Effects of Task Goal and Personal Preference on Seated Reaching Kinematics After Stroke

Ching-yi Wu, ScD, OTR; May-kuen Wong, MD; Keh-chung Lin, ScD, OTR; Hsieh-ching Chen, PhD

Background and Purpose—Current theories of motor control in rehabilitation focus on how the nervous system responds to many types of external and internal constraints to execute motor behavior to accomplish a task. However, the dynamic interplay between these 2 constraints remains unclear. This study examined the impact of some aspects of internal and external constraints on motor performance in persons with stroke.

Methods—Twenty-seven persons with stroke used the uninvolved arms to perform an upper-extremity reaching task under 4 experimental conditions, formed by the crossing of functional goals and personal preferences. For the higher level of a functional goal, subjects took a drink from a can of beverage. For the lower level of a functional goal, subjects brought the can to the mouth without drinking. The level of personal preferences was determined, by interview, by the degree of predilection for particular beverages.

Results—Significant and large effects of functional goals and personal preference were found in the variables of movement time and reaction time. However, the data trend of the 4 testing conditions varied according to presence of visuospatial neglect and side of lesion.

Conclusions—Offering choices for the treatment activities and incorporating functional goals to therapeutic tasks might enhance response rate or movement efficiency, depending on the side of the lesion and presence of visuospatial neglect. The findings suggest that the consideration of the neglect phenomenon is a necessity when rehabilitative treatment planning incorporates constraint factors. (Stroke. 2001;32:70-76.)

Key Words: hemiplegia ■ motor activity ■ neglect ■ rehabilitation

Current theories of motor control in rehabilitation focus on how the nervous system responds to various external and internal constraints to develop and execute motor behavior. Such motor behavior should be efficient in accomplishing a task.1-4 External constraints are the limitations or demands imposed by the environment and the task. Internal constraints arise from the actor’s characteristics and may be psychological, physiological, or biomechanical.5,6 The external and internal constraints do not stand alone to explain motor control in the individual with neurological dysfunction. Rather, they interact and interrelate.4 The potential contributions of the systemic relation between these 2 categories of constraints in evaluation of and intervention in clinical populations has been little studied.2,7 This study examined the impact of some aspects of external (ie, functional goals) and internal (ie, personal preferences) constraints on motor performance in persons with cerebrovascular accident (CVA).

Functional Goals

Goals represent what an individual attempts to achieve.8 Jennerod,8 Newell,9 and Davis and Burton10 proposed that goals interact with the environment surrounding the performer and the performer’s attributes to determine the pattern of movement coordination. Reed11 further suggested that as the functional importance or the functional level of the task goal increases, the precision of performance or the performance of movements may be enhanced.

Previous research12-17 examined how different levels of functional goals influenced reaching performance of neurologically intact and impaired persons using the dominant hands or the affected arms. For example, Wu and Lin15 and Van Vliet et al14 evaluated how healthy young adults or patients with CVA performed the reach-to-grasp movement under conditions with higher functional goals (eg, taking a drink from a cup of water) and lower functional goals (eg, moving the cup of water). Results showed that a higher functional goal produced shorter movement time (MT) (effect size r=0.88), higher maximal instantaneous velocity (r=0.53), higher average velocity (r=0.81), or more direct movement trajectory (r=0.57) than a lower functional goal.

In contrast to the findings of the 2 studies reviewed above,14,15 Trombly and Wu16 found no differences in reach-
ing performance of stroke patients for performing the functional task versus the nonfunctional one. One possible explanation for the inconsistent results is the nature of the task. Van Vliet et al\textsuperscript{14} and Wu and Lin\textsuperscript{15} adopted a simple functional task (ie, reaching). Trombly and Wu\textsuperscript{16} used a more complex and bimanual functional activity (picking up the telephone receiver with the affected arm, dialing the phone number with the unaffected arm, and listening), although only the reaching performance of the affected arm was compared. These inconsistent findings indicate that variables assumed to affect movement execution can be manipulated more easily in simple reaching tasks to better specify the mechanism of motor control.

