



SURFACE VEHICLE RECOMMENDED PRACTICE

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(R) Calculation and Measurement of the Time to Complete In-Vehicle Navigation and Route Guidance Tasks

RATIONALE

This revised version of SAE J2365 addresses the calculation and measurement of the time needed to accomplish in-vehicle visual manual tasks. It was prepared and adopted in 2015. One goal of the review and revision at that time was to revise SAE J2365 to include useful material from SAE J2364, "Navigation and Route Guidance Function Accessibility While Driving," including the "Static Method." In this way both a method for predicting in-vehicle secondary task times, and a procedure for measuring such task times (originally in SAE J2364) are presented in one integrated document. SAE J2364 had previously been stabilized and can be accessed for archival purposes. Another goal of the 2015 revision of SAE J2365 was to include useful material from SAE J2678, "Navigation and Route Guidance Function Accessibility While Driving Rationale," which was the original rationale for SAE J2364. At the conclusion of the SAE J2365 revision effort in 2015, J2678 was effectively superseded by this new version of SAE J2365. Of the 3 original Recommended Practices (SAE J2364, SAE J2365, and SAE J2678), SAE J2365 results as a working and current Recommended Practice.

INTRODUCTION

Navigation and Route Guidance Systems have some functions that can take significantly more time to use than conventional controls and displays such as the headlights, windshield wipers, the speedometer, the fuel gauge, or the radio. Consequently, there are concerns that interacting with visual-manual navigation and route guidance systems could unduly distract drivers from the primary task of driving. Automated route planning provided by such systems is a convenience for drivers and reduces their pre-trip workload. Driving with route guidance may offer some safety benefit, but care should be taken in the design of these systems to limit the distraction due to the visual demands placed on the driver while the vehicle is in motion. A measure of the usability of such a System is the time required to complete tasks of interest. Navigation and route guidance systems can have some functions that can take significantly more time to use than conventional controls and displays. Furthermore, at various points in the design of such a System, there may be alternative user interfaces under consideration, and ease of use (as measured by task completion time) can be one of the selection criteria. Therefore, the determination of task completion time is useful.

Task completion times can be determined using a sample of drivers to complete tasks of interest. However, that process may require a completed design, available only late in development, and obtaining a suitable driver sample may be cumbersome. As an alternative, the method described in this Recommended Practice may be used to calculate and estimate static total task times, early in the design.

A static procedure for measuring secondary task time is presented that can be used to verify the estimated static task times.

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TABLE OF CONTENTS

1. SCOPE.....	2
2. REFERENCES	2
3. DEFINITIONS	3
4. TASK TIME CALCULATION METHOD	6
5. EXPERIMENTAL MEASUREMENT METHODS.....	9
6. TASK TIME MEASUREMENT PROCEDURE FOR THE STATIC METHOD	10
7. NOTES.....	11
APPENDIX A MENTAL OPERATOR TIMES	12
APPENDIX B BACKGROUND	13
APPENDIX C CALCULATION EXAMPLE	22
APPENDIX D BIBLIOGRAPHY	34

1. SCOPE

This Recommended Practice can apply to both Original Equipment Manufacturer and Aftermarket route-guidance and navigation system functions for passenger vehicles. The methods apply only to the presentation of visual information and the use of manual control inputs to accomplish a navigation or route guidance task. They do not apply to visual monitoring tasks which do not require a manual control input, such as route following. Voice-activated controls or passenger operation of controls are also excluded.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J287	Driver Hand Control Reach
SAE J1048	Symbols for Motor Vehicle Controls, Indicators and Tell-Tales
SAE J1050	Describing and Measuring the Driver's Field of View
SAE J1139	Direction-of-Motion Stereotypes for Automotive Hand Controls
SAE J2119	Manual Controls for Mature Drivers
SAE J2396	Definitions and Experimental Measures Related to the Specification of Driver Visual Behavior Using Video Based Techniques

2.1.2 ISO Publications

Available from American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, Tel: 212-642-4900, www.ansi.org.

