Coordination of Component Mental Operations in Sequences of Discrete Responses

Shu-Chieh Wu (scwu@mail.arc.nasa.gov)
Roger W. Remington (roger.w.remington@nasa.gov)
NASA Ames Research Center, Mail Stop 262-4
Moffett Field, CA 94035 USA

Harold Pashler (hpashler@ucsd.edu)
Department of Psychology, University of California, San Diego
La Jolla, CA 92093 USA

Abstract

In daily life we often perform sequences of actions, which with practice are accomplished by overlapping mental operations for successive actions. Is it possible to derive performance predictions for such sequences from a characterization of the mental operations for a single stimulus-response pair? We explore this by examining the joint timing of eye movements and manual responses in a typing-like task following Pashler (1994). Participants made separate choice responses to a series of five stimuli spread over a wide viewing area. Replicating Pashler's results, responses to the first stimulus (RT1) were elevated, with inter-response intervals (IRI) for subsequent items rapid and flat across items. The eyes moved toward the next letter about 800 ms before the corresponding manual response (eye-hand span). Analyses of manual responses show multiple components to the RT1 elevation. Analyses of dwell times show that the eyes move to the next stimulus before the completion of all central processing.

Introduction

Current frameworks of human performance modeling often follow traditional theories of human cognition, treating human behavior as a succession of stages composed from a limited number of component mental operations, such as perceptual, cognitive and motor processes. The nature and duration of these mental operations are derived from studies of response time in discrete tasks, which often last less than one second. In the real world, however, tasks are rarely completed with a single discrete action. Rather, they often require the performance of a series of discrete actions integrated into a fluid behavior sequence in response to multiple stimuli during an extended period of time. In the transition from discrete to continuous new behaviors emerge, not previously observed, such as coordination and overlapping among component mental operations. It is an important question for human performance modeling whether models of single-task performance, described at the level of elementary mental operations, are sufficient to characterize behavior in extended, fluid sequences.

The successes of current human performance modeling suggest the answer is yes, at least for highly skilled behavior (e.g., Gray et al., 1991; Matessa et al., 2002). Coordination and overlapping among component operations are simulated by enforcing logical dependencies among operations distributed across different resources, interleaving upcoming operations in the slack time created by queued bottleneck processes, and allowing operations from different resources to proceed concurrently. The success of this approach depends on the underlying assumption that component mental operations inferred from discrete task performance do not function differently in extended task environments. This assumption has yet to be tested. Also, success has been achieved for tasks that are largely perceptual-motor, with good fits obtaining after about 100 contiguous trials (e.g., John et al., 2002).

The goal of the present research is to investigate the coordination of component mental operations in extended task sequences that require a sequence of simple choice responses. To better contrast the coordination among component operations that may arise in extended task performance with the simple progression through set stages thought to underlie discrete task performance, we choose an extended task that consists of a monotonic sequence of identical discrete tasks. This approach helps place the emphasis on the coordination among component operations of different instances of the same task rather than among different tasks. Of all possible cases of coordination, we are especially interested in how movements of the eyes are coordinated with other underlying mental operations. Eye movements are an integral part of most cognitive activities. Their effortless and seamless integration with other components of task performance provides possibly the best example of coordination and the most challenging task for human performance modelers. Yet in existing frameworks the implementation of eye movements (or gaze resources) tends to be greatly simplified. In addition, the way by which eye movements are used is usually based on empirical findings from task conditions where eye movements are specifically made to meet instructions rather than generated naturally in accord with task goals. Little has been known on how task-driven eye movements are coordinated with the succession of stages and processes thought to characterize the underlying mental operations.

In this paper, we present our recent work on how eye movements are integrated with underlying component mental operations in extended tasks. We begin by reviewing existing literature on extended task performance with eye movement measures. Then we present the results of two earlier extended task experiments, followed by a new

experiment designed to address specific issues raised by the previous work. In the end, we discuss the implications of our results with an emphasis on how they inform us on modeling human performance in extended tasks.

Eye movements in extended tasks

Although eye movements occur naturally in almost all daily activities, to characterize the patterns of eye movements researchers in the past have focused activities with a clear script. Examples of such activities range from golf putting (Vickers, 1992), driving (Land & Lee, 1994), to tea making (Land & Hayhoe, 2001), and block-copying (Pelz et al., 2001). A common finding in such observations is that the eyes move in anticipation of upcoming actions during activities that involve scripted behavior.