The aforementioned studies using clinical populations examined the impaired extremity. The deficits of stroke patients, however, are by no means limited to the affected arm. The arm ipsilateral to a unilateral-hemisphere stroke is often clinically described as being “unaffected,” but substantial evidence indicates that ipsilateral function may be abnormal.\textsuperscript{18–21} Interventions that focus on specific motor control deficits through practice with the ipsilesional upper extremity may result in functional improvements in both limbs.\textsuperscript{18}

A pioneering work by Dean and Shepherd\textsuperscript{12} showed that stroke patients in the experimental group (functional reaching training) using the unaffected arm reached faster and farther ($r=0.61$ for MT; $r=0.69$ for maximum reaching distance) than those in the control group (cognitive-manipulative task training with reaching over small distances). However, Morris\textsuperscript{22} argued that the distance reached was greater in the experimental group than the control group during training. Accordingly, it is not immediately clear whether the positive effects found in the experimental group were due to the greater extent of the reaching distance. In other words, the inconsistency in the biomechanical factors may confound the effects of functional training. To rule out this confounder, the present study kept the biomechanical factors the same during all conditions and attempted to examine the immediate effects of functional tasks on the reaching performance of stroke patients by use of a simple functional task (ie, the drinking task). Two different levels of functional tasks were used. The task with a higher functional goal involved drinking a can of beverage, and the lower functional goal involved bringing a can of beverage to the mouth without drinking it.

### Personal Preferences

A further aim of this study was to examine the effects of internal constraints on movement performance. Previous research on internal constraints focused on the neurological or biomechanical factors of an individual. The psychological factors have yet to be investigated. An animal (monkey) study by Hyvarinen and Poranen\textsuperscript{23} demonstrated that sensorimotor neurons in Brodmann’s area 7 discharged only during active reaching for objects of interest. It was necessary for the activation of such cells that the monkey be interested in the target or like the task. This study implied that providing options based on personal preferences might be crucial for the organization of movement. Florey,\textsuperscript{24} King,\textsuperscript{25} and Schonitz\textsuperscript{26} further posited that performance could be enhanced if persons select activities on the basis of their interests. If a person selects what he/she likes or prefers, the person may more actively engage in doing the task, leading to enhanced performance.\textsuperscript{27}

Sporadically, studies\textsuperscript{28,29} have examined the influence of personal preferences on motor performance of adults. Bakshi et al\textsuperscript{28} examined the number of movement repetitions and physiological change when subjects performed the most- and least-preferred tasks for a fixed duration. The results showed nonsignificant differences in these dependent variables. Many of the participants did indicate, however, that if they had the option, they would have terminated the least-preferred activity well before the required test duration. The opinions provided by participants implied that significant differences would probably have been observed between the task preferences if the researchers had operationalized the concept of personal preferences in a different way. Furthermore, the number of repetitions involved visual observation and may not be sensitive to changes in movement performance. The present study used computerized kinematic analysis to investigate movement performance when the participant chose the most-preferred and least-preferred beverage for performing the drinking task.

### Movement Kinematics

Kinematics describes the spatiotemporal characteristics of movement that are planned by the central nervous system.\textsuperscript{30} Measuring the kinematics of movement can detect whether the central nervous system organizes one movement differently from another.\textsuperscript{31,32} Kinematic variables used to measure reaching movement in the present study included reaction time (RT), MT, total displacement (TD), the amplitude of peak velocity (PV), percent of movement where PV occurs (PPV), and the number of movement units (MU). RT reflects advance planning preceding movement initiation. Systematic variations in RT partially represent the effects of the cognitive process about the forthcoming movement before the response is initiated.\textsuperscript{33} It is also recognized that planning may be ongoing after movement initiation. This ongoing planning may be partially reflected by the rest of the variables (ie, MT, PPV, MU). MT refers to the time for the execution for the reaching movement. The path of the hand in 3D space is described by TD in $x$, $y$, and $z$ coordinates. Once the movement, for example reaching for the target, starts, the arm generally accelerates toward the target and then decelerates at each point of direction change or correction of trajectory.\textsuperscript{30} One acceleration and 1 deceleration phase constitute an MU. The PV corresponds to the changeover from the acceleration to the deceleration phase.\textsuperscript{34,35} The more corrections of trajectory there are during movement performance, the longer the deceleration phase and the more MUs.

