The Comparison of Motor Performance Between Part and Whole Tasks in Elderly Persons

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Key Words: coordination training • motor control • task performance and analysis

Objective. When teaching clients a multistep functional task, therapists tend to break down the task into part tasks with discrete movements. The purpose of this study was to compare the kinematic performance between part and whole tasks in elderly persons.

Method. A counterbalanced repeated-measures design was used. Twenty elderly persons without motor problems (7 men, 13 women) performed a signature task in two conditions. For the part-task condition, the participants did the task in a step-by-step manner: (a) reach for a pen, (b) bring the pen to the paper, and (c) sign the name. For the whole-task condition, the participants performed the task in an integrated continuous flow. Kinematic performances for two movement segments (i.e., reaching for the pen, bringing the pen to the paper) were compared between conditions.

Results. Generally, the whole-task condition elicited a more efficient, more forceful, and smoother movement than the part-task condition.

Conclusion. The results suggest the importance of keeping a multistep functional task whole.


In occupational therapy, activity analysis serves as the critical precursor to the design of activity adaptations required to optimize clients’ performance. Generally, therapists analyze an activity by identifying its steps and the level of capability these steps demand (Trombly, 1995), assuming that executing each step separately and then bringing together all these steps is equal to performing the activity in its entirety. In addition, therapists may adapt an activity by modifying the way a person performs the activity. For clients who are easily fatigued or who have poor motor control (e.g., persons with Parkinson’s disease), therapists may suggest that these clients break down a sequential task into component parts and perform one part at a time (Morris & Iansek, 1996).

In motor learning literature, there are similar considerations of whether to have persons practice a task in its entirety (i.e., whole practice) or in separate steps (i.e., part practice). The decision seems to depend on several factors, including the nature and inherent complexity of a task (Rose, 1997). For example, Haugen and Mathiowetz (1995) suggested that for tasks involving connected discrete movements, practicing the discrete movements separately is beneficial. It seems obvious that if practice is given on part of a task, improved performance resulting from the part practice would transfer strongly to the whole task because the part seems to represent one element of the whole.
From the motor control perspective, however, there is concern that practicing a part in isolation may change the movement organization of the part so that it is no longer the same as it is in the context of the whole task (Bennett, Marchetti, Iovine, & Castiello, 1995; Schmidt & Lee, 1998). Further, from the perspective of ecological psychology (Gibson, 1979; Reed, 1982), breaking down a functional task may create part tasks with less meaningful goals, thus hampering the performance.

The purpose of this study was to examine kinematically the motor performance of elderly persons in part and whole tasks. The findings of this study may contribute to the theoretical development of occupational therapy regarding task analysis and adaptation. If the movement organization in part tasks is different from the organization of the corresponding segments in a whole task, the findings may suggest that therapists should be cautious when analyzing an activity in terms of its steps. If whole-task conditions elicit better performance than part-task conditions, the findings may suggest the importance of identifying and using functional whole-task goals in activity analysis and adaptation.

**Literature Review**

In the contemporary view of occupational therapy, it is believed that a person's occupational performance is a product of the dynamic relationship between the person and his or her occupations and environments (Watson, 1997). The purpose of occupational therapy services is to create a fit, or match, among the person, the activity, and the environment (American Occupational Therapy Association, 1994). To facilitate the person–activity–environment fit, therapists may adapt tasks or activities by altering the task demands, environmental parameters, or the client's approaches to the task (Watson, 1997). For a task involving multiple steps, therapists may consider the task to be too complex or difficult; therefore, therapists may have clients break down the task into discrete steps and execute only one step at a time.

**Part Versus Whole Practice**

In situations where clients have to learn a new task (or relearn an old task) in order to function independently in daily life, therapists design practice sessions that have the clients practice the tasks in their entirety or in separate steps. A number of studies have examined the issue of "part–whole" training (e.g., Fabiani et al., 1989; Goetl & Shute, 1996; Murray, 1981). Generally, it is suggested that the effectiveness of part–whole training critically depends on the nature of the whole task and the characteristics of the component part tasks (Healy & Sinclair, 1996). For example, Naylor and Briggs (1963), using a cognitive prediction task, reported that whether part practice is appropriate depends on the inherent complexity and organization of the whole task. For instance, a complex task with loosely interrelated components is well suited to part practice. Additionally, Newell, Carlton, Fisher, and Rutter (1989), using a perceptual–motor video game, indicated that the advantage of part practice in facilitating overall task performance is due to the use of "natural" response components in the part tasks.