The existence of preview in extended task performance characterizes the proactive nature of eye movement control. In tasks that require mostly non-visually based decisions, it seems intuitive that the eyes could move away prior to the response as soon as information acquisition is completed. *But, when can the eyes move and what determines it?* Answers to these questions are critical to understanding the coordination between eye movements and other mental operations. As typical fixation durations generally range from 200 to 400 ms, exceeding the time needed for perceptual registration, which can be estimated at around 100 to 150 ms (Salthouse & Ellis, 1980), this suggests that certainly other variables are involved.

Previous Research

Previously, we (Wu & Remington, 2004) examined the coordination between ongoing mental processing and the generation of eye movements in a task requiring multiple manual responses to multiple stimuli on each trial. Specifically, we were interested in two empirical questions. First, in an extended task with multiple stimuli to be responded to, when do the eyes move away from a stimulus? Second, in such an extended task how is the processing sequence affected by difficulty manipulations at separate stages? By independently varying the difficulty of perceptual and central stages we can determine which is on the critical path for the sequence of responses.

We adopted a typing-like task introduced by Pashler (1994). Participants viewed a series of five letters sequentially and responded to each individually in different preview conditions. Pashler manipulated preview to test how the mental processing of two or more stimuli were overlapped in time. He measured the reaction time (RT) to the first stimulus (RT1) and computed the inter-response intervals (IRIs) for subsequent responses. With no preview, RT1 and subsequent IRIs were roughly equivalent and constant across the stimulus sequence. With preview, RT1 was elevated, compare to no preview, while IRIs were constantly low. The same effects were observed regardless of whether 1 or 4 preview items were presented. Pashler interpreted the constant IRIs as an indication of a bottleneck central processing stage of response selection, which would only allow the selection of one response at a time. The fact that IRIs reflected the duration of response selection is further supported by the findings that varying the duration of stimulus recognition and response production had little to modest effect on the durations of IRIs.

Pashler's (1994) task presents a simple example of the operations of three critical mental components (perception, response selection, and response production) and a clear theoretical account for the coordination among them. In this case, characterization of a single task was sufficient to account for the IRI results without further assumptions. The model, however, did not predict the elevated RT1. The experimental paradigm represents a good compromise between the simplicity of typical discrete trial experiments, and real-world behavior.

In our previous work, we adopted Pashler's complete preview condition and incorporated an eye movement component by reducing the size of stimulus letters and increasing the separation between them. Identification of stimulus letters thus required successive saccades and fixations. In two separate experiments, we examined response time, dwell time (fixation duration), and eye-hand span associated with manipulation of the duration of perception and response selection stages.

Our first experiment examined the effect of perceptual difficulty on dwell time. Perceptual difficulty was manipulated by having two luminance conditions for the stimuli, Dim and Bright (5.2 and 46.2 cd/m2, respectively). Participants made sequential fixations to each of the five stimulus characters randomly drawn from the set T, D, and Z, and made choice responses accordingly. Those three letters were mapped to three response keys (V, B, and N) on a PC keyboard and assigned to the first three digits of the right hand. We measured the manual RT to each of the five stimuli and the IRIs. In addition, we derived three eye movement related measures: 1) eye-hand spans, which represent the elapsed time between the initial fixation on a particular stimulus to the moment when the corresponding manual response is generated; 2) dwell time, which represents the duration for which fixation is maintain on a particular stimulus; and 3) release-hand spans, which represent the elapsed time between the end of fixation on a particular stimulus to the moment when the manual response is generated. In fact, dwell times and release-hand spans make up eye-hand spans.

Figure 1 shows mean manual RTs, eye-hand spans, and dwell times as a function of stimulus in our first experiment. The pattern of manual RT results resembled what Pashler (1994) found in conditions with preview; specifically, the elevation of RT1 and constantly short IRIs of subsequent responses. The effect of perceptual difficulty was minimal on RT1/IRIs and appeared to be restricted to S1. Dwell time was lengthened in the Dim condition, though the amount of increase did not reach statistical significance. Results of this experiment confirmed that dwell time encompasses perceptual processes.