### Hypothesis

On the basis of the propositions of current motor control theories\textsuperscript{1,4,9} and empirical findings of research on functional goals\textsuperscript{12–17} and personal preferences,\textsuperscript{28,29} the following hypotheses were generated to test the effects of functional goals and personal preferences on reaching kinematics.

The condition of a higher functional goal with the most-preferred task object was hypothesized to elicit the best
performance of movements and that of a lower functional goal with the least-preferred task object the worst performance among the 4 conditions. The condition of a higher functional goal with the least-preferred object would lead to better performance relative to the condition of a lower functional goal with the most-preferred target. The latter prediction was based on the position that engagements in tasks directed toward a goal of functional meaningfulness would considerably enhance task performance. Enhanced performance of movements would be evident on kinematic variables including shorter RT, shorter MT, less TD, higher PV, greater PPV, and fewer MUs.

Subjects and Methods

Subjects
Twenty-seven patients with stroke (19 men, 8 women, 55 to 76 years old, mean age 63 years) were recruited from 2 medical centers (Chang Gung Memorial Hospital and National Taiwan University Hospital) in Taiwan. All subjects signed informed consent forms approved by the Institutional Review Board. Stroke location was identified by CT or PET images of the brain. The subjects, who were all right-handed, consisted of 8 right CVA (RCVA) patients without neglect, 7 RCVA patients with neglect, and 12 left CVA (LCVA) patients. Average time after onset of stroke was 2.86±2.48 months (range 0.1 to 9.4 months). None of the patients showed clinical signs of motor apraxia in a review of medical charts. All subjects were able to understand and respond to directions given by the experimenter. Subjects had no history of previous stroke, bilateral stroke, medical instability, disorientation, incontinence, hearing loss, or visual deficit that would prevent participation.

Materials and Instrumentation
Different kinds of beverages, including cola, black tea, coffee, tomato juice, and lemon juice, were used in this experiment. A 6-camera motion analysis system (VICON 370 3-D, Oxford Metrics Inc) was used in conjunction with 1 personal computer (IBM clone) to capture the movement of markers during reaching and to collect 2 channels of analog signals simultaneously. One marker was attached over the head of the fifth metacarpal of the hand to be tested. Another marker was attached on the beverage bottle. The system was calibrated to have averaged residual errors not exceeding 3 mm for each camera before data acquisition. After data acquisition, the VICON system analysis software was used to track the kinematic data and to save the 3D location of the markers together with analog data in binary format. Another IBM computer instrumented with an 8255 I/O interface was used to activate 1 flashing light and to read the on/off status of the reaching performance, which included TD, PV, PPV, and MU.

Procedures
On arrival in the motion analysis laboratory, the clinical measures described above were administered first. The participants were then asked to select their most-preferred and least-preferred beverages among the 5 types of beverage.

Each patient sat on a chair in front of a table in the laboratory and initially placed the “unimpaired” hand on a switch located directly in front of the shoulder. The target object was placed in line with the patient’s mid sagittal plane. Each patient received 4 experimental conditions. The 4 conditions are as follows.

1. \((F+/P+):\) The subject was asked to take a drink of the beverage that he/she liked most.
2. \((F+/P+):\) The subject was asked to take a drink of the least-preferred beverage.
3. \((F+/P+):\) The subject brought the most-preferred beverage to the mouth without drinking.
4. \((F+/P+):\) The subject brought the least-preferred beverage to the mouth without drinking.

Data Analysis
An analysis program coded by MATLAB language (The Mathworks Inc) was used to process collected data. Kinematic information on the reaching performance, which included TD, PV, PPV, and MU, was obtained. Collected analog data were processed to obtain RT and MT information.

Data Reduction
The focused hypothesis was tested by contrast analysis, that is, focused ANOVA in which specific predictions were tested by comparison (or contrast) with the data obtained. For the present study, contrast weights (ie, lambda) numerically reflecting the hypothesis were assigned and included the numbers \(-2, -1, +1, \) and +2. The analysis was performed on a 4×4 mixed (ie, 1 between-factor and 1 repeated-factor) ANOVA to test the a priori hypothesis.38 The between factor was the sequence and the repeated factor (or the within factor) was the order. Order refers to the order of administration of the treatment. The treatment effect, which is essentially a test of the differences in kinematic variables for the 4 experimental conditions, was embedded in the interaction effect of sequence with order. This practice allowed the use of a more precise error term by removing the confounding effects of sequence and order.37 The focused \(F\) for our contrast analysis was obtained as follows: 

\[
F_{\text{contrast}}=r^2(F_{\text{maxima of f(contrast)}}, \) where \(r^2\) is the square of the correlation between the contrast weights (ie, \(\lambda\) and the residualized means. 38