Studies on part–whole training, however, usually involved complex, artificial experimental tasks, which are quite different from the functional tasks that occupational therapists teach clients to do in clinics. In addition, these studies only measured the outcome of learning (e.g., how well the part practice is transferred to whole-task performance). The quality of movement when a person is doing part or whole tasks remains unknown. Willingham (1998) suggested that motor skill learning is a direct outgrowth of motor control processes. Therefore, it is important also to investigate the motor control aspects of a movement when it is being executed under part and whole tasks.

**Motor Control Perspectives**

Dynamic systems theory proposes that movement patterns of human beings emerge from the interplay of constraints derived from organisms, tasks, and environments (Newell, 1986). The goal of a task specifies the outcome of the action and affects movement organization (Adam, 1992; Fisk & Goodale, 1989; Marteniuk, MacKenzie, Jeannerod, Athenes, & Dugas, 1987). Accordingly, breaking down a task may in effect create new tasks, each with a different goal, and thus change the movement characteristics (Davis & Burton, 1991). Bennett et al. (1995) asked clients with Parkinson's disease and control participants to perform a drinking action involving reaching toward a glass, grasping it, and bringing the glass to the lips. The participants also performed two isolated movements of reaching to grasp the glass and of bringing the glass to the lips; these two isolated movements were not in order. Bennett et al. reported that the kinematic profiles (e.g., peak velocity and percentage of movement where peak velocity occurs) of the isolated movements were different from those of the corresponding segments in the drinking action, suggesting different movement organizations. However, they did not provide exact values for the isolated movement conditions.

According to ecological theories (Gibson, 1979; Reed, 1982), people perceive their environment in terms of its functional utility for them, and their actions are guided by this function-based information. Research findings have demonstrated that tasks with functional goals elicit better performance than tasks with less functional goals (Lin, Wu, & Trombly, 1998). Therefore, it is suspected that the breakdown of a functional task may produce part tasks with less meaningful goals, thus affecting the kinematic performance. The purpose of this study was to compare the kinematic performance between part and whole tasks in elderly persons without disabilities.
Motor Performance in Elderly Persons

A number of studies have examined age-related differences in movement control. By using kinematic analysis, it has been reported that movement in elderly persons is slower, less forceful, and less smooth relative to the movement in young adults. Several reasons have been proposed to account for the movement patterns in elderly persons. According to Wein, MacDonald, Mallat, Leavitt, and Roy (1998), slower, less smooth movement might reflect elderly persons’ reliance on visual feedback to guide their movement. Bennett and Castiello (1994) regarded the movement in elderly persons to reflect a strategy of placing more emphasis on movement accuracy than on speed in order to compensate for declined sensory and motor function (e.g., visual acuity, proprioceptive accuracy). By training elderly persons to move at the preferred speed of young adults, Morgan et al. (1994) found that even at a faster speed, elderly participants had less smooth movement, suggesting central deficits in motor coordination that force them to rely on visual guidance to control the movement. On the basis of these findings, it is of interest to study movement kinematics in elderly persons.

Hypothesis

On the basis of the ecological theories (Gibson, 1979; Reed, 1982) and research findings on functional goals (Lin et al., 1998), we hypothesized that the movement in each segment of a whole task would be better organized (i.e., more time and energy efficient), more forceful, and smoother than the movement in the corresponding part tasks, as measured during a signature task in a sample of elderly persons without motor problems. A better organized, more forceful, and smoother movement would have shorter movement time, lower ratio of peak to average velocity, higher peak velocity, and fewer movement units.

Method

Design

A counterbalanced repeated-measures design (Rosenthal & Rosnow, 1991) was used. Each participant was randomly assigned to one of two sequences: AB or BA, where A represents the part-task condition and B represents the whole-task condition. The part-task condition required participants to perform a signature task in an ordered step-by-step manner, whereas the whole-task condition required the participants to perform the same task in an integrated continuous flow.

Participants

A sample of convenience composed of 20 elderly persons (7 men, 13 women) participated in this study. Participants were recruited from the Harvard Cooperative Program on Aging in Cambridge, Massachusetts. All participants had normal or corrected-to-normal vision and no known neurological disorders affecting the motor system. The participants’ ages ranged from 63 years to 77 years ($M = 69.5$ years, $SD = 3.87$). Eighteen participants were right handed, and two were left handed.