Our second experiment examined the effect of response selection difficulty on dwell time. The difficulty of response selection was manipulated by using two sets of stimuli to create two mapping conditions. One set included four alphabets T, D, Z, and Q mapped in this arbitrary order onto keys V, B, N, and M, and assigned to the four digits of the right hand; another set included digits 1, 2, 3, and 4 mapped in this natural order to the same four keys and fingers.

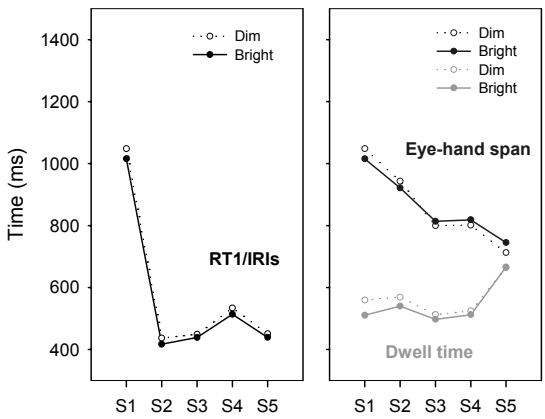

Figure 1. Results of Wu & Remington (2004), Experiment 1

Figure 2 shows mean manual RTs, eye-hand spans, and dwell times as a function of stimulus in our second experiment. Again, the manual RT results replicated the general pattern observed in our first experiment and in Pashler's (1994) study; RT1 was elevated, and IRIs were constant and rapid. In addition, mapping difficulty had a strong effect on manual as well as oculomotor responses. Difficult response mapping resulted in increases in IRIs. It also significantly increased dwell times. Results from this experiment suggest that fixation durations appear to include response selection related processes as well.

Present Experiment

Results from our previous work (Wu & Remington, 2004) provided some answers to the questions posed earlier. In an extended task such as this, the eyes move away at some point during the response selection stage but definitely after completion of the perceptual stage. Results from our previous work also featured some unexpected patterns of coordination between the eyes and the hand. One in particular is the interrelated temporal constraint among dwell times, IRIs and eye-hand spans. Except for the Hard mapping conditions in the second experiment, dwell times were mostly constant across stimuli, as were IRIs. In other words, the eyes dwell for a constant duration, and the hand releases responses also at a constant but faster rate. This leads to the observed decrease in eye-hand span across stimuli.

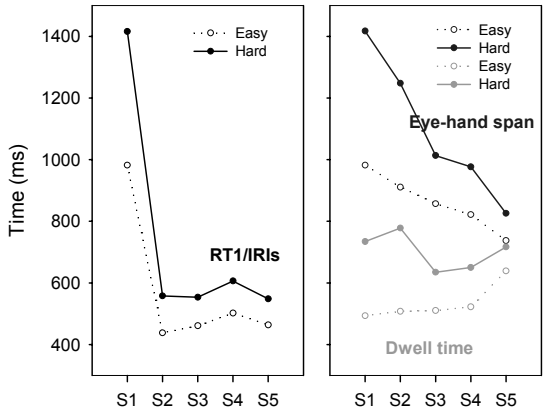

Figure 2. Results of Wu & Remington (2004), Experiment 2

The response of RT1 to the Easy and Hard mapping conditions was also unexpected. Though we always see an elevated RT1, its increase of approximately 400 ms in the hard condition was about twice the increase in IRI and dwell time, which were both about 200 ms. This means that the dwell time did not fully accommodate the increase in RT1. Certainly, this is difficult to account for in a model that assumes that eye movements are triggered at a fixed point in processing. It is difficult to speculate about the reasons for the greater increase without more information about the source of the general elevation of RT1 seen in all our experiments. Thus, the present experiment was designed in part to investigate variables responsible for elevated RT1. In particular we examine the role of planning for a sequence of responses or fixations.

We also attempt to vary the central difficulty within a trial. One explanation for constant IRIs is that the earlier responses are delayed in order to be coordinated with stages in the processing of the subsequent response. It follows that, if no subsequent response is required, eye-hand spans should not be elevated. In the present experiment, we vary central difficulty using a Go/No-Go procedure. On each trial, only 2 or 3 positions contained target characters mapped with a key response. The rest were filled with dummy characters and participants were asked to skip them. We compare dwell time on Go and No-Go responses, and eye-hand spans on Go responses that are preceded and/or followed by No-Go responses to evaluate the impact of central difficulty.

