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Influences of Age and Training on Script Development

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ABSTRACT

This investigation provides a test of the developmental script hypothesis proposed by Hershey, Walsh, Read, and Chulef (1990). It is hypothesized that in complex problem solving situations, increases in task-specific experience lead to an increase in information selection and search consistency. Specific goals of the present study were to examine how age and domain-specific knowledge acquired through training influence search processes. Fifty-seven participants, aged 16–80, individually solved a series of six financial investment problems. For virtually all individuals, the selection of a set of common task information increased over consecutive trials. Furthermore, over the six trial sequence a majority of individuals developed a consistent search pattern. The only participants who failed to display sequential processing consistency were untrained older adults. The discussion focuses on how age-related differences in processing resources, prior experience, and knowledge of the task may have been responsible for the observed effects.

One of the hallmarks of intellectual competence is the ability to efficiently solve problems and make decisions (Horn & Noll, 1997; Salthouse, 1991; Schaie, 1994). By definition, the competent and efficient problem solver is one who can adaptively learn from prior experiences and bring his or her knowledge to bear on the situation at hand (Feigenbaum, 1989). This is particularly true in information-rich domains where knowledge usually determines both the nature of the search process one engages in as well as the quality of the solution (Frensch & Funke, 1995; Sternberg & Frensch, 1991).

The focus of this investigation involves a test of the problem solving script hypothesis, originally proposed by Hershey et al. (1990). This hypothesis suggests that in complex domains, individuals acquire highly efficient problem solving scripts through repeated task-specific experiences. Scripts are believed to be well-organized, goal-directed knowledge structures that map out both practical and efficient information selection and search processes. The script hypothesis was tested by examining changes in information search patterns as participants solved a set of six financial planning problems. Of particular interest was how individuals of different ages and with different levels of domain-specific knowledge solved the problems. Before turning to the specifics of the experiment, however, a review of the relevant script literature is provided.

Scripts and Their Development

A review of the literature suggests that scripts constitute a specialized form of procedural knowledge (Bower, Black, & Turner, 1979). Unlike procedural knowledge, which is typically viewed as implicit or "non-conscious" (Konoske & Ellis, 1991; Zeitz & Spoehr, 1989), scripts are knowledge structures that are subject to full conscious awareness. A script is a goal directed, self-contained series of actions (Galambos, 1986) that

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serves to define a situation (Schank, 1975; Schank & Abelson, 1977). In problem solving and decision making contexts, scripts are hypothesized to be the foundation of knowledge required to generate effective solutions (Hershey et al., 1990).

In a comprehensive review of the script literature Ableson (1981) pointed out that:

> . . . a script is a hypothesized cognitive structure that . . . in its weak sense, is a bundle of inferences about the potential occurrence of a set of events [and] . . . in its strong sense, involves expectations about the order as well as the occurrence of events. (p. 717)

It is worth noting that in Abelson's definition there is explicit reference to two separate issues: (a) the existence of *specific events* within a larger event sequence, and (b) a *temporal specification* of how the overall event sequence is likely to unfold. These two components of the definition are important because each will later serve to generate key predictions for the developmental script hypothesis, which will be introduced below.

Events represented in a script are assumed to be a good sample of the most available actions or problem solving steps in long-term memory (Tversky & Kahneman, 1973), and the frequency of mention of an event across subjects is assumed to be an index of the salience or centrality of that item (Galambos, 1986). From the early 1980s to the mid 1990s numerous studies were published that examined the psychometric properties of scripted behaviors, from common and mundane tasks such as using a toothbrush (Greene, Houston, Reinsmith, & Reed, 1992) and washing a car (Graesser, Woll, Kowalski, & Smith, 1980), to tasks that are specialized and complex, such as carrying out a psychology experiment (Hershey, Wilson, & Mitchell-Copeland, 1996), treating an accident victim, and dealing with a gas leak (Hershey & Farrell, 1999).

Hershey et al. (1990) found evidence of script use when comparing the performance of expert and novice financial planners who solved a complex retirement investment problem. Relative to novices, experts selected more high-level task information, and they processed that information in a more goal-directed, efficient manner. Presumably, these differences were due to the fact that experts' scripts had been refined through years of experience at solving similar problems. However, the lack of longitudinal data in that study did not allow firm conclusions to be drawn regarding how problem solving scripts evolve.

Over the past 20 years a relatively large body of script-related research has been generated. Of central relevance to the present investigation, however, are a small handful of studies that focus on developmental differences in scripted representations.

Studies of Developmental Differences

The topic of scripts has largely been ignored in the literature on adult cognitive development (Hershey & Farrell, 1999; Rebok, 1989). Light and Anderson (1983) were one of the first to examine age differences in scripts, in a cross-sectional investigation focusing on everyday activities experienced by young and old adults (e.g., going grocery shopping). They found "no support for the hypothesis that young and older adults differ in the way in which conventional activities are represented in semantic memory" (p. 441). They further concluded that age-related deficits in processing resources were insufficient to compromise the processing characteristics of individuals' scripts, at least for routinely experienced activities.

Hess (1985) examined age differences in reading comprehension and in the subsequent retrieval of script-based story actions. This study revealed little in the way of age differences associated with the comprehension or perceived relevance of scripted actions. However, age differences were found in the ability to recall and recognize particular actions. Specifically, older individuals had greater difficulties remembering less typical actions, and actions that were not centrally related to the goal of the script. As a possible explanation for the age-based effect, Hess speculated that the retrieval deficit "might be accounted for by quantitative differences in some general memory factor [which] . . . appears to be affected by available processing resources" (1985, p. 1149). In a follow-up study, Hess, Donley, and Vandermaas (1989) localized the source of the age difference described by Hess (1985) at the encoding stage of processing, speculating that relative to younger individuals, older adults fail to effectively link script-based actions together when they are initially encountered. It was argued in later papers that the extent of one's scripted-related knowledge also plays an important role in determining how efficiently script-based actions are encoded and subsequently retrieved (Hess, 1990; Hess & Flannagan, 1992; Hess & Tate, 1991).

In a more recent investigation of performance on everyday tasks, Hershey and Farrell (1999) predicted age-related improvements in the quality of individuals' problem solving scripts. In that study, participants, aged 20–69, solved seven different real-world problems by determining the correct solution sequence from among a set of activities provided. Although older adults were found to have experienced the problems more frequently, the quality of their solutions was somewhat poorer than those of younger individuals. According to the investigators, one possible explanation for the unanticipated negative relationship between age and quality of performance was that general age-related cognitive declines might have been stronger than any buffering offered by increases in domain-specific knowledge acquired over the life span.

Other studies that have used the Tower of Hanoi problem (TOHP) have consistently found age-related declines in the quality of individuals' solutions (Brennan, Welsh, & Fisher, 1997; Davis & Bernstein, 1992; Vakil, Hoffman, & Myzliek, 1998). The experiment conducted by Brennan et al. (1997) using three- and four-ring variants of the task provides a good example of this line of work. On the simpler three-ring version of the task, the performance of the young ($M_{\text{age}} = 19$) and the young-old participants ($M_{\text{age}} = 65$) did not differ, but both groups solved the problems more efficiently than members of the old-old group ($M_{\text{age}} = 75$). However, on the more complex four-ring task, the performance of both older groups was inferior to that of younger individuals, suggesting that age-related processing declines may impede use of a script when the requirements of the task increase beyond a certain level of difficulty.

Little in the way of age differences has been found in scriptedness when familiar or everyday problems are used, as evidenced by the findings reported in Light and Anderson (1983), and Hershey and Farrell (1999). When a script-based task is designed to be more challenging, however, such as when an additional memory load is added or substantial processing resources are otherwise required, then age-related declines become more pronounced (Brennan et al., 1997; Hess, 1985; Hess et al., 1989).