- ISO 16673 Road vehicles – Ergonomic aspects of transport information systems – Occlusion method to assess visual demand due to the use of in-vehicle systems, First Ed. 2007-04-01
- ISO 26022 Road vehicles – Ergonomic aspects of transportation information systems – Simulated lane change test to assess in-vehicle secondary task demand, First Ed. 2010-09-01
- ISO 15008 Road vehicles – Traffic Information and Controls Systems – Ergonomic aspects of in-vehicle visual presentation of information.
- ISO 3958:1996 Passenger Cars-Driver Hand Control Reach (1996)
- ISO 15007 Road vehicles – Measurement of driver visual behavior with transport information and control systems.

2.1.3 Alliance of Automobile Manufacturers Publications

Available from Alliance of Automobile Manufacturers

Statement of Principles, Criteria and Verification Procedures on Driver Interactions with Advanced Systems In-Vehicle Information and Communication, Driver Focus – Telematics Working Group, June 26, 2006.

2.1.4 NHTSA Publications

Available from NHTSA

Guidelines for Reducing Visual-Manual Driver Distraction During Interaction with Integrated In-Vehicle Electronic Devices, p. 237, Docket NHTSA-2010-0053, April 2013.

3. DEFINITIONS

For the purposes of this Practice, the following definitions apply.

3.1 ACCESSIBLE BY THE DRIVER

A device is able to be used by a properly restrained driver.

EXAMPLE: The controls to complete the task are within reach of a restrained driver as defined by SAE J287; the display is visible with head movement as defined by SAE J1050; **and** the system is operable by the driver.

3.2 COMPUTATIONALLY-INTERRUPTED TASK

Task where the driver must wait 1.5 seconds or more for the driver interface to respond to an input in order to complete the task.

EXAMPLE: The driver enters information, the system goes off-board, and the driver must wait for confirmation.

3.3 CONTROL

Device used to enter information into a vehicle system or another device used in a vehicle.

NOTE: Includes non-physical controls such as a gesture sensor.

3.4 DISPLAY

Device that presents information to a driver, by visual means for purposes of this Practice.

3.5 DRIVER INTERFACE

General term used to describe the means by which a driver interacts with a vehicle or vehicle subsystem. An interface typically includes one or more controls and/or displays, as well as the system's operating logic.

3.6 ENTRY METHOD

Description of how an entry task goal is accomplished.

EXAMPLE: A location might be entered using (1) the street address method (entering the city, street, building number, and routing criteria) or (2) the intersection method (entering the city, the first street name, the second street name, and routing criteria).

3.7 ENTRY OPERATOR

A mental operator or a physical action.

3.8 GLANCE DURATION

Time from the moment at which the direction of gaze starts to move to towards a target (e.g., a display) to the moment it starts to move away from it.

NOTE: This includes transition time to that target per SAE J2396.

3.9 GOAL

System end state sought by a driver who undertakes a task.

EXAMPLES: Obtaining guidance to a particular destination; increasing magnification of a map display; determining the location of a point of interest; and canceling route guidance.

3.10 INTERRUPTED VISION METHOD

Evaluation of secondary task performance and duration when periodically interrupted to simulate primary driving task activities.

EXAMPLE: An occlusion method.

3.11 MENTAL OPERATOR

An elementary perceptual or cognitive action, or an action involving memory.

EXAMPLE: A key stroke, a reach, or a mental operation (see Appendix A for a Table of Mental Operator Times).

3.12 NAVIGATION AND ROUTE GUIDANCE SYSTEM

System that identifies the current position of a vehicle on the earth's surface and selects a pathway to a user-specified destination.

NOTE: It also provides directions to a destination by indicating the route or routes to take using graphics, text, voice, or other means.

3.13 OCCLUSION INTERVAL

Time period that a driver display or interface is intermittently rendered not visible when using an interrupted vision method.

3.14 PSEUDO CODE

Description of a method or series of steps in a computer program-like format that uses English (or some other natural language) phrases, in a structure similar to that of a programming language (usually an indented outline).

NOTE 1: Pseudo code lacks the syntax rules of formal computer languages such as BASIC or C and is not intended to compile.

NOTE 2: Pseudo code is often a precursor to formal coding.

EXAMPLE 1: Add a to b, then compute the square root of the sum.

EXAMPLE 2: If the display window is blank, then enter another letter.