Method

Participants Fourteen undergraduate students recruited from local colleges near NASA Ames Research Center participated in the experiment for course credits.

Apparatus The experiment was conducted using a PC with a 21-inch monitor. Participants were seated in a comfortable chair with their head secured on a head-and-chin rest placed 53.5 cm in front of the monitor. Eye movements were recorded with an infra-red video-based eye tracking system (ISCAN), which outputs data at a temporal resolution of 120 Hz and a spatial resolution of approximately 0.5˚ visual angle.

Stimuli and Display The primary stimulus display consisted of a row of five small characters (letters or symbols) spread over a wide viewing area. The characters were spaced equally (5.5˚ apart) and centered on the middle of the display. Each character subtended 0.34˚ in height and was presented at 11.7 cd/m2.

Design and Procedure Each trial began with the presentation of a white fixation cross (0.3˚) in the center of the display. After the participant had maintained fixation

within a 6˚ radius around the fixation for 500 ms, the fixation was erased and a small filled square (0.34˚) appeared at the leftmost stimulus position. Participants were instructed to move their eyes to fixate the small square when it appeared and maintain fixation at that location. The small square remained for 1 sec, followed by a blank interval of 500 ms. Then the five stimulus characters appeared simultaneously. Participants were asked to look at the characters one at a time, decide what they are, and make responses accordingly. Participants then pressed the spacebar to proceed to the next trial, which began following an inter-trial-interval of 250 ms.

There were six experimental conditions and two control conditions. Trials of different experimental conditions differed in the number of required successive responses in a sequence (one, two, and three), and in the stimulus position on which these sequences occurred (first and second). The six types of trials can be represented as the following: TXXTT, TTXXT, TTTXX, XTXXT, XTTXX, and XTTTX, with T denoting letter stimuli that required a key response (Go stimuli) and X denoting letter stimuli that required no response (No-Go stimuli). Go stimuli were randomly drawn from the letter set T, D, and Z, with the constraint that no letter was repeated in two adjacent positions. This constraint however does not prevent repetition of responses; the same letter could occur in two positions interposed by Xs. Five participants had 40 trials of each type administered in 2 blocks of 120 trials. Nine participants had 60 trials of each type administered in 3 blocks of 120 trials.

Trials in both of the two control conditions consisted of a single target (Go) stimulus in the first position (i.e., TXXXX), though different instructions were given for each. In the first condition, called Respond-Then-Scan (i.e., TXXXX), participants were asked to respond to the first letter stimulus, as before, and fixate each of the rest. In the second condition, called Respond-Only (i.e., T____), they were asked to respond as quickly as possible to the first stimulus only. There were 40 trials in each control condition. The two control conditions were administered after the experimental conditions and in the same order (Respond-Then-Scan first, Respond-Only second) to each participant.

No single aspect of task performance (e.g., manual or oculomotor, speed or accuracy, etc) was emphasized. The only specific instruction given to the participants was to treat each character independently and not group responses.

In all experiments eye movements were monitored and recorded. The recording of eye movements began at the moment when the small square appeared, and ended after the participant had responded to the rightmost stimulus. A calibration procedure was administered before each block of trials to maintain accuracy of recordings.

Results and Discussion

Figure 3 presents mean manual RTs and eye-hand spans as a function of stimulus. Cases where RT1 occurred to S1 (S1-RT1) are plotted separately from cases where RT1 occurred to S2 (S2-RT1). We discuss manual responses and eye fixations separately.