To demonstrate the degree to which the independent variables exerted an influence on reaching kinematics, the effect size \(r\) was calculated for each dependent variable by the procedures described by Rosenthal and Rosnow.38 The effect size measures, which are free of sample-size influence, indicate the magnitude of the effect of interest.

Results
The most notable effects of functional goals and personal preferences were manifested by the variables RT and MT. Because the data trends varied according to the presence of neglect and side of lesion, Figures 1 and 2 show the means and SDs associated with RT and MT and experimental conditions by types of stroke patients.

We performed the mixed ANOVAs to obtain the omnibus Fs. The results of the mixed ANOVAs showed nonsignificant order and sequence effects. Furthermore, we performed the contrast analysis on the basis of the focused \(F\). Results of the contrast analysis testing the a priori hypotheses described earlier showed significant and large effects for RT and MT.

Design
A counterbalanced repeated-measures design37 was used. \((F+/P+), (F+/P+), (F+/P+), \) and \((F+/P+), \) represent the conditions of a higher level of functional goal with the most-preferred beverage, a higher level of functional goal with the least-preferred beverage, a lower level of functional goal with the most-preferred beverage, and a lower level of functional goal with the least-preferred beverage. Each incoming subject was randomly assigned to 1 of the 4 sequences: 

\[
(F+/P+)(F+/P+)(F+/P+)(F+/P+), (F+/P+)(F+/P+)(F+/P+), \] or 

\[
(F+/P+)(F+/P+)(F+/P+)(F+/P+).\]
for all 3 types of stroke patients. There were nonsignificant and small effects for the other dependent variables, including TD, PV, PPV, and MU, for those 3 groups (see Table 1).

The means of RT and MT for the 4 conditions, however, shown in Figures 1 and 2, were not fully congruent with the hypotheses. To search for a more robust theory, we attempted to conduct further exploratory analysis of the data. Table 2 summarizes the results of the post hoc contrast analysis. Large effects in favor of the new direction in the group of RCVA patients without neglect were found: for RT, focused $F(1, 12) = 5.19$, $r = 0.67$; for MT, focused $F(1, 12) = 5.72$, $r = 0.73$. Results for the group of LCVA patients with neglect showed large effects for RT, focused $F(1, 9) = 5.38$, $r = 0.80$; and MT, focused $F(1, 9) = 5.18$, $r = 0.86$. Results for the group of LCVA patients were as follows: RT, focused $F(1, 24) = 7.26$, $r = 0.69$; and MT, focused $F(1, 24) = 6.90$, $r = 0.68$. The post hoc contrast analysis suggests a direction different from that hypothesized. For the RCVA patients without neglect and LCVA patients, RT is greatest in the condition of a higher functional goal with the most-preferred beverage and least in the condition of a lower functional goal with the least-preferred beverage, opposite to the original hypothesis. MT is least in the condition of a higher functional goal with the most-preferred beverage and greatest in the condition of a lower functional goal with the least-preferred beverage. The other 2 conditions showed similar magnitudes for both variables.

### Discussion

This study supports the idea that external and internal constraints play a role in movement planning and production. It shows that higher functional goal and preferred task object have a positive impact on the temporal rather than spatial or spatiotemporal aspect of movement output. These findings are in line with the proposition that reaching-to-grasp movement can occur without overt irregularities in the trajectories or velocity profiles and only in the temporal variables. Hermsdorfer and colleagues found that PV obtained from LCVA patients occurred at the same percentage of the MT as in healthy adults. However, LCVA patients needed more time to execute the task than the healthy adults. Such dissociable kinematic performance occurred not only in LCVA patients compared with normal controls but also in patient responses to constraint changes, as reported in the present study. These findings suggested that subtle changes in instructions relevant to the functionality of task goal and preference of the task object lead to very different results pertaining to RT and MT.