Study Objectives and Hypotheses

This study serves as a conceptual replication and extension of the Hershey et al. (1990) financial planning experiment. The goal was to test the developmental script hypothesis by examining whether individuals acquire scripts as they solve a series of six, complex retirement investment problems. Of particular interest is the extent to which individuals' *age*, *knowledge* of the task, and prior problem solving *experience* influence script development. Based on the literature cited above, one would expect that all three of these factors might have an impact on performance. Two between-subjects factors – age and training – each with two levels, were crossed to form four subgroups: young untrained participants, young trainees, old untrained participants, and old trainees. These two between-subject dimensions were combined with the six-level repeated-measures dimension (experience) to form the basis of a mixed-model design.

Recall that when Abelson (1981) described the characteristics of scripts, he included two different components as part of his definition: (a) the existence of a specific set of events that would transpire, and (b) a temporal specification of how the event sequence would unfold. Based on that definition, and on the findings of Hershey et al. (1990), in the present study the working definition of a *problem solving script* contains two parallel components: (a) expectations about a specific set of cues to consider in a particular problem solving context, and (b) expectations about the sequential order in which those cues should be processed. In order to test the developmental script hypothesis, both components of this definition were operationalized and measured independently of one another.

The first research question, which is based on part one of Abelson's definition (above), is designed to determine whether individuals select an increasingly similar set of information from the task database on consecutive trials. It is predicted that as participants develop scripts they will show an increase in the percentage of common cues requested over the six trials. The second research question, based on part two of Abelson's definition, seeks to determine whether script development is associated with a change in processing consistency. It is predicted that the sequential order in which common cues are considered will also increase over trials. Such an increase would provide compelling evidence in support of the developmental script hypothesis, because the 401(k) investment task used in the present study is an ill-defined problem (Simon, 1973), which does not necessarily require that cues be processed in a fixed order. Therefore, appreciable increases in processing consistency can be attributed to the acquisition of a script on the part of the problem solver.[1]

We also expect to find that trained individuals will select more common cues across trials and demonstrate higher levels of trial-to-trial processing consistency than their untrained counterparts, based on a superior knowledge of the task derived from the training. However, based on equivocal findings in the developmental script literature, it is difficult to posit how age will impact cue selection and search processes. College students (in the 16–21 year-old age range) were selected for inclusion in the study based on the assumption that they would be relatively naive regarding issues related to savings and retirement finances. Older individuals (all over the age of 50) were included in the study based on the assumption that they would bring to the task a lifetime of financial decision-making experience. However, these older adults are of an age where they would have presumably experienced declines in their basic processing resources. This being the case, we were hesitant to specify a priori hypotheses regarding the nature and direction of age differences in information selection or processing consistency. The emergence of any higher order interactions between age, training, and experience on the task would be of particular interest, in that they would provide evidence for intriguing trade-offs among the three independent variables in terms of the influence they have on performance.

In addition to the processing aspects of the study described above, scores will be examined on a series of self-report items designed to tap perceptions of performance and the task. One question queried individuals as to whether the difficulty of the task changed over trials. It is predicted that individuals will report that the problems become progressively easier as a function of experience (presumably because as they develop and refine their scripts, the need for processing resources will be reduced). Individuals were also asked whether they had developed a strategy to solve the problems. It is anticipated that groups that show greater evidence of script use will report a greater awareness of their use of a processing strategy. Other self-report items included individuals' perceptions of how challenging they found the problems, how interesting they found the problems, and how thorough they were when solving the problems. We hope to find that group means for the latter two items will not show significant differences across groups, which would help to rule out competing explanations for observed age or training differences in information selection and processing consistency.

METHOD

Participants[2]

Members of the two young groups were undergraduate students attending a large, West-coast urban university. Their participation was solicited via fliers left in dormitory mailboxes and notices posted on campus bulletin boards. The mean age of young untrained

[1]Use of a script does not necessarily lead one to produce a high quality (or even a reasonable) solution, however it should, by virtue of proceduralization, serve to reduce the demand on processing resources. On that basis one might argue that the acquisition of a script reflects an adaptive problem-solving tactic.

[2]The data reported in this study were collected as part of a larger study of aging, expertise, and problem solving performance. Other aspects of the performance of these participants can be found elsewhere (Hershey & Walsh, 2000/2001; Hershey & Wilson, 1997; Walsh & Hershey, 1993).

participants ($N = 14$) was 19.0 years ($SD = 0.23$), and the mean age of the young trainees ($N = 14$) was 18.2 years ($SD = 0.21$). Members of the two older groups were university alumni or their spouses who were recruited through an older adult subject pool maintained by the psychology department. The mean age of old untrained participants ($N = 14$) was 68.7 years ($SD = 1.86$), and the mean age of the old trainees ($N = 18$) was 72.9 years ($SD = 1.22$).

Design

As indicated above, a 2, Age of Subject (young; old), × 2, Training Status (trained; untrained), × 6, (repeated measures) mixed model design was employed. Half of the subjects were randomly assigned to attend two, 3-hour educational sessions that formed the basis of the training manipulation.[3] Approximately 7 days after completion of the training (minimum = 4 days, maximum = 10 days) participants attended a problem solving session during which they solved the six retirement investment problems. To minimize the possibility of order effects, the presentation position for each problem was determined in advance using a partial counterbalancing procedure with a random start.

Separate training sessions were held for younger and older groups of participants. These training sessions, which were primarily informational in nature, included a conceptual overview of financial planning for retirement and specific information about 401(k) plans. The overview was designed to acquaint participants with the three major dimensions of the 401(k) task: (a) the factors that influence one's financial need in retirement, (b) factors that influence the affordability of a retirement investment, and (c) the factors that vary across different types of retirement investment vehicles (dimensions further described in the procedure section, below). Thus, they were introduced to the complete representational model (Novick, 1988) of the problem, providing them with veridical and well-organized task, related declarative knowledge structures.

The first training session focused on two issues: determining the value of one's unmet retirement need, and assessing the affordability of an investment. The second session, which was always conducted 3 days after the first, introduced trainees to a number of different types of retirement investment vehicles, with a special emphasis on the characteristics of 401(k) plans. In addition, during the second session, trainees were presented with two sample cases of how variables from each of the three information domains could be combined to determine a recommended investment amount. These problems were similar in format and content to the six problems that would subsequently be used during the testing phase of the investigation. It is important to point out, however, that the training was not designed to provide participants with a specific script per se, or to suggest that a single optimal solution sequence existed. An instructor who was experienced in leading financial and retirement intervention seminars conducted all training sessions.

Attrition in the experiment was low. Only 1 participant in the training group failed to complete the second training session, thereby making himself ineligible to participate in the test phase of the study. Analysis of the post-training domain-specific knowledge test scores using a 2 (Age Group) × 2 (Training Status) ANOVA confirmed that the training had the intended impact. Trainees' scores on the test ($M = 68\%$, $SD = 9.4$) were superior to those of untrained individuals ($M = 44\%$, $SD = 9.5$), $F(1, 53) = 97.46$, $p < .01$. Also consistent with expectations, older participants' knowledge scores ($M = 60\%$, $SD = 13.6$) were somewhat higher than younger individuals' scores ($M = 53\%$, $SD = 16.2$), $F(1, 53) = 6.55$, $p < .01$. The two-way interaction for this test failed to obtain, $F(1, 53) = 2.10$, *ns*.