Materials

A pen in a penholder and sheets of 3-in. x 3-in. paper were used. A horizontal black line (2 in. long) was drawn on each sheet of paper. Each line was 1 in. above the bottom of the paper and an equal distance from the left and right sides. The word signature was printed under each line.

Instrument

The three-sensor OPTOTRAK™ 3020 system1 connected to the Dell OPTIPLEX XM 575 computer2 was used for recording three-dimensional movement kinematics. A trigger connected with the computer was used to give the participant a visual start signal while simultaneously beginning data collection. One infrared light emitting diode (IRED) was attached on the ulnar styloid of the participant’s dominant hand. The position of the IREDS over time was sampled by OPTOTRAK at a frequency of 100 Hz, with .1 mm accuracy at a distance of 2.5 m. Static reliability for the instrument has been established in this lab (intraclass correlation coefficient > .99). The two-dimensional raw data from the OPTOTRAK were converted to three-dimensional coordinates, using a direct linear transformation algorithm. After being collected, the data were stored for off-line analysis.

Procedure

During the experiment, the participant sat at a table with the dominant hand resting on a start position (i.e., on the table directly in front of and in line with the shoulder). The signature task consisted of three steps: (a) reaching for a pen, (b) bringing the pen to the paper, and (c) signing one’s name. Each participant performed three practice trials and five test trials for each of the two conditions. Only the test trials were used for further analysis. The two conditions were operationalized as follows:

1. Whole-task condition. The participant performed the signature task in an integrated continuous flow, in response to a visual start signal.
2. Part-task condition. The participant performed each step in response to a visual start signal, with a pause of 2 sec to 3 sec between steps.

Data Reduction and Analysis

Data reduction. The converted OPTOTRAK data were filtered by the Northern Digital Data Analysis Program

1Northern Digital, Inc., 103 Randall Drive, Waterloo, Ontario N2V 1C5, Canada.
2Dell Computer Corporation, One Dell Way, Round Rock, Texas 78682.
(DAP) at a low-pass cutoff frequency of 5 Hz using a second-order Butterworth filter with forward and backward passes. On the basis of pilot data, the start and end of movement steps were defined as the first and the last points in time when the hand’s y velocity (i.e., the velocity in the participant’s sagittal plane) exceeded or decreased to 5 mm/sec. For some trials in the whole-task condition, the hand’s y velocity exceeded 5 mm/sec at the point when the hand grasped the pen. Therefore, an additional criterion was used for detection of the turning point (i.e., the end of the first step and the start of the second step). The point in time when the y position was furthest from the start position was used to determine that turning point. Out of the total 100 whole-task condition trials from the 20 participants, 20 trials from 12 participants (20% of the total trials) had a y velocity greater than 5 mm/sec at that point and were determined by the alternative y position criterion.

None of the test trials had missing points, and they were all processed by a custom-written program to provide kinematic scores for the first and second movement steps. The third step, signature part, was not analyzed because each person had a different name and the between-subject kinematic scores for the first and second movement steps were all processed by a custom-written program to provide kinematic scores for the first and second movement steps. The point in time when the hand grasped the pen. Therefore, an additional criterion was used for detection of the turning point (i.e., the end of the first step and the start of the second step). The point in time when the y position was furthest from the start position was used to determine that turning point. Out of the total 100 whole-task condition trials from the 20 participants, 20 trials from 12 participants (20% of the total trials) had a y velocity greater than 5 mm/sec at that point and were determined by the alternative y position criterion.

None of the test trials had missing points, and they were all processed by a custom-written program to provide kinematic scores for the first and second movement steps. The third step, signature part, was not analyzed because each person had a different name and the between-subject variance would be too large to find significant differences. The dependent kinematic variables were the following:

- **Movement time.** Movement time is the duration of execution of a movement and is regarded as an index of time efficiency. According to Nelson (1983), movements are optimized with respect to various objectives, or “costs.” One of the objectives is to achieve time efficiency by minimizing movement time.

- **Ratio of peak to average velocity (PV/AV).** Peak velocity is the highest instantaneous velocity during the movement. Average velocity is defined as the total displacement divided by the movement time. (The total displacement refers to the path of the hand in three-dimensional space.) The PV/AV is considered an indicator of energy efficiency (Nelson, 1983). A more energy-efficient movement would have a lower PV/AV; a movement with minimum energy cost would have a PV/AV close to 1.5.

- **Amplitude of peak velocity.** Amplitude of peak velocity is correlated with the force of a movement (Nelson, 1983). A certain amount of force is necessary to drive the movement.