For the groups of RCVA patients without neglect and LCVA patients, the condition of providing a preferred task with a functional goal facilitated more efficient movement than the other conditions, as shown by MT. A preferred task might recruit more brain neurons to more efficiently coordi-

### Table 1. Results of Contrast Analyses for 3 Groups of Stroke Patients

<table>
<thead>
<tr>
<th>Dependent Variables</th>
<th>RCVA Without Neglect</th>
<th>RCVA With Neglect</th>
<th>LCVA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Focused $F(1, 12)$</td>
<td>$r$</td>
<td>Focused $F(1, 9)$</td>
</tr>
<tr>
<td>RT</td>
<td>3.19*</td>
<td>0.67</td>
<td>3.47*</td>
</tr>
<tr>
<td>MT</td>
<td>4.46*</td>
<td>0.73</td>
<td>8.18†</td>
</tr>
<tr>
<td>TD</td>
<td>0.067</td>
<td>0.13</td>
<td>0.02</td>
</tr>
<tr>
<td>PV</td>
<td>0.21</td>
<td>0.23</td>
<td>0.12</td>
</tr>
<tr>
<td>PPV</td>
<td>0.11</td>
<td>0.32</td>
<td>0.43</td>
</tr>
<tr>
<td>MU</td>
<td>0.003</td>
<td>0.027</td>
<td>0.028</td>
</tr>
</tbody>
</table>

Negative $r$ indicates that the effect is different from hypothesis.

* $P<0.05$, † $P<0.01$.  

Figure 1. The mean RT with SD bars is displayed separately for the 3 groups as a function of testing condition.

Figure 2. The mean MT with SD bars is displayed separately for the 3 groups as a function of testing condition.
To demonstrate performance change with simple movement, the task target perceived as functional or familiar might evoke efficient completion of the task movement, faster. The task target perceived as functional or familiar might exhibit improved accuracy of target detection when the search involved a higher functional goal and the least-preferred target the most RT. A higher functional goal with the least-preferred target produced similar RTs. Either functional goal or preferred beverage offered less motivation than the combination of both factors, resulting in longer RT for these conditions. As was the case for the RCVA without neglect and the LCVA groups, the tradeoff phenomenon between RT and MT was shown in this group. The trend for MT is opposite to that for RT. Subjects initiated movement more quickly but then took more time to complete the movements.

With regard to the variable TD, no significant difference was found among the 4 conditions, suggesting that functional goal and preference might not influence distance control of reaching. There are also no significant differences among the 4 conditions for the variables PV, PPV, and MU. These findings are not congruent with those of the previous studies, in which better spatial control or higher PV was found in the functional task than in the nonfunctional or less functional task. One possible reason is that all of the previous studies examined the effects of task functionality regardless of the preference issue. Our study combined both factors of functionality and preference. When performing preferred and functional tasks, the subject may parameterize temporal

### TABLE 2. Results of Post Hoc Contrast Analysis

<table>
<thead>
<tr>
<th>Kinematic Variables/Types of Stroke Group</th>
<th>Post Hoc Hypotheses</th>
<th>Effect Size r</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCVA without neglect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RT</td>
<td>($F_+P_+&gt;F_+P_-=F_+P_-=F_+P_-$)</td>
<td>0.72</td>
</tr>
<tr>
<td>MT</td>
<td>($F_+P_+&lt;F_+P_-=F_+P_+=F_+P_-$)</td>
<td>0.77</td>
</tr>
<tr>
<td>RCVA with neglect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RT</td>
<td>($F_+P_+&lt;F_+P_+=F_+P_+=F_+P_-$)</td>
<td>0.80</td>
</tr>
<tr>
<td>MT</td>
<td>($F_+P_+&gt;F_+P_-=F_+P_+=F_+P_-$)</td>
<td>0.86</td>
</tr>
<tr>
<td>LCVA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RT</td>
<td>($F_+P_+&gt;F_+P_-=F_+P_+=F_+P_-$)</td>
<td>0.69</td>
</tr>
<tr>
<td>MT</td>
<td>($F_+P_+&lt;F_+P_-=F_+P_+=F_+P_-$)</td>
<td>0.68</td>
</tr>
</tbody>
</table>

($F_+P_+)$ indicates the condition of a higher functional goal with the most-preferred beverage; ($F_+P_-$), the condition of a higher functional goal with the least-preferred beverage; ($F_+P_-$), the condition of a lower functional goal with the most-preferred beverage; ($F_+P_-$), the condition of a lower functional goal with the least-preferred beverage.