Procedure

All participants were tested individually during the problem-solving session. Each subject was presented with six different financial investment scenarios. For each scenario, the goal was to determine how much money a hypothetical individual or couple should contribute to a 401(k) retirement savings plan. The problem presented below is an actual problem participants encountered. In terms of format and level of detail, it is representative of the other five problems.

> The O'Keefes are a middle-aged couple that have been married for a number of years. They have a teenage son and own a small, pleasant home on the outskirts of Los Angeles. Bob O'Keefe is a supervisor at the Gas Company and Judy runs a small but profitable home-based business. Recently, Bob's employer has offered him the opportunity to invest in a 401(k) retirement savings plan. If you were Bob and Judy's financial advisor, what types of information would you want to obtain from them before advising them whether or not to make an investment in the plan?

Each trial was conducted using a two-phase methodology. During the first phase, the participant was

[3]Twenty-eight individuals for each age group were subjected to random assignment with respect to the training dimension. Following assignment, 4 members of the old trained group requested that their spouses also be allowed to attend the training. This request was granted with the provision that the spouses complete the data collection portion of the project following training. This led to a somewhat larger *N* in the old trained group.

allowed to request any information needed to generate a solution. During the second phase, the requested information was provided, and the individual solved the problem (i.e., they determined a specific investment amount for the hypothetical individual). Information was provided on index cards that were placed on a large information board. Only the titles of the cards (e.g., *Current Gross Income*) were visible, and the participant had to turn the card over to view the specific parameter for each variable (e.g., $32,000). The total number of cues in the task database and the nature of the information available were not revealed to the participants. This was done to ensure that the set of information ultimately considered represented only those cues the individual thought to be important to generate a solution.

Participants were instructed that they could only view one card at a time, which allowed the experimenter to track their step-by-step information search process. If at any time during a trial participants wanted additional information, they simply needed to ask for it and it would be provided. Individuals were also asked to think aloud as they solved the problems, in order to provide for an audio recording of the solutions. As a participant worked through a problem, detailed records were kept of the specific pieces of information selected, and the sequential order in which the information was considered. In designing the task the decision was made not to provide participants with performance feedback on the quality of their solutions. Had feedback been provided, it may have altered or shaped individuals' naturally evolving scripts, which we sought to avoid. Moreover, there is a certain ecological validity associated with the decision not to provide feedback, in that it is atypical for individuals' to receive immediate performance feedback when engaged in financial planning activities (often, the quality of one's efforts may only be ascertained years after investment decisions have been made).

Following completion of the problem solving session, all participants were given a questionnaire about perceptions of their performance, which also included questions about retirement planning and investing. Finally, individuals were debriefed and received payment ($5.00 per hour) for their participation in the study.

Two items from the questionnaire administered at the end of the problem solving session potentially had bearing on the script hypothesis. The first item was a 7-point bipolar completion statement that read: "As you successively solved the problems, the investment decisions became" (1 = easier; 4 = not easier or harder; 7 = harder). The second question was a 7-point Likert item that read: "Over the course of solving the six problems did you develop a strategy or hard and fast rules for dealing with the task information?" Anchor statements at the endpoints of the scale were: 1 = no particular strategy; and 7 = developed hard and fast rules. Three other questions were posed that were designed to elicit more general perceptions of the task. One item asked "How challenging did you find the problems?" (1 = not challenging, 4 = moderately challenging, 7 = very challenging), another requested participants to rate the extent to which they "carried out a thorough consideration of the financial problems, taking into account most of the details" (1 = poor consideration, 4 = average consideration, 7 = good consideration), and a third asked subjects "How interesting was it to work on the problems?" (1 = not interesting, 4 = moderately interesting, 7 = very interesting).

Task Analysis

Prior to the data collection phase of the study a thorough task analysis of the problem was carried out in order to form a conceptual model of the 401(k) investment decision (see Fig. 1). This conceptual model, developed with the assistance of a panel of expert financial planners,[4] served three purposes. First, it served as a skeleton that was used to flesh-out the various parameters for the six hypothetical problem scenarios. Second, it served as the template upon which the information search patterns of participants were represented. Third, it served as a structural outline for the training given to roughly half the sample. The information represented in the conceptual model focuses on three major issues that have been arranged into separate sub-hierarchies of problem relevant information.

The top hierarchy in Figure 1 represents information related to whether the hypothetical investor has a projected need for additional resources during retirement. The middle hierarchy represents information related to the characteristics of the 401(k) plan, and the bottom hierarchy contains information about the financial affordability of an investment. Together these three hierarchies define the problem space of the 401(k) task. A unique information set was constructed for each of the six problems by creating realistic values for the 66 variables represented across the three hierarchies.

Representation of Search Processes

A scoring template used to represent participants' search processes was constructed using brief abbreviations for each of the 66 variables (see Fig. 2, panel A for an example). For each problem, an individual's step-by-step search process was plotted by highlighting each variable selected, and then inserting connecting arrows to indicate the order of the search. These graphic

[4]Details of the validation process appear elsewhere (see Hershey, 1990; Hershey & Wilson, 1997; Walsh & Hershey, 1993).