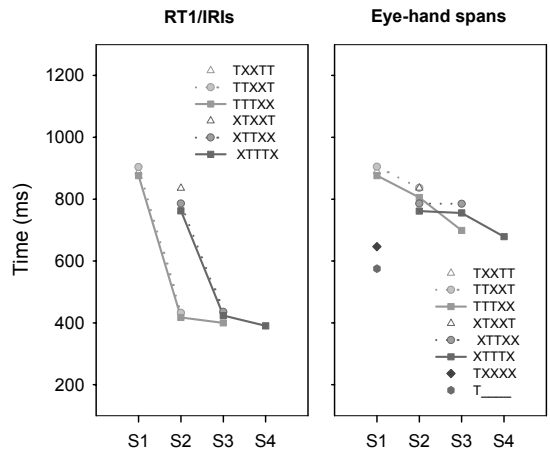

Figure 3. RT1/IRIs and eye-hand span results from the present experiment

Manual Responses The general pattern of elevated RT1 followed by rapid, flat IRIs is apparent in Figure 3. It is striking how closely aligned the curves for all stimulus conditions are. The only significant effect of the arrangement of stimulus was that RT1 was significantly slower when made to S1 (S1-RT1) than to S2 (S2-RT1). The general elevation of RT1 for both S1-RT1 and S2-RT1 suggests that cost is incurred for the first response in a sequence, not just to the first possible stimulus position. These similarities in patterns and magnitudes strongly suggest that the RT1/IRIs patterns are related closely to the production of sequences of responses. Indeed, the fact that RT1s for sequences such as "TTTXX" are equivalent to those for "TXXTT" is a strong indication that the difficulty of the next item has no effect on the current response. In other words, difficulty does not propagate backwards.

There are at least two possible explanations for the difference in RT1 between S1-RT1 and S2-RT1. It is consistent with at least some of the RT1 elevation being due to retrieval of stimulus-response mappings. If one assumes that the No-Go stimulus can elicit retrieval of response mapping for Go stimuli then that retrieval would have been done during S1 processing. This account is similar to accounts of first-trial cost in task switching studies (Logan & Bundesen, 2003). Alternatively, there is more uncertainty associated with S1 targets. If S1 is a non-target then S2 will always be a target. This reduction in uncertainty is a possible confound, though it is difficult to see how it would produce a speed up since the identity of S2 is not known until it is fixated.

Comparisons with the two control conditions provided evidence of sources contributing to the general RT1 elevation. RT1 was fastest (575 ms) in the Respond-Only condition, where participants were instructed to respond only to the first item and ignore the rest. RT1 was 72 ms slower (647 ms) in the Respond-Then-Scan condition, where participants were instructed to respond to the first item and fixate the others in turn. A plausible explanation for this overhead is that the elevated RT1 in the Respond-Then-Scan condition reflects a dual-task cost (cf. Pashler,

Carrie, & Hoffman, 1993), where the response task and the fixation task compete for a limited-capacity resource. There were no instructions as to how to perform manual and eye movement components; participants were free to do them concurrently or in sequence. We cannot say at present whether this overhead in combining the two behaviors, respond and fixate, arises from trying to do the two concurrently or would also be present with a strictly serial strategy. Some evidence suggests that trying to do the manual response concurrently with the fixation scan would cause interference. Pashler et al. observed interference between manual responses and voluntary eye movements in dual-task conditions, where participants were instructed to do both task as rapidly as they could. However, in their experiments substantial cost occurred only for anti-saccades, where subjects had to move away from a newly presented stimulus. A small cost obtained when moving to a specified color. Note that in both conditions the cost could reasonably be ascribed to a decision on the stimulus to determine where to move. In the present experiment the scan is fixed, making it difficult to see how stimulus decision processes could account for cost in the Respond-Then-Scan condition.

It is also hard to see why there should be a dual-task cost unless participants attempted to do the two tasks concurrently. Since there were no constraints or instructions on how to perform the task, any attempt to do them concurrently would have arisen naturally.

Another explanation might be that the Respond-Then-Scan condition forces participants to switch between tasks, resulting in a task-switching cost. However, task-switching costs are generally thought to arise from the retrieval of task-relevant knowledge, usually stimulus-response mappings. It is hard to explain how a switch cost would appear on S1 rather than on S2.

We prefer at present a more general explanation in terms of increased preparation time for the more complex behavior of Respond-Then-Scan. This account also helps explain why RT1 is further elevated in the full-response condition, with 2-3 targets. Here the preparation involves not only the sequencing of an initial response with a subsequent pattern of fixations, but of interleaving the responses.