For the RCVA patients with neglect, among the 4 conditions, the task with a higher functional goal and the most-preferred target elicited the least RT and that with a lower functional goal and the least-preferred target the most RT. This improvement may be attributed to the motivational value of the functional reach for preferred objects. According to Mesulam, attentional systems mainly attempt to shift the attentional searchlight toward motivationally significant events. He observed that patients with neglect improved in accuracy of target detection when the search involved a reward-induced motivational enhancement of targets. Simon et al also proposed that movement performance in patients with neglect may improve when motivational stimuli are afforded during the task. In the present study, reaching for a preferred object for a functionally enriched goal may provide motivational enhancement, which led to enhanced performance associated with RT in patients with stroke. A higher functional goal with the least-preferred target and a lower functional goal with the most-preferred target produced similar RTs. Either functional goal or preferred beverage offered less motivation than the combination of both factors, resulting in longer RT for these conditions. As was the case for the RCVA without neglect and the LCVA groups, the tradeoff phenomenon between RT and MT was shown in this group. The trend for MT is opposite to that for RT. Subjects initiated movement more quickly but then took more time to complete the movements.
variables such as RT or MT as the most important characteristics of the movement and therefore showed reduced movement duration but not enhanced distance or spatiotemporal control. Another possible reason for this discrepancy is the task used. Some of the previous work required force exertion for the functional task (eg, pressing the bell) but not for the nonfunctional task (eg, touching the bell without ringing). Greater force exertion may be associated with higher PV. Accordingly, functional tasks elicited higher PV. In the present study, force is controlled across all conditions, resulting in the similar magnitude of PV in the 4 conditions. The third possible explanation is the hand used to perform the task. Van Vliet et al asked stroke patients to perform the tasks with the impaired arm, whereas the present study used the unimpaired arm. The differential effects suggest that the impaired and unimpaired sides respond to constraints differently.

The differential improvement in temporal control of reach for various types of stroke patients, achieved by modification of task functionality and preference, may have implications in rehabilitation. Rehabilitation programs should be planned and selected under consideration of type of stroke. One of the undesirable characteristics of patients with neglect, difficulty in initiating a movement, may be reduced by use of functional goal and preferred task. In contrast, the application of functional goal and preferred task in LCVA patients and RCVA patients without neglect may not reduce response time but rather may facilitate the movement efficiency in terms of shortening time for execution. In addition, the task-related training for the impaired and the unimpaired arms might facilitate various degrees of improvement. The functional tasks may enhance overt improvement of the impaired arm involving better spatial and temporal control. However, the unimpaired arm might be improved only in the temporal aspect for performing the functional task.

Two issues are in order here. The first one is associated with study power. The power of this study should be adequate, because moderate to large effects were found in some dependent variables with a small sample size for each subgroup. Replication of this study with a larger sample size, however, would confirm and enhance the generalizability of these findings. The second one is concerned with the approach to choosing the preferred object. The present study asked the subject to select the most- and least-preferred beverage for tasks to be performed. An alternative way to operationalize beverage preference is asking subjects to assign preference weights for each beverage, which would allow a finer-tuned analysis of motivational forces.

Conclusions
The unique contribution of this study is to reveal the differential improvement in temporal control of reaching of various subtypes of stroke patients (eg, neglect syndrome) when movement constraints such as functional goal and personal preference were imposed. Patients with neglect responded to internal and external constraints differently than patients without neglect with either RCVA or LCVA, indicating that consideration of the neglect phenomenon is a necessity when rehabilitative treatment planning incorporates constraint factors. This study also first demonstrated the RT-MT tradeoff phenomenon when different kinds of constraints were provided. These aforementioned findings justify further research efforts to differentiate various constraints and performance in patients with different perceptual and cognitive problems. In addition, as discussed previously, the refined approach to selecting preferred objects might be useful to determine whether stroke patients with/without neglect or patients with/without LCVA demonstrated differences in level of ranking. If so, any preexisting motivational differences between the groups could be established.

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References


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