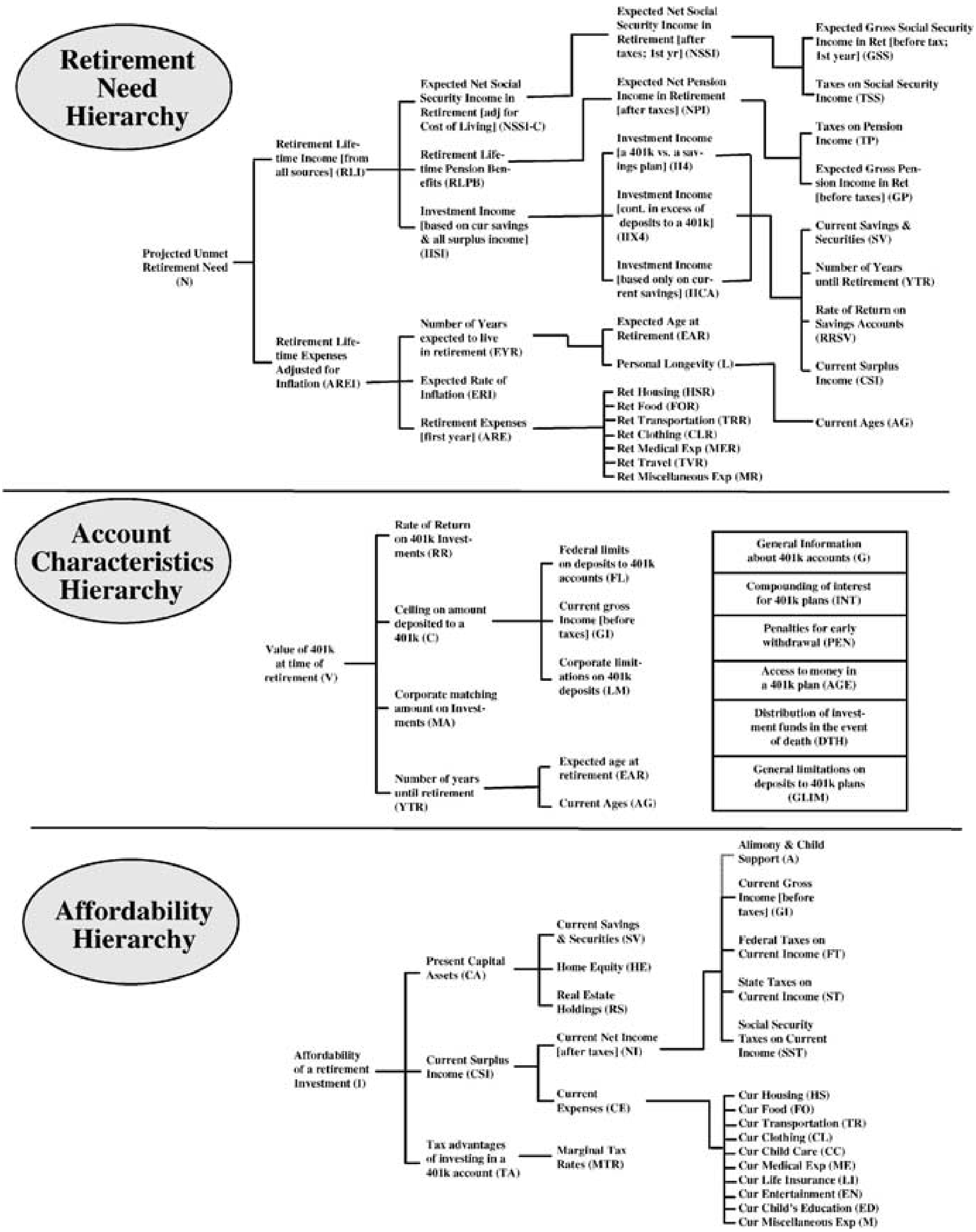

Fig. 1. Conceptual model of the problem space for the 401(k) task. The top information hierarchy contains concepts related to determining one's unmet financial need during retirement, the center hierarchy contains information specific to the characteristics of the investment plan, and the bottom hierarchy involves issues related to the affordability of an investment. Variables and concepts were generated through a logical task analysis of the 401(k) problem. Abbreviations in parentheses are used in the process tracing maps of Figures 2, 3, and 4.

representations have previously been referred to as *problem solving process maps* (PSPM; Hershey et al., 1990; Walsh & Hershey, 1993). The PSPM representations were then analyzed to identify training and age-based differences in the types of information selected, and the sequential consistency of participants' search.

Inclusionary Criteria

The two major analysis goals were to: (a) calculate the percentage of variables that individuals selected in common across the five adjacent "trial-pairs" (i.e., Trials 1 and 2, 2 and 3, 3 and 4, 4 and 5, and 5 and 6), and (b) for those common variables selected across trials, determine whether they were considered by individuals in a consistent sequential order. To ensure that these measures could be reliably and meaningfully interpreted, data were only considered from participants who selected four or more variables on each of the six trials. This resulted in the elimination of 3 subjects from the pool, which reduced the sample to 57 individuals. One of the individuals excluded was from the old untrained group, and the other two were old trainees.

A rank-order correlation coefficient, Spearman's rho, was used to examine the degree of trial-to-trial processing concordance. For this analysis each variable selected was assigned an order number (from first to last). Next, these orders on adjacent trials were correlated using the rho statistic. Rho reaches its upper bound (+1.00) in situations where the two sets of common variables are considered in exactly the same order (i.e., A, B, C, D, E → A, B, C, D, E). The statistic obtains its lower bound (−1.00) in situations where two sets of variables are considered in exactly the opposite order (i.e., A, B, C, D, E → E, D, C, B, A). If the two sequences are random with respect to one another then rho takes on a near-zero value. Because in this context rho values reflect the magnitude of overlap in search sequences, throughout the remainder of the paper they are referred to as *concordance scores*.

It was a concern that the concordance score measure of processing consistency would be unreliable in cases where 50% or fewer of the variables selected were common across adjacent trials. Of the 285 trial-pairs (i.e., 57 Ss × 5 trial pairs ea.), only 33 (11.6%) were found to contain fewer than 50% of the variables in common. For each of those 33 cases, the concordance score for the "missing" trial-pair was replaced with the mean of the individual's remaining valid concordance scores.

RESULTS

Studies of developmental differences in real-world problem solving often run the risk of confounded effects due to group differences in subject variables related to both age and the dependent measure(s). With this in mind, we first examined whether there were age differences in 2 subject variables potentially related to performance on the task: income and level of education. It would be of concern if the scores for either of these indicators differed as a function of age, and at the same time covaried with the dependent measure. Income was not found to differ as a function of age, $t(50) = 0.85$, *ns*, ruling out a potential confound on the basis of socioeconomic status.[5] The mean level of education, however, was found to differ for younger and older participants, $t(55) = 7.80$, $p < .01$, with the two groups having completed 13.9 and 16.2 years of formal education, respectively. Despite this difference, educational level was not found to be correlated with either of the measures used to evaluate the script hypothesis: the mean percentage of common variables selected ($r = .08$, *ns*), or the mean concordance scores ($r = -.10$, *ns*). The lack of association seen in these two correlations suggests that any observed age effects found for either of these dependent measures are likely to reflect developmental differences in processing strategies, rather than an artifact brought about by pre-existing group differences in education.

Profiles of Script Development

Figures 2 through 4 contain the PSPMs of 3 participants who displayed very different information search profiles. These figures are presented to illustrate the range of different forms seen in the development of individuals' scripts. The six panels in Figure 2 represent the performance of one individual's problem solving efforts. An examination of this participant's search behavior provides insights into the processing strategy used. The arrows indicate the sequence in which pieces of information were considered. On the first trial (Fig. 2a), this individual considered 11 different pieces of information, drawn exclusively from the

[5]The lack of an age difference in income level was due to the fact that all young participants in the study were students, few of whom were employed, and most older members of the study were retired, and thus, not wage earners.