3.15 SHORTCUT

An alternative method by which a task may be completed more quickly.

EXAMPLE: When a city is being selected, recently visited cities appear before the alphabetical list of cities.

3.16 STATIC METHOD

Evaluation of the duration of a single secondary task performed by a participant without interruption.

3.17 STATIC TOTAL TASK TIME

Task time measured with the participant only performing the task of interest without interruption.

NOTE: It can be measured in a stationary vehicle, buck, or mock-up.

3.18 SUBGOAL

Action or change in system or device state necessary to achieve a goal.

EXAMPLE: Reach to a device, enter a street name, enter a street address.

3.19 TASK

Sequence of control operations (i.e., a specific method) leading to a goal or subgoal at which the driver will normally persist until the goal is reached.

EXAMPLE: Obtaining guidance by entering a street address using a scrolling list method until route guidance is initiated.

3.20 TOTAL TASK TIME

Time to complete a task.

3.21 VEHICLE IN MOTION

When a vehicle's speed exceeds the minimum nonzero speed that can be reliably detected by the vehicle's sensors.

4. TASK TIME CALCULATION METHOD

4.1 Overview

The task time calculation method is based on the Goals, Operators, Methods and Selection rules (GOMS) model described by Card, Moran, and Newell (1980, 1983). For background on the calculation method see Green (1999b,d). Although the Practice applies to Navigation and Route Guidance Tasks, the GOMS method can be applied to some other kinds of in-vehicle driver/vehicle interface entry tasks.

The basic approach involves top-down, successive decomposition of a task. The analyst divides the task into logical steps. For each step the analyst identifies the human "mental operators" and device task operations. In the event that an analyst applying the method runs into difficulty dividing a given task into individual steps, the GOMS method should be applied in reverse (i.e., starting with the list of operators and aggregating them to determine subgoals and goals).

The GOMS approach assumes error-free performance, well-learned tasks, and particular locations of controls; assumptions which may be violated in the operation of motor vehicles. Modifications have been made to the GOMS model (e.g., Kieras, 1997) to improve the accuracy of the method and adjust the parameters to more closely approximate the task times in motor vehicles.

4.1.1 Process:

- Obtain either a:
 - Working prototype of the interface; or
 - Simulation of the interface; or
 - Recording of the activity of a user operating the interface; or
 - Step-by-step operational description.
- Also obtain the navigational (city and street) database to be used, as well as any other data the system might access (e.g., dynamic traffic information). Supporting documentation (e.g., quick reference card, user manual) is also helpful.

- 4.1.2 Identify the goals (e.g., enter a street address, enter an intersection).
- 4.1.3 For each goal, identify other associated subgoals needed to achieve it. Goals and subgoals may be at multiple levels.
- 4.1.4 For each goal and subgoal, identify the methods (e.g., the list search method) used to achieve it. Document the methods with a detailed explanation.

4.1.4.1 Participant activity recording procedure

A recording of the activity and behavior of the participant using an interface can assist in the accurate analysis of the methods. Such recordings provide a useful record of screen actions, example screens, and when a user pauses for a mental operation, pauses that analysts might otherwise miss when considering what users might do. When recording, ensure that the camera is perpendicular to the test screen and any interference due to the user's hand is minimized. Also make sure the image is closely cropped around the display so that the change of single characters is readily apparent on the recording. Using a second camera viewing from the side, and painting the sides of switches contrasting colors can make the depression of short throw switches easier to see on the recording.

EXAMPLE: Video recording.

- 4.1.5 Convert the detailed explanation of the methods or steps into pseudo code.
- 4.1.6 Identify the computational assumptions with regard to a user's knowledge of the elements and alternative methods of task completion (Table 1).

Determine the appropriate mental, keystroke, and other entry operators for each step using the data in Appendix A.

NOTE: Use of a spreadsheet is recommended for recording data.

The most challenging aspect of this step can be to determine where to include mental operators. Suggested rules for where to include them follow.