- **Number of movement units.** A movement unit is defined as one acceleration phase and one deceleration phase (Brooks, Cooke, & Thomas, 1973). A smooth, graceful movement would have only one change in the direction of the forces, thus one

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*Northern Digital, Inc., 103 Randall Drive, Waterloo, Ontario N2V 1C5, Canada.

**Data analysis.** The score of each dependent variable was averaged over the five test trials. The a priori hypothesis that the whole-task condition would elicit better performance than the part-task condition was tested with a 2 x 2 mixed analysis of variance (ANOVA), with one between factor (sequence of conditions: AB vs. BA) and one repeated factor (order of conditions: first presented vs. second presented). The condition effect was embedded in the sequence-by-order interaction (Rosenthal & Rosnow, 1991).

**Results**

*First Step: Reaching for the Pen*

Table 1 shows the descriptive statistics and effect sizes of the kinematic variables for the part-task and whole-task conditions. The calculation of effect size r revealed large differences between the two conditions. The results of the sequence-by-order mixed ANOVA indicated significant differences between the two conditions in all dependent variables for movement time, \( F(1, 18) = 48.01, p = .0001 \); for PV/AV, \( F(1, 18) = 6.98, p = .0166 \); for peak velocity, \( F(1, 18) = 47.26, p = .0001 \); and for number of movement units, \( F(1, 18) = 7.65, p = .0127 \).

*Second Step: Bringing the Pen to the Paper*

Table 2 shows the descriptive statistics and effect sizes of the dependent variables. Results of the sequence-by-order ANOVA indicated significant differences for movement time, \( F(1, 18) = 42.50, p = .0001 \); for peak velocity, \( F(1, 18) = 40.10, p = .0001 \); and for movement units, \( F(1, 18) = 15.38, p = .001 \). However, for the PV/AV, the difference between the part-task and whole-task conditions was not significant, \( F(1, 18) = .03, p = .8629 \).

**Discussion**

The results of this study indicate that movement organization in part tasks is different from the movement organization of the corresponding segments in a whole task, especially in the first step of a three-step task. Further, the findings support the a priori hypothesis that the whole-task condition elicited a more time-efficient, more forceful, and smoother movement relative to the part-task condition, as reflected in the shorter movement time, higher peak velocity, and fewer movement units in both movement steps. The whole-task condition also elicited a more energy-efficient movement than the part-task condition in the first-step movement, as reflected in the lower PV/AV, but did not in the second-step movement.

The results of this study confirm Bennett et al.’s (1995) findings that the organization of a movement per-
formed in isolation is different from its organization when the movement is nested within a complete functional action. Although Bennett et al. had the isolated “reach–grasp” and “take-to-lips” movements as two different conditions, the part-task condition in the present study partitioned the signature task according to the temporal order. Therefore, this study extended the findings of Bennett et al. to the situations where isolated movements are performed in temporal order and under the broader context of the whole functional task.

The results of this study agree with previous findings on functional goals (Lin et al., 1998), showing that a functional whole task elicited a better quality of movement than part tasks with less functional goals. Whereas previous research by Lin et al. (1998) compared tasks with the same length of movement but with different goals, the present study examined part versus whole tasks in which the interim goals were the same, but attention was focused on the interim goal versus the end goal. The better movement quality in the present study's whole-task condition suggests that focusing on the functional end goal could enhance performance throughout the entire process of the task.

According to ecological theories (Gibson, 1979; Reed, 1982), motor performance is influenced by the information contained in the context. The present study suggests that performing a functional task as a whole (i.e., focusing on the functional end goal) may provide more enriched informational support for motor performance than performing each part task separately (i.e., focusing on interim goals). The goal of signing one’s name may have facilitated better performance because it evoked actions that were more tied to the familiar use of the pen and the signature sheets relative to the interim goals of reaching for the pen and bringing the pen to the paper. Or, relatedly, the whole-task condition elicited better performance because it resembles more closely an event that might be encountered in the natural environment, whereas the part-task condition is composed of more artificial or arbitrary responses (Adam et al., 1996).

Our findings suggest that there may be benefits to performing the signature task as a whole for elderly persons without motor problems. However, the findings may not be generalized beyond this study sample without further investigation. According to dynamic systems theory (Newell, 1986), differences in personal characteristics (organismic constraints) may change the resultant movement pattern. Gibson (1979) also indicated that a person's level of motor competence must be appropriate in order to use available environmental resources; reciprocally, the feature of the environment must be suited to the person's capabilities in order to be used maximally for action (Adolph, Eppler, & Gibson, 1993). Therefore, some neurological disorders may change how persons perceive the environment and thus change the way they act upon the environmental resources. Future research is needed to investigate whether part-task strategy enhances motor performance in persons with neurological disorders, such as Parkinson's disease.