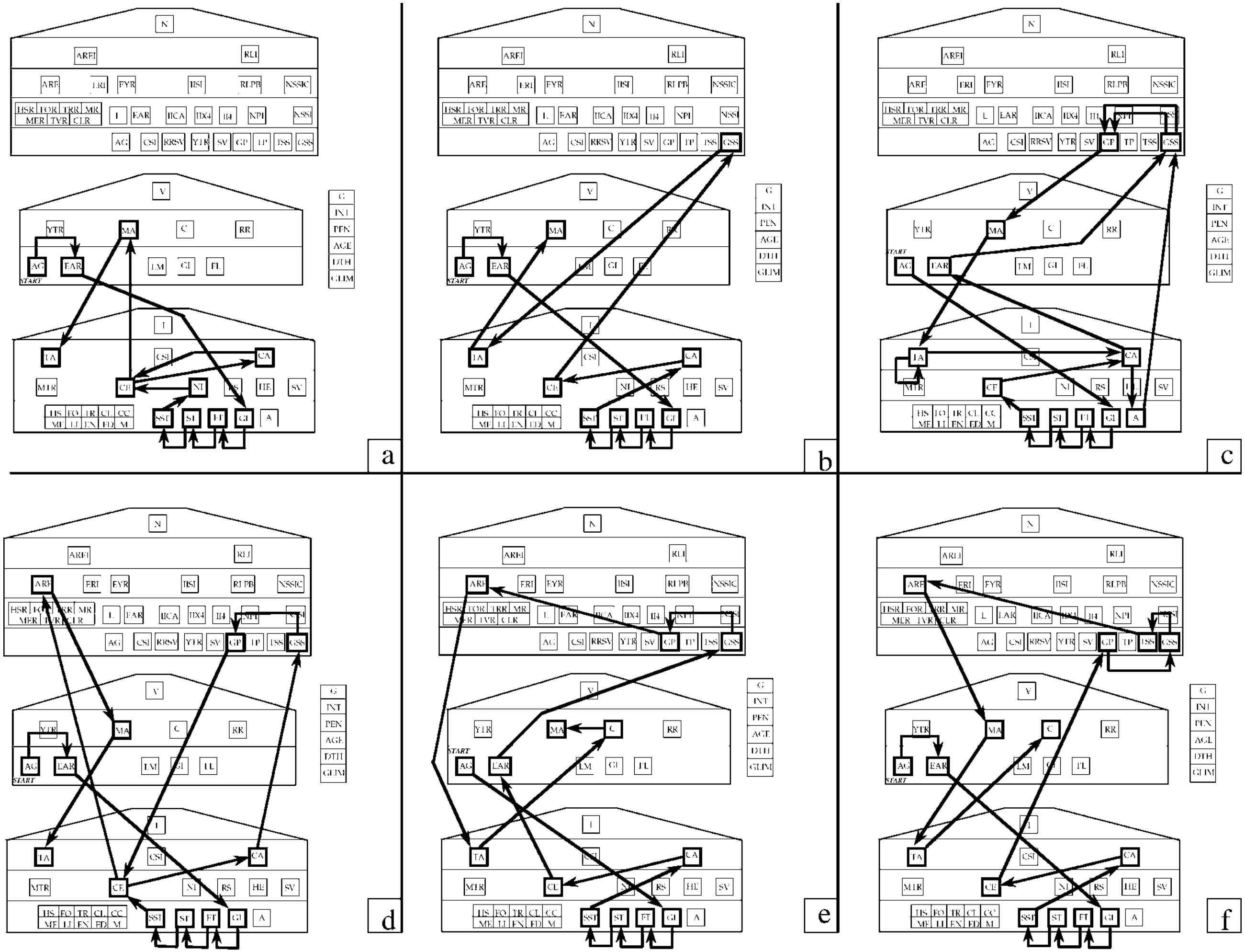

Fig. 2. Problem solving process maps (PSPMs) for participant #67. Maps A through F correspond to the first through sixth problems this individual solved, and the abbreviations (within nodes) on the maps correspond to those shown in Figure 1. Arrows on the map reveal the sequence of the individual's search process. Note how this participant's script appears to expand over successive trials.

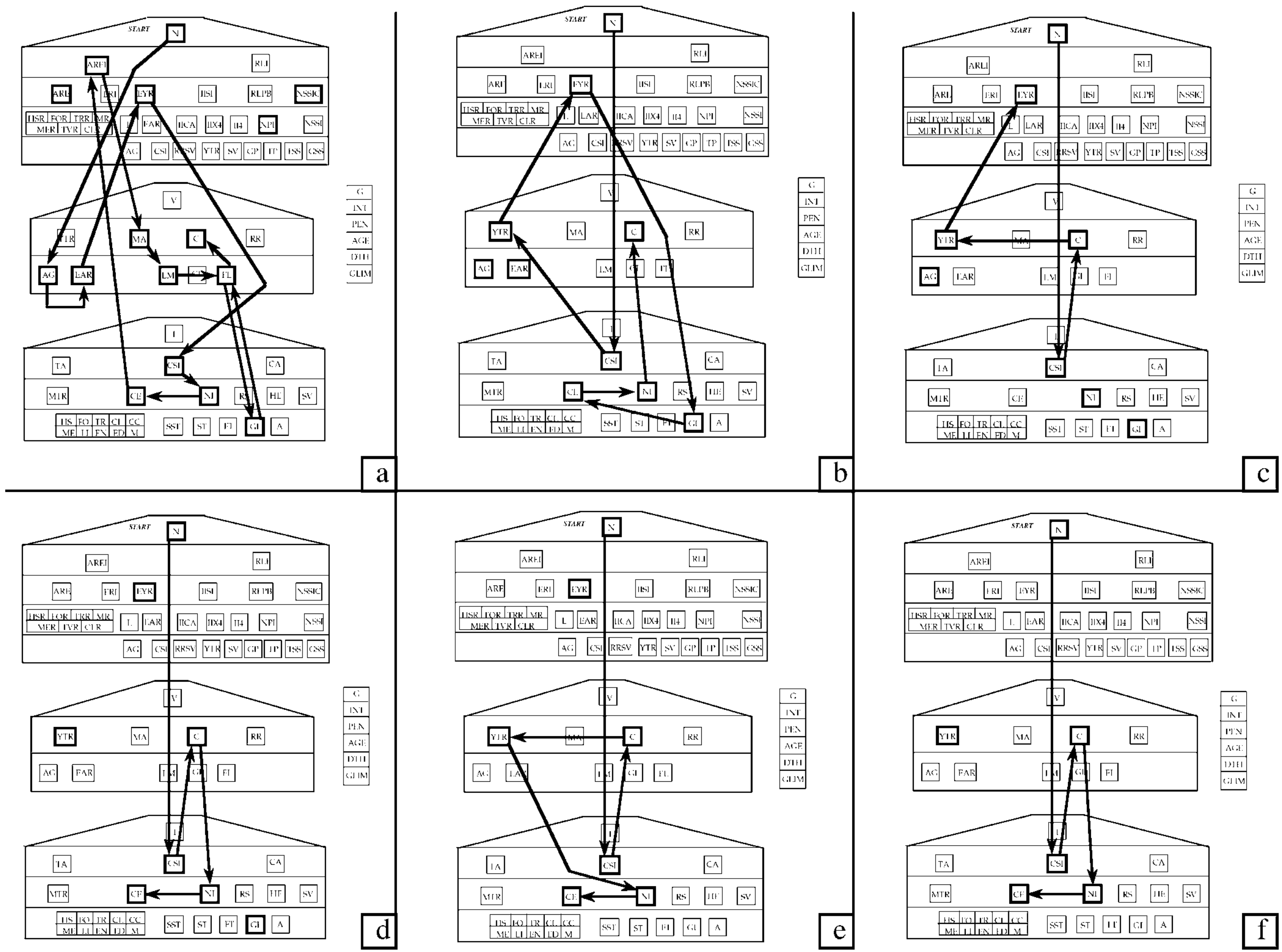

Fig. 3. Problem solving process maps (PSPMs) for participant #85. Maps A through F correspond to the first through sixth problems this individual solved, and the abbreviations (within nodes) on the maps correspond to those shown in Figure 1. Arrows on the map reveal the sequence of the individual's search process. Note how this individual's script appears to become increasingly refined over trials.