- 4.1.6.1 Include at least one mental operator every time a menu must be read or a major decision needs to be made.
- 4.1.6.2 If a decision can be fully anticipated because all of the information needed is visible well in advance of the decision point, a mental operator is not included in the sequence. So, when scrolling through a list entry-by-entry (assuming the entries are shown on a display), the sequence of mental operators would be "cursor, cursor, cursor," not "mental, cursor, mental, cursor, mental, cursor;" because the user could think about what needs to be done next in parallel with pressing a cursor key. However, if the cursor action clears the screen (e.g., in alphabetic advance), then a mental operator would be included because the user needs to read the display. The sequence would be "mental, next screen, mental, next screen," etc. There are times that this rule needs to be modified, such as when scrolling to the place in the alphabet where decisions can be anticipated. Some of the mental operators can be omitted in such cases.
- 4.1.6.3 When scrolling through long lists, a mental operator may occur just before pressing the enter key to confirm that the correct item is being selected. For decisions based on short lists, no mental operator is needed.
- 4.1.7 Determine the execution times for each mental operator (from Appendix A).

NOTE: Use of a spreadsheet is recommended for recording data.

Table 1 - Computational assumptions

Analysis Assumption	Comments	Adjustment to Analysis
Error-free performance	The computational method assumes drivers start with accurate and complete information about the destination and do not make any mistakes in entering information. In fact, errors can be quite high, ranging from 10 to 50 % of the trials.	Rather than attempting to determine the probability of each error and the time to correct it, the completion time can be increased by 25% to account for typical performance.
Routine cognitive task	The method assumes that drivers know what to do at each step. However, navigation system use is not a highly learned task for some drivers and drivers sometimes forget what to do.	Model estimates are improved by including additional mental operations where forgetting is likely to occur (Card, Moran and Newell, 1983). Adjustments for forgetting should be based on empirical analysis or using expert rules.
Automotive context (the original model was developed for predicting task times in an office)	The position of a mouse varies from movement to movement but automotive controls do not. However, automotive controls may require greater reach accuracy. In addition, vehicle motion may slightly elevate times to reach for controls.	Use automotive-specific estimates of reach and movement time. Evaluators may wish to develop their own operator values or correction factors, as well as additional application rules to improve estimates.
Warm start	The navigation system is assumed to be on and the disclaimer screen is cleared.	Start task estimate from the "main menu."
Use only visible, non-cognitively loading shortcuts	Many of the goals can be achieved using more than one method. Some shortcuts, while visible, are not simple. For example, if the goal was to scroll to a name starting with the letter "z" and the initial point was the letter "a," then in some systems, the optimal method to get there would be to scroll backwards in the alphabet.	Ignore methods of which only experts would be aware or which are cognitively loading (such as reciting the alphabet backwards). Data on the frequency of use of shortcuts are needed.
Include system response time (except for computationally-interrupted tasks)	Delays in system response occur as systems scroll lists, update maps, and so forth.	Since the user waits for these updates, system response time should be included in the task time except for computationally interrupted tasks.
Perfect knowledge of the address.	Likely problems include (1) incomplete knowledge of the city of the destination (is the street address in Ann Arbor or Ann Arbor Township?), (2) missing prefix for streets (1st St vs. S 1st St), and missing street suffix (Allen vs. Allen Road).	For ease of computation, assume the complete address is known.
Parallel completion of control operations and decision making.	For some tasks drivers will operate controls and plan operations at the same time.	For operations performed in parallel, use the longest completion time of control operations and decision making to estimate total task completion time.

4.1.8 Add up the execution times for each mental operator.

4.1.9 Adjust the keystroke times using the age multiplier as desired. For young drivers (18-30), use the keystroke, mental and search times as is, for middle-aged drivers (40-55), multiply the keystroke times by 1.4. For drivers 55-60 multiply the keystroke times by 1.7. For older drivers (>65), multiply the keystroke times by 2.2.

4.1.10 Verify that the times make sense and revise as needed. Review the inclusion of mental operators.

4.1.10.1 Use of participant activity recordings

Recordings of typical users interacting with the system can help verify methods, selection rules, mental operators and times. When played back at slow speed, a frame-accurate recording can be used to estimate screen update and system calculation times.

5. EXPERIMENTAL MEASUREMENT METHODS

Procedures for measuring secondary task times to compare with the calculated estimates are summarized below.

