed with pads of any number of fingers in order to grasp the alloy tube	a. Forearm is between midposition and pronation. b. Elbow is sufficiently extended to reach the distal target plank. c. Shoulder movement and stabilization to maintain position

10	Washer: displace distally from tin to target plank	Pincer or 3 jaw-chuck grasp, with pads of the thumb and fingers in opposition, in order to grasp the washer	as object is released. d. Thumb and finger extension to release tube/washer.
11, 13, 14	Ball bearing, from tin on table, vertically displaced to tin on shelf	Opposition of pads of ring finger and thumb, middle finger and thumb, and index finger and thumb, respectively	a. Forearm is between midposition and pronation. b. Elbow flexed when first grasping object, then extends to reach top of shelf.
12, 15,16	Marble, from tin on table, displace vertically to tin on shelf	Opposition of pads of index finger and thumb, ring finger and thumb and middle finger and thumb, respectively	c. Shoulder flexion to reach top of shelf and shoulder stabilization to maintain position as object is released.
17-19	Hand from lap to various pericranial positions	Palmer side of hand (hand does not need to be open) reaches to back side of head, to top of head, and to mouth, respectively	a. Forearm pronation and supination. b. Full elbow flexion c. Shoulder abduction, flexion, and external rotation.

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