A multistep functional task may be considered beneficial to movement because it has a functional goal, or it may be regarded as a hindrance to performance because it has a long (or complex) sequence. By using kinematic analysis, this study demonstrated that for the participants (i.e., elderly persons living in the community), the whole-task condition elicited a more efficient, especially in terms of time cost; more forceful; and smoother movement relative to the part-task condition. Therefore, this study shows the potential importance of keeping a functional task whole; breaking down a functional task into part tasks may disrupt the kinematic benefits of functional goals associated with whole tasks.

With regard to the issue of part–whole training, our findings of differences in kinematic profiles between part and whole tasks suggest that practice on part tasks may, in fact, result in movement organization different from whole practice. Therefore, for a client learning a functional task, it seems important to have the client practice the task in its entirety. Even if clients cannot perform whole tasks in the beginning of training, the findings suggest that whole-task performance in persons with neurological disorders, such as Parkinson's disease.

Table 1
Descriptive Statistics and Effect Sizes for the Part-Task and Whole-Task Conditions of the First Step

<table>
<thead>
<tr>
<th>Variable</th>
<th>Part Task</th>
<th></th>
<th></th>
<th>Whole Task</th>
<th></th>
<th></th>
<th>Effect Size ($\eta$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Movement time (sec)</td>
<td>0.98</td>
<td>0.20</td>
<td></td>
<td>0.69</td>
<td>0.08</td>
<td>.85</td>
<td></td>
</tr>
<tr>
<td>PV/AV</td>
<td>2.05</td>
<td>0.39</td>
<td></td>
<td>1.81</td>
<td>0.11</td>
<td>.52</td>
<td></td>
</tr>
<tr>
<td>Peak velocity (mm/sec)</td>
<td>464.59</td>
<td>92.72</td>
<td></td>
<td>539.57</td>
<td>94.10</td>
<td>.85</td>
<td></td>
</tr>
<tr>
<td>Number of movement units</td>
<td>1.22</td>
<td>0.33</td>
<td></td>
<td>0.98</td>
<td>0.13</td>
<td>.54</td>
<td></td>
</tr>
</tbody>
</table>

Note: $PV/AV =$ ratio of peak to average velocity.

Table 2
Descriptive Statistics and Effect Sizes for the Part-Task and Whole-Task Conditions of the Second Step

<table>
<thead>
<tr>
<th>Variable</th>
<th>Part Task</th>
<th></th>
<th></th>
<th>Whole Task</th>
<th></th>
<th></th>
<th>Effect Size ($\eta$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Movement time (sec)</td>
<td>0.82</td>
<td>0.15</td>
<td></td>
<td>0.58</td>
<td>0.06</td>
<td>.83</td>
<td></td>
</tr>
<tr>
<td>PV/AV</td>
<td>1.74</td>
<td>0.19</td>
<td></td>
<td>1.75</td>
<td>0.17</td>
<td>-.04</td>
<td></td>
</tr>
<tr>
<td>Peak velocity (mm/sec)</td>
<td>538.41</td>
<td>127.76</td>
<td></td>
<td>692.07</td>
<td>153.67</td>
<td>.83</td>
<td></td>
</tr>
<tr>
<td>Number of movement units</td>
<td>0.95</td>
<td>0.27</td>
<td></td>
<td>0.66</td>
<td>0.19</td>
<td>.67</td>
<td></td>
</tr>
</tbody>
</table>

Note: $PV/AV =$ ratio of peak to average velocity.
practice should start as soon as clients have the ability to do the whole task and that clients should focus on the final goal from the outset.

Conclusion

With regard to the therapeutic use of activity analysis and adaptation in occupational therapy, findings from this study suggest that although therapists analyze an activity by identifying its steps and the level of capability these steps demand, performing each sequential step of a task separately is not equal kinematically to performing an activity in its entirety. This study compared the motor performance of part and whole tasks in elderly persons without disabilities. In general, the whole-task condition elicited a better quality of movement than the part-task condition. The results confirm previous findings of the relationship between functional goals and kinematic movement and suggest the importance of keeping functional tasks as a whole in clinical practice. ▲

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References