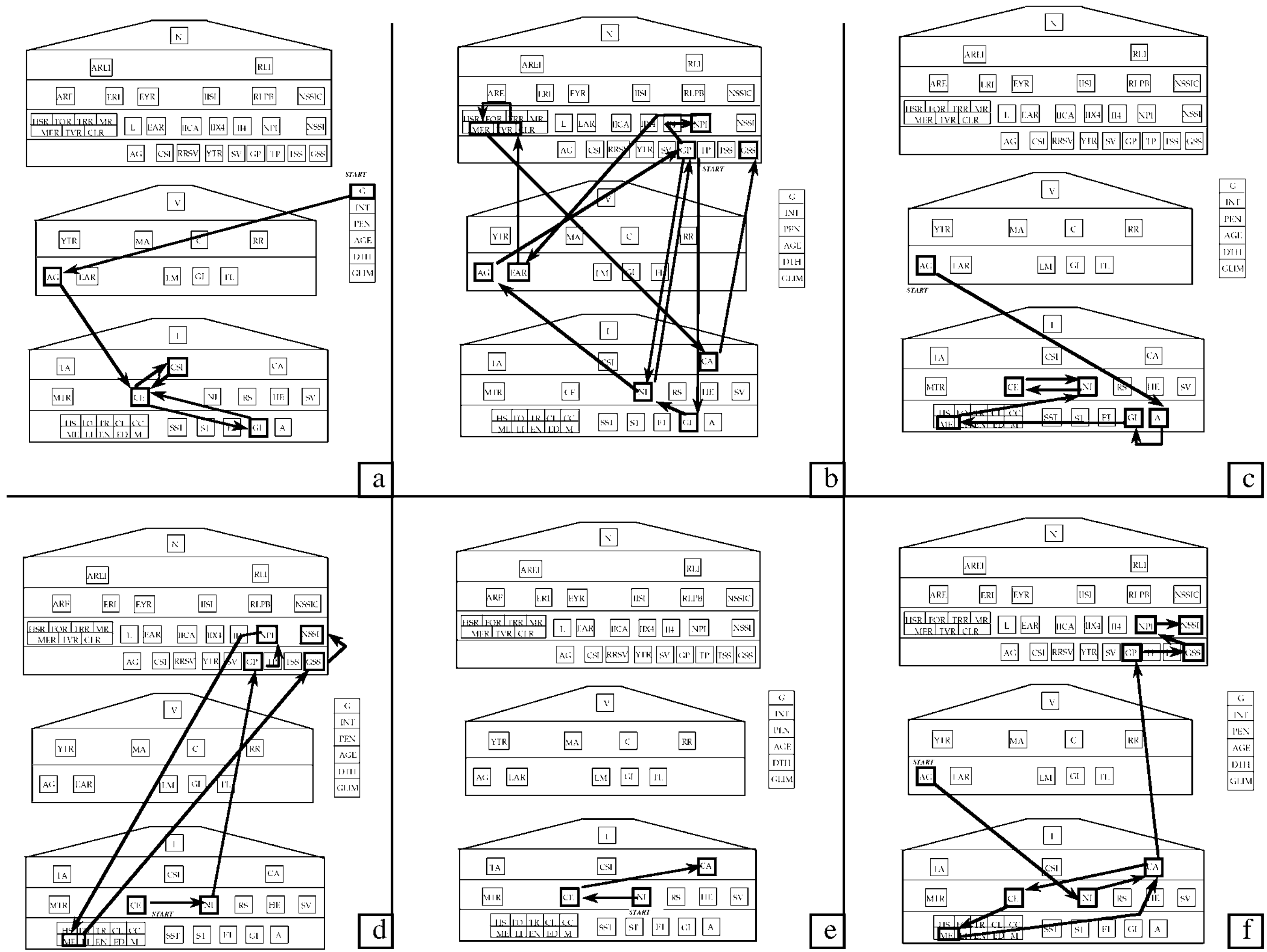

Fig. 4. Problem solving process maps (PSPMs) for participant #56. Maps A through F correspond to the first through sixth problems this individual solved, and the abbreviations (within nodes) on the maps correspond to those shown in Figure 1. Arrows on the map reveal the sequence of the individual's search process. Note how this individual fails to select a common core of information on successive trials, indicating the absence of a single dominant problem solving script.

bottom two hierarchies of the conceptual model. Particularly interesting is the change in this participant's search sequence across the remaining trials. By the final problem, he had increased his search to 15 pieces of information selected from all three hierarchies. This individual's search profile became richer and more comprehensive as it gradually expanded over trials. Whereas the information selection and search profile on any two adjacent trials were fairly similar, the patterns of processing seen on non-adjoining trials (e.g., Trials 1 and 6) are quite different. Thus, the evolution of a script for this participant took the form of a gradual process, in which different pieces of information were systematically added to the sequence from one trial to the next. The tendency to expand one's search over trials was one of two commonly observed developmental profiles seen among members of the sample.

The PSPMs shown in Figure 3 illustrate a very different profile. On the first trial, this individual considered 13 pieces of information distributed across all three information hierarchies.[6] On subsequent trials, however, cues were systematically eliminated so that by the sixth trial only 5 of the original 13 remained. The tendency to "prune back" the search process over trials was the other commonly observed developmental profile. Although the change in this individual's search is just the opposite of that seen in the previous case (Fig. 2), in both instances the overlap in variables selected and the consistency in which those cues were processed suggests the existence of a script-like mental representation.

Figure 4 shows the PSPMs of a participant who, unlike the previous two, demonstrated little evidence that a single script was used to guide the selection of task information. This participant's PSPMs reveal substantial variability in the selection of information from one trial to the next. As many as 10 cues were selected on one problem (panel 4b), and as few as 3 were selected on another (panel 4e). Moreover, the specific cues selected differed from trial to trial. This irregular developmental profile, notable for its lack of a clear search pattern, was rarely witnessed among members of the sample.

Measures of Script Development

A 2 (Age Group) $\times$ 2 (Training Status) $\times$ 5 (Trial-Pairs) analysis of covariance (ANCOVA) was conducted to assess group differences in common variables selected. Mean scores across trial-pairs for this dependent measure are shown as a function of age and training in Table 1. In that the focus of this study was on the information selection and search aspects of individuals' performance, and not on the quality of their problem solving efforts; in this ANCOVA and in the one that follows a measure of solution quality was entered into the model as a covariate.[7] Main effects of age group, training status, and the covariate all failed to obtain significance (all F ratios < 1). However, there was a significant main effect for the repeated measures factor, $F(4, 212) = 5.82$, $p < .01$, corresponding to a nearly monotonic increase in the percentage of common variables selected across trial-pairs for all participants (see values along the bottom line of Table 1). None of the higher-order interactions approached significance. This repeated measure effect provides empirical support for the first component of the script hypothesis.

To evaluate group differences in processing consistency, a 2 (Age Group) $\times$ 2 (Training Status) $\times$ 5 (Trial-Pairs) mixed model ANCOVA was computed using subjects' concordance scores as the dependent measure. Mean scores across trial-pairs for this dependent measure are shown as a function of age and training in Table 2. As in

[6] This participant actually selected 16 pieces of information to solve the first problem, but only used 13 of them. Pieces of information that were selected but not viewed during the second (i.e., search) phase of the trial were not included as part of the computation of common variables or concordance scores.

[7] By adjusting for individual differences in solution quality it was possible to obtain more reliable estimates of the influences of age and training on information selection. This same logic is applied in the analysis of covariance for the concordance score measure, reported below. The interested reader is referred to Hershey (1990), Hershey and Wilson (1997), or Hershey, Walsh, Brougham, Carter, and Farrell (1998) for more detailed information on how the quality of individuals' solutions are derived, and the way in which solution quality is related to age and training.

Table 1. Means and Standard Deviations (in Parentheses) for Percentage of Common Variables Selected Over Trial-Pairs as a Function of Age and Training Status.

Group	Trial-pair				
	1	2	3	4	5
Young					
Untrained	77.6 (22.4)	73.7 (22.7)	86.9 (16.5)	87.1 (13.1)	83.6 (13.2)
Trained	77.6 (14.5)	81.3 (16.3)	75.6 (17.8)	77.4 (21.3)	94.1 (9.9)
Old					
Untrained	63.1 (17.9)	77.0 (21.8)	78.6 (21.2)	85.4 (12.2)	84.8 (20.4)
Trained	69.0 (22.6)	90.1 (12.8)	81.6 (17.9)	81.2 (19.1)	83.3 (19.1)
All participants	71.6 (20.1)	80.9 (19.2)	80.8 (18.3)	82.7 (17.0)	86.4 (16.4)

Table 2. Means and Standard Deviations (in Parentheses) for Concordance Scores over Trial-Pairs as a Function of Age and Training Status.