There was one other significant RT1 effect whose meaning is not clear. S2-RT1 decreased significantly (from 837, 784, to 761 ms, *ps* < .05 based on pairwise *t* tests) as the number of required subsequent responses went up. This decrease was not observed for S1-RT1. It is hard to see how subsequent targets could facilitate a response to a current target. One argument is that the presence of a subsequent target could induce participants to rapidly complete the first item. The eyes fixated the next item prior to responding to the current one. If the next item is not a target they might decide to delay responding, and continue moving the eyes. If it is a target they know they must respond quickly and deal with the new item.

Dwell Time and Eye-Hand Span As in previous experiments, fixation durations remained relatively constant across stimuli. Not surprisingly, fixation durations on target (Go) stimuli were always longer than No-Go stimuli. More interesting comparisons arise when one regards fixation durations as a consequence of the previous stimulus (Figure 4). Here the dwell times suggest that the attempt to interleave the mental operations for successive stimuli pushes cost on to the subsequent stimulus. When the fixated stimulus is a target (a Go stimulus) dwell times were shorter by ~60 ms for targets that were preceded by dummy stimuli (i.e., XT) than by target stimuli (i.e., TT). When the fixated stimulus was a dummy stimulus this difference (TX compared to XX) was ~30 ms. This effect was found in several individual comparisons as well as in an analysis grouping all occurrences of each.

Condition	s1		s2		s3		s4	s5		T preceded by T or X	
TXXTT	450.4	c	324.6	d	300.1	b	415.9	838.6		a	TT
TTXXT	467.6	a	478.8	c	315.1	d	307.9	768.9		b	XT
TTTXX	460.6	a	484.8	a	443.1	c	349.5	439.5			
XTXXT	339.9	b	394.4	c	344.0	d	329.9	776.8		X preceded by T or X	
XTTXX	332.7	b	409.5	a	445.5	c	370.5	527.7			
XTTTX	336.6	b	395.7	a	433.3	a	473.3	581.8		c	TX
TXXXX	534.3		451.9		362.5		334.3	425.6		d	XX

Figure 4. Dwell times for S1-S5 in all conditions

Lengthened dwell times for stimuli preceded by targets suggest that the demand of making manual responses interfered with eye movement related processes. The eyes leave a stimulus prior to the completion of all the processing, such that the remaining processing for the previously fixated item delays one or more operations on the subsequent stimulus. A more detailed explanation rests on assumptions about the underlying resource architecture, which specifies the operations that can occur in parallel and those that must be done sequentially. The effect can be explained by adopting the common assumption that perceptual, cognitive, and motor operations execute in parallel, constrained only by logical or data dependencies. By this account, dwell times for the second stimulus are lengthened because cognitive resources required for stimulus-response mapping for the first stimulus postpone central processes on the second. Since central cognitive operations logically require data from perception, the inference is that this time is shorter by ~70 than that required for response selection. With continued explorations of similar factors it should be possible to obtain parameter estimates for processing operations that would permit a full model of extended task performance based on individual trial data.

Other aspects of the eye-hand span results resembled those found in previous experiments. As before, eye-hand spans decreased across the stimulus/response sequence. Figure 5 shows the results of the two constituents of eye-hand spans, dwell times and release-hand spans. There are several notable findings. First, it is evident that the difference among RT1s in cases where RT1 occurred to S2 was mainly due to the difference in release-hand spans. If one assumes that release-hand spans represent the time taken to complete remaining processes after fixation is terminated, it is foreseeable that release-hand spans may also include processes necessary for programming and coordinating response sequences. The fact that eye-hand spans decreased at a constant rate suggests that the coordination may not be restricted to each pair of responses. In the present set of experiments the maximal number of responses is set at five. It is possible that participants could

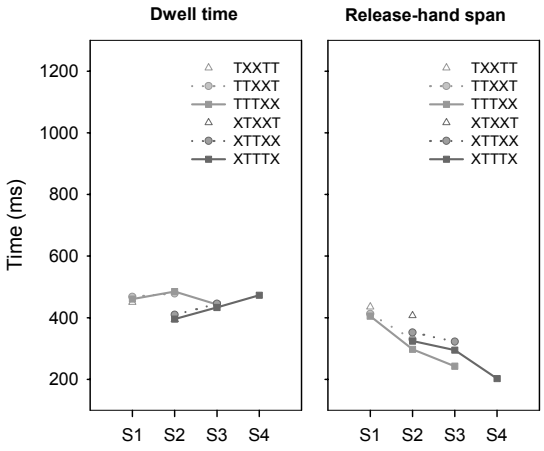

Figure5. Mean dwell time and release-hand span results

plan for five responses. Whether the trend will hold for longer sequences has yet to be tested.