5.1 Overview

Direct measurement of eyes off-the-road time, i.e., glance time measurement, can require significant effort and may not be possible during product development. To get around this difficulty, two simpler alternative device evaluation and measurement procedures have been developed among others: a Static Method described in Article 6, and an Interrupted Vision (or occlusion) Method described in ISO 16673, for example. Either method can be used to screen navigation functions for accessibility to the driver while the vehicle is in motion, depending on the needs and preferences of the evaluator.

5.1.1 Static Method

The Static Method described in Article 6 measures the "static" total task time. In this method, the participant uses the driver interface without interruption to accomplish the navigation/route guidance related task of interest. In brief, a sample of participants, after practice, completes each task of interest several times using a stationary vehicle or buck with a functioning or simulated driver interface for the navigation system under test. The Static Method approximates the total glance time a driver will spend looking at the display of an in-vehicle device. The total time for one task is measured from the time the participant begins the task until the task is completed. The measured times can be used to help determine if the task for that interface may be performed while driving.

5.1.2 Interrupted Vision Method

An Interrupted Vision Method requires the participant to use the driver interface to accomplish the navigation/route guidance task of interest, while the participant's view of the visual display is periodically occluded by blocking the participant's view or blanking the display. This method determines task partitionability using occlusion goggles or display blanking, and measures occlusion total shutter open time or display blanking time.

The data collection protocol (participant sample size, number of practice and test trials, test context) to obtain the total task time is similar to that of the Static Method, except that vision is periodically interrupted. The occlusion total shutter open time can be used to help determine if the task for that interface may be performed while driving.

Examples of an Interrupted Vision Method are given in ISO 16673; and in the NHTSA Guidelines for Reducing Visual-Manual Driver Distraction, which refer to ISO 16673.

5.2 Use of Either the Static Method or an Interrupted Vision Method

Either the Static or Interrupted Vision Method can be used; depending on the needs of the experimental evaluator.

Static total task time as measured by the Static Method provides a useful surrogate measure of visual distraction since it is easy to measure, it can be readily accomplished early in a product design process, and it can be estimated as described in Article 4.

An Interrupted Vision Method approximates the situation where a driver is looking back and forth between the road and an in-vehicle interface, looking at each location for a brief period of time, as would occur in actual driving. An Interrupted Vision Method generally has higher face validity than the Static Method.

6. TASK TIME MEASUREMENT PROCEDURE FOR THE STATIC METHOD

The following procedure can be used to determine total task time for the Static Method.

6.1 Evaluation Setup

The navigation and route guidance driver interface under evaluation shall be operational (prototype hardware or simulated) and the driver interface must be fitted in the design intent location within a stationary vehicle, simulator buck, mock-up or equivalent.

6.2 Participants

The participants shall be:

- Licensed drivers not familiar with, or technically knowledgeable about, the specific driver interface under investigation;
- Capable of operating the driver interface, learning and completing the test procedure, and
- 45 to 65 years of age.

6.3 Participant Sample Size

A minimum of 10 participants should be tested.

6.4 Participant Training

Prior to testing, each participant should be trained in the use of the driver interface and the task of interest. Following training, each participant should be given five (5) practice trials for each task prior to testing.

6.5 Test Trials and Data Analysis

Each participant should be tested individually. A minimum of 3 test trials shall be completed for each task. The data to be entered for the specific tasks in the 3 test trials should be different from that entered during the practice trials but should be equivalent in difficulty. A given task or trial should be completed without pause or interruption. Coaching is not allowed during test trials but feedback on errors is permitted when a task is completed. The participant should be given the next task upon completion of a previous task.

Each task that is desired to be accessible while the vehicle is in motion should be tested. The specific data to be entered for each of the 3 test trials should be unique but at a representative level of difficulty for that task.

The databases used should represent the databases planned for, or available in, the production system.

6.6 Time Measurement

The duration of each trial should be measured using the software that controls the driver interface, a hand-held stopwatch, or other means.