Group	Trial-Pair				
	1	2	3	4	5
Young					
Untrained	.29 (.51)	.57 (.45)	.49 (.36)	.86 (.16)	.83 (.17)
Trained	.64 (.37)	.55 (.59)	.74 (.30)	.78 (.21)	.87 (.08)
Old					
Untrained	.17 (.57)	.35 (.69)	.28 (.63)	.33 (.67)	.40 (.65)
Trained	.66 (.43)	.78 (.26)	.74 (.27)	.77 (.22)	.82 (.38)
All participants	.46 (.51)	.57 (.52)	.57 (.44)	.70 (.41)	.74 (.41)

the previous analysis, the marker of solution quality was used as a covariate, based on part of the finding that mean concordance scores and solution quality were found to be significantly correlated, $r = -0.30$, $p < .01$.[8] The ANCOVA revealed an effect for the covariate, $F(1, 52) = 5.07$, $p < .05$, as well as significant main effects for both the repeated measures and training status factors, $F(4, 212) = 9.27$, $p < .01$, and $F(1, 52) = 4.55$, $p < .05$, respectively. The repeated measures effect reflects a general increase in concordance scores over trials (see values along the bottom line of Table 2), thus providing support for the second part of the script hypothesis. The training effect revealed that trained participants' scores ($M =$ .74) were significantly larger than those of untrained individuals ($M = .46$). The main effect of age group was not found to be significant, $F(1, 52) = 1.70$, *ns*. Of the higher order interactions, two were significant: the age group by training status interaction, $F(1, 52) = 6.44$, $p < .05$ (see Fig. 5), and the age group by repeated measures effect, $F(4, 212) = 2.58$, $p < .05$ (see Fig. 6). The training status by repeated measures interaction failed to obtain significance, $F(4, 212) = 1.91$, *ns*, as did the three-way interaction, $F(4, 212) = 1.16$, *ns*.

[8]A negative correlation was observed in this case due to the way in which solution quality was calculated. It was operationalized as an error score, representing the absolute value of the difference between individuals' recommended investment values and the optimal investment values (which were arrived at by the panel of expert judges who initially reviewed the scenarios). Thus, on a conceptual level this finding indicates that those who had higher levels of processing consistency tended to generate smaller solution errors.

Self-Perceptions of Performance

It was anticipated that if individuals developed scripts to solve problems, then they should

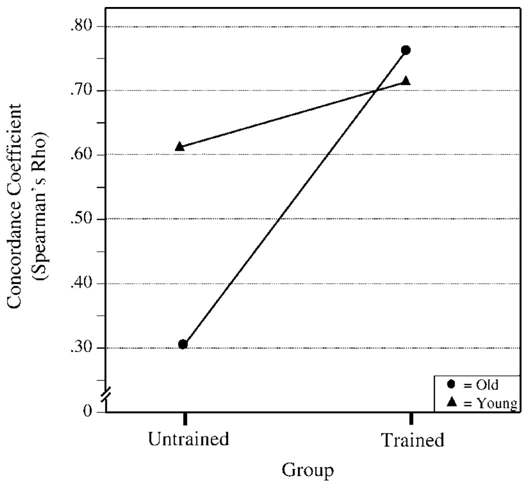

Fig. 5. Mean concordance scores shown as a function of age group and training status.

perceive that the task becomes progressively easier as their scripts become increasingly refined and engrained. Contrary to expectations, perceived changes in task difficulty were found to be uncorrelated with mean concordance scores, $r = .10$, *ns*. This finding begs the question as to whether perceived changes in task difficulty were systematically related to age and training. To address this issue, a 2 (Age Group) × 2 (Training Status) ANOVA was calculated using the perceived difficulty ratings as the dependent measure. Both the age group and training status main effects failed to reach significance, as was the case with the two-way interaction (all $p > .05$).

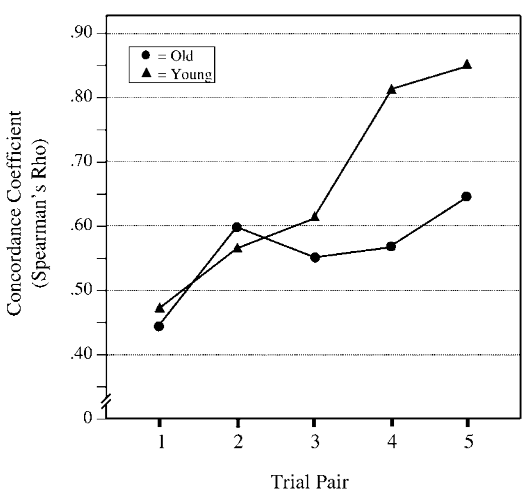

Fig. 6. Mean concordance scores plotted over adjacent trial-pairs shown as a function of age group.

An additional self-report item asked participants whether they developed a strategy for solving the problems (1 = no particular strategy; 7 = developed hard and fast rules). Individuals were not provided with specific definitions or examples as to what constituted a "strategy" or "hard and fast rules." Rather, they were allowed to interpret the anchor terms subjectively, in light of their own experience with the task. Forty-eight of the 57 participants provided an answer to this question; nine responses were coded as missing. The Pearson correlation between the strategy item and mean concordance scores was non-significant, $r = .18$, *ns*. To assess group differences in perceptions of strategy development, a 2 (Age Group) × 2 (Training Status) ANOVA was calculated using individuals' perceived strategy scores as the dependent measure. The main effect for age group obtained, $F(1,\ 44) = 20.97$, $p < .01$, with the mean strategy score of young participants collapsed over training conditions ($M = 5.44$, $SD = 0.97$) being significantly larger than that of old participants ($M = 3.76$, $SD = 1.51$). However, neither the effects of training status, $F(1, 44) < 1$, *ns*, nor the two-way interaction, $F(1, 44) < 1$, *ns*, were significant. The mean strategy score of trained individuals collapsed over age groups ($M = 4.68$, $SD = 1.60$) was nearly identical to that of untrained participants ($M = 4.74$, $SD = 1.39$).

Participants also rated how challenging they found the set of financial problems. For this variable, a 2 (Age Group) × 2 (Training Status) ANOVA revealed a main effect of training, $F(1,\ 53) = 6.12, p < .05$, with trained individuals ($M = 4.67$, $SD = 1.27$) finding the problems less challenging on an average than their untrained counterparts ($M = 5.44$, $SD = 1.05$). The mean score for younger individuals on this item ($M = 5.11$, $SD = 1.20$) did not differ significantly from that of older participants ($M = 4.97$, $SD = 1.27$), $F(1, 53) < 1$, and the two-way interaction also failed to obtain, $F(1, 53) < 1$. Furthermore, the Pearson correlation between how challenging participants found the task and mean concordance scores failed to reach significance, $r = .00$, *ns*.

Finally, we separately examined whether there were differences in how thorough individuals reported they were when solving the financial problems, and whether they reported being differentially interested in the task. The same 2 (Age Group) $\times$ 2 (Training Status) ANOVA format was again used to examine these two dependent measures. In both analyses neither main effects of age nor training emerged, and the two-way interactions also failed to reach significance (all effects $p > .05$, both ANOVAs). These two sets of findings suggest that the observed age- and training-related effects in concordance scores were not due to systematic group differences in task-specific levels of thoroughness or interest.

DISCUSSION

The results of this study provide clear support for the developmental script hypothesis proposed by Hershey et al. (1990). Across the entire sample there was a striking increase over trial-pairs in the percentage of common cues selected, and there was an increase over trial-pairs in the order in which those cues were processed. This form of behavioral rigidity (Calhoun & Hutchison, 1981) in complex problem solving situations could clearly be considered an adaptive strategy (Rosman, Lubatkin, & O'Neill, 1994) for dealing with large amounts of task-relevant cues. Moreover, it was shown in the present investigation that the strength of individuals' scripts (as measured by mean concordance scores) were significantly correlated with the quality of their solutions.