General Discussion

The conditions of the experiment were designed to identify variables contributing to the elevation of RT1, and provide insight into the relationship of eye movements to manual responses by examining the effects of stimuli that required no manual response. Our previous experiments showed large eye-hand spans indicating that substantial processing remained on previous item after the eyes had moved. Analyses of dwell time responses to manipulations of stimulus-response compatibility suggested that dwell times encompassed central processes associated with response selection. Here dwell times for targets were elevated by ~70 ms when the preceding stimulus required a response. A straightforward account in terms of stage processing might estimate that the processing remaining after the eye movement is ~70 ms + the time for perceptual processing on the next task. Given a reasonable estimate of perceptual processing time of ~150 ms, it would seem that ~220 ms of central processing remain after the eyes move.

However, this explanation has difficulty accounting for the smaller increase (~30 ms) found on No-Go fixations in the same condition. That there is any effect of previous target at all is evidence that central processing is required to decide whether or not to respond to the No-Go stimulus. It might be assumed that the smaller effect for No-Go dwell times indicates more than postponement. That is, there may be interference between response-related processes on the two adjacent target stimuli. Since evidence for postponement is well known in dual-task studies, more evidence will be required to determine whether interference is acting here, rather than a more complicated postponement process.

Conclusions

We have evidence that RT1 elevation is due to a combination of factors including preparation for eye movement sequences, preparation for hand response sequences, and retrieval of stimulus-response mappings. Dwell times indicate that there is imperfect time sharing of the processing and response to successive stimuli. Mental operations on the previously fixated stimulus result in delays in processing the subsequent stimulus. These data can provide numeric estimates of internal processing times required to fully model these results.

Acknowledgements

This research was supported by funding from the Airspace Operations Systems (AOS) Project of NASA's Airspace Systems Program.

References

Gray, W. D., John, B. E., & Atwood, M. E. (1993). Project Ernestine: Validating a GOMS analysis for predicting and explaining real-world task performance. Human-Computer Interaction, 8, 237-309.

John, B., Vera, A., Matessa, M., Freed, M., & Remington, R.W. 2002. Automating CPM-GOMS. In Proceedings of the ACM SIGCHI 2002 Conference on Human Factors in Computing System: Changing Our World, Changing Ourselves (pp.147-154). New York: ACM.

Land, M. F., & Hayhoe, M. 2001. In what ways do eye movements contribute to everyday activities? Vision Research, 41, 3559-3565.

Land, M. F., & Lee, D. N. 1994. Where we look when we steer. Nature, 369, 742-744.

Logan, G. D., & Bundesen, C. (2003). Clever homunculus: Is there an endogenous act of control in the explicit task cuing procedure? Journal of Experimental Psychology: Human Perception and Performance, 29, 575-599.

Matessa, M., Vera, A., John, B., Remington, R. W., & Freed, M. (2002). Reusable templates in human performance modeling. In W. Gray & C. Schunn (Eds.), Proceedings of the Twenty-Fourth Annual Conference of the Cognitive Science Society.

Pashler, H. 1994. Overlapping task operations in serial performance with preview. Quarterly Journal of Experimental Psychology Section A-Human Experimental Psychology 47, 161-191.

Pashler, H., Carrie, M. & Hoffman, J. (1993). Saccadic eye movements and dual-task interference. The Quarterly Journal of Experimental Psychology, 46A, 51-82.

Pelz, J., Hayhoe, M., & Loeber, R. 2001. The coordination of eye, head, and hand movements in natural task. Experimental Brain Research, 139, 266-277.

Salthouse, T. A., & Ellis, C. L. 1980. Determinants of eye-fixation duration. American Journal of Psychology, 93, 207-234.

Vickers, J. N. 1992. Gaze control in putting. Perception, 21, 117-132.

Wu, S.-C., & Remington, R. W. (2004). Coordination of component mental operations in a multiple-response task. In S. N. Spencer (Ed.), Proceedings of the Eye Tracking Research and Applications Symposium 2004. New York, NY: ACM SIGGRAPH.