6.7 Task Timing

6.7.1 Task timing is determined as follows:

- Start: The task is initiated by a verbal/audio command from the evaluator. The timing of a task starts as soon as the evaluator's command is completed. The visual display is set to the initial visual presentation for the task of interest, such as the main menu or function start screen. The participant's hand can be on or near the control or the screen.
- Duration: Tasks are timed from beginning to end without interruption, including error times, except for computationally interrupted tasks.
- End: Timing ends with the beginning of system confirmation that the last operation is accepted and the participant's goal has been achieved.
- The logarithmic mean of the task time for all (30) trials for a given task can be used as a task time metric. See 6.8.

6.7.2 The time component of the task time due to a computational interruption can be determined as follows:

- If the computational interruption is less than 1.5 seconds, the entire computational interruption is included in the task time;
- If the computational interruption is greater than or equal to 1.5 seconds, without feedback indicating the computational interruption and estimated completion, then the entire computational interruption will be included in the task time; or
- If the computational interruption is greater than or equal to 1.5 seconds with feedback indicating a computational interruption and estimated completion, then only 1.5 seconds of the delay is included in the task time.

6.8 Calculation of logarithmic mean of task time for Static Method:

Compute the log mean for all three (3) trials for each of ten (10) participants. Compare this value to the log of the suggested criterion given below.

$$\left(\sum_{j=1-10} \left(\sum_{i=1-3} (\log TTT_{ij}) \right) \right) / n < \log 15$$

6.9 Suggested Criterion for the Static Method

In general, navigation function tasks that are accessible by the driver while a vehicle is in motion should have a logarithmic mean static total task time of less than 15 seconds.

7. NOTES

7.1 Revision Indicator

A change bar (|) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY THE SAE SAFETY AND HUMAN FACTORS STANDARDS STEERING COMMITTEE

APPENDIX A

MENTAL OPERATOR TIMES

- A.1 Table A1 shows the mental operator times that can be used. These values were based on (1) the classical Keystroke-Level Model operators described by Card, Moran, and Newell (1980, 1983) obtained from a variety of office tasks, (2) data from Olson and Nilsen (1997-1998) for spreadsheet use, (3) data from Manes, Green, and Hunter (1998) for entering data into a Siemens Ali-Scout Navigation System, and (4) reach times from Methods Time Measurement-1 (MTM-1), the most popular predetermined time system used by industrial engineers (Schwab, 1971). The age correction factor (in 4.1.9) is based on the work of Manes, Green, and Hunter (1998). Mental operator time estimates based on the office data may be too low because navigation data entry tasks are not well learned (i.e., not routine cognitive tasks) and because automotive interior design may not facilitate rapid keyboard entry as in an office, even when the vehicle is stationary. The mental operator times from office work were adjusted upwards to be consistent with empirical studies of driver behavior. Additional information on the development of the operator times appears in Green (1999b). Some validation data appear in Nowakowski and Green (2000) and Nowakowski, Utsui, and Green (2000). Note that times are based on hard key operation of specific systems and may need to be adjusted for the specific device of interest (e.g., adjust operator times for touch screen input).

Table A1 - Mental operator times (seconds)

Code	Name	Mental Operator Description	Time(s) Young Drivers (18-30)	Time(s) Older Drivers (55-60)
Rn	Reach near	from steering wheel to other parts of the wheel, stalks, or pods	0.31	0.53
Rf	Reach far	from steering wheel to center console	0.45	0.77
C1	Cursor once	press a cursor key once	0.80	1.36
C2	Cursor 2 times or more	time/keystroke for the second and each successive cursor keystroke	0.40	0.68
L1	Letter or space 1	press a letter or space key once	1.00	1.70
L2	Letter or space 2 times or more	time/keystroke for the second and each successive cursor keystroke	0.50	0.85
N1	Number once	press the letter or space key once	0.90	1.53
N2	Number 2 times or more	time/keystroke for the second and each successive number key	0.45	0.77
E	Enter	press the enter key	1.20	2.04
F	Function keys or shift	press the function keys or shift	1.20	2.04
M	Mental	time/mental operation	1.50	2.55
S	Search	search for something on the display	2.30	3.91
Rs	Response time of system-scroll	time to scroll one line	0.00	0.00
Rm	Response time of system-new menu	time for new menu to be painted	0.50	0.50

NOTE 1: The keystroke times shown in Table A1 include the time to move between keys.

NOTE 2: System response times to show new menus may be empirically determined.