Abelson's (1981) bipartite definition of scriptedness was found to be an effective way to conceptualize and operationalize participants' processing activities. Both the information selection and processing consistency markers revealed strong general developmental effects over as few as six trials. In complex problem solving domains it is of adaptive significance to know (a) which cues should be attended to, and (b) to have a strategic plan for processing task information. Toward that end, the strength and richness of one's schema-based knowledge of the domain should be an important predictor of processing efficiency.

From a cognitive developmental perspective, the most interesting findings involved the effects associated with the age and training factors. Neither age nor training status was found to have an impact on the percentage of common cues selected over trials. Almost invariably, participants requested roughly the same set of information they selected on the previous problem, and the tendency to do so increased monotonically over trials. In contrast, both age group and training status were found to be related to the measure of processing consistency, as seen in the two-way interaction plotted in Figure 5. A striking effect of training was identified, with trained individuals showing greater processing consistency than their untrained counterparts. Old untrained participants, in particular, were shown to have low concordance scores relative to the other three groups. Moreover, a clear age-related effect was seen in the age group by repeated measures interaction for concordance scores (see Fig. 6). The difference between age groups was apparent by the third trial-pair, after which young individuals showed a marked increase in concordance scores, and old participants showed a near flat-line function. The results of this study stand to make a unique contribution to the cognitive literature because there exist relatively few experimental studies of scriptedness, and only a small handful of those that have been published consider how age or training influence the script acquisition process.

It is interesting to speculate as to why old untrained participants failed to fully develop a script to solve the problems. One possible explanation is that they lacked both the basic processing resources and the domain-specific knowledge needed to acquire a coherent solution sequence. The data suggest that knowledge acquired through training will provide a necessary foundation to process information in an efficient fashion (as witnessed by the lack of a difference in concordance scores among young and old trainees, see Fig. 5). Even when processing resources are limited (as presumably was the case with older trainees), a veridical mental model of the domain apparently provides sufficient support upon which a script can be formed.

A resource limitation explanation for the observed age differences in processing consistency is perhaps even more plausible when one considers the fact that think-aloud protocols were taken as part of the experimental procedure. That is, the process of thinking aloud can be quite taxing from a resource consumption standpoint (Ericcson & Simon, 1996), and it may have interfered with either the acquisition of a script or its execution. A methodological artifact of this type would be expected to have the most detrimental impact on individuals who had both limited resources to begin with, and weak mental models of the problem domain (i.e., old untrained individuals). Clearly, future studies are warranted that explore the impact of developmentally based resource limitations on complex problem solving performance.

The non-existent age effects in the Light and Anderson (1983) study and the small negative age effects reported by Hershey and Farrell (1999) suggest that prior knowledge can play an important role in script-based processing. Familiar scripts were used in both experiments (e.g., going grocery shopping; fixing a flat tire), and presumably, individuals were able to draw upon their prior knowledge while engaging in the memory and problem solving tasks. In the present experiment, the absence of age differences in processing consistency among trainees suggests that their newly acquired schematic knowledge helped to make the task (at least to some extent) familiar, and thus, reduce processing demands to the point where a script could be readily acquired. Why then was it the case that young untrained individuals were able to develop a consistent processing sequence over trials while older untrained individuals were not? One possible explanation is that processing resource limitations impaired the ability of older untrained adults to encode a high quality trace of the problem solving process. Alternatively, there could have been insufficient working memory or attentional resources available during script retrieval to fully coordinate a replication of previous solution sequences. Of course, the low levels of processing consistency among older untrained adults could have resulted from a combination of both encoding and retrieval deficits. Additional research will be required to determine the source of this performance deficit.

The self-report data regarding perceived task difficulty and strategy development also revealed interesting findings consistent with the script hypothesis. Task difficulty ratings were not found to differ as a function of either age or training status. From a developmental perspective, findings regarding the strategy development item proved more intriguing. Overall, participants indicated that they developed a strategy while solving the series of problems, and these perceptions were found to be unrelated to training status. However, age was related to perceived strategy development, a finding that is consistent with the age-related effect seen among the concordance scores shown in Figure 6. Specifically, the plot of the two-way (Age $\times$ Repeated Measures) interaction in that figure shows that by the fourth trial-pair, older participants' concordance scores were substantially lower than those of younger individuals. Therefore, the relatively low strategy development scores of older participants could reflect a metacognitive awareness that they had not developed hard and fast rules to process task information. Alternatively, it could be that older participants used more stringent criteria to evaluate whether they had developed hard and fast rules, particularly in light of the fact that when completing this item they were allowed to interpret the meaning of "strategy development" in light of their own task-specific experiences.

Limitations of the present research involve the exclusive use of an exceedingly complex investment task to assess script development, and the use of participants who were de facto selected on the basis of their intellectual ability (i.e., all were in college or had completed at least a bachelor's degree program). These considerations raise questions regarding the generalizability of the findings. Perhaps future studies could be designed which challenge individuals to solve problems that range from simple to complex. Such a design would allow for more precise estimates of the conditions under which script development is facilitated by pre-existing knowledge, and the conditions under which it is hampered. It would also be worth systematically examining the extent to which adults of various ages and with varying levels of intellectual abilities are differentially affected by varying levels of processing load.

Towards this end, in future studies the use of a dual task paradigm to manipulate task complexity and the inclusion of a more diverse group of participants could prove informative.

Another limitation of this study is that it is not possible to definitively conclude why, in certain instances, there was a lack of age-based performance differences (e.g., for common variables selected, or for the task difficulty item). Younger and older individuals could have selected similar sets of variables across problems, but for different reasons. Younger participants may have differentially relied on their basic processing abilities to select a consistent set of information (recalling specifically what they had considered on previous trials), whereas older individuals could have differentially relied on their more extensive declarative knowledge of the problem domain when making their selections. In terms of future research, we see the value in collecting markers of both domain-specific knowledge and processing abilities in order to be able to tease apart the unique contributions of each in the problem solving context.

Another potentially profitable future research direction would involve conducting a study in which participants are provided with incremental performance feedback as they solve a series of problems. Such a design would allow for an examination of how script development is affected by perceptions of performance. In fact, one could even provide individuals with false feedback (either positive or negative) in order to see how perceptions of solution quality influence the consistency of one's search. Of particular interest from a cognitive developmental perspective would be to examine how individuals' scripts change as a function of age, knowledge, and the type of feedback provided.

The findings from this study have important implications for both emerging theories of cognitive aging, and more applied efforts designed to train individuals to become efficient problem solvers. In a recent paper that outlined a set of pressing issues for cognitive aging theorists, Salthouse (1999) argued that investigators should focus their attention on whether there are interactions between age, process abilities (i.e., fluid abilities), and product aspects of cognition (i.e., domain-specific knowledge). The present line of work is consistent with that theoretical objective. The data from this experiment provide evidence that there is an interaction between age and task-specific knowledge when individuals solve complex problems, as seen in the measure of processing consistency. However, information regarding how each differentially contributes to information selection and search processes awaits further investigation.

From an applied perspective, the results of this study have revealed that rapid script acquisition is facilitated by domain-specific training. In the absence of training, it needs to be realized that it will take older adults longer to develop an internally consistent processing approach than younger individuals. Therefore, if the goal is to have individuals develop their problem solving skills to some criterion level, additional practice time on the task should be budgeted for older learners.

In summary, the goal of this study was to examine whether there was evidence to support the developmental script hypothesis. Data from the experiment provide clear support for the notion that individuals can develop strong problem solving scripts in as few as six trials. Importantly, however, there was evidence to indicate that the nature of script development was contingent upon individuals' age and level of domain-specific knowledge.

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