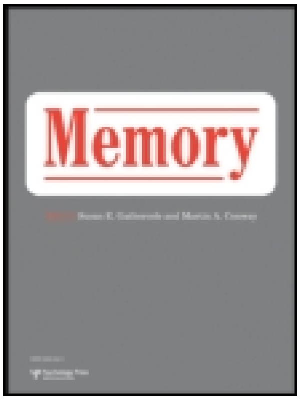

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Distance effects in memory for sequences: Evidence for estimation and scanning processes

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Distance effects in memory for sequences: Evidence for estimation and scanning processes

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The current study sought to uncover how temporal information is represented in our knowledge about routine events. In Experiment 1 we collected norming data on eight routines taken from Galambos (1983). In Experiment 2 participants were presented with two actions of varying distance from a routine and asked "Are the actions in the correct order?". We found that a number of variables interact with distance, including action position, routine familiarity, and experimental block. These data suggest that sometimes participants are faster when the actions are far apart in the routine, while at other times they are faster when actions are closer together, providing evidence for both distance and reverse-distance effects, respectively. A model is presented to help interpret these data in which temporal information for routine events is both: (1) coarsely coded, and processed by an estimation mechanism; and (2) represented serially, and processed by a scanning mechanism.

While our daily experiences lay the foundation for our knowledge of routine events, how that knowledge is represented and accessed is still in question. An important issue with regard to the memory for routine events is the representation of temporal information. When asked to give a description of a routine event, such as going to a restaurant, people are able not only to generate the important actions involved (e.g., ordering from the menu, eating the meal, etc.), but also to specify how the actions relate to one another in time (e.g., ordering the meal occurs before eating the meal). While it is clear that knowledge of the temporal structure of routine events is stored and available for subsequent retrieval, it is not yet clear what the organisation and processing of that temporal information is like.

One perspective on the temporal representation of actions within a routine is that information about the position of an action in a sequence is coded by inter-item associations between actions that are temporally adjacent (Ebenholtz, 1963; Young, 1962). Representative actions from a routine would then be organised according to when they take place in the routine, with earlier actions connected to later actions (see Figure 1a). If one is cued with an early action, the only way to access actions later in the routine is to pass through intermediate ones along the way. It is expected that if memory for routine events is organised by a sequential ordering of the constituent actions, then an action would be easier to access if one has already been exposed to another action that occurs close in time. This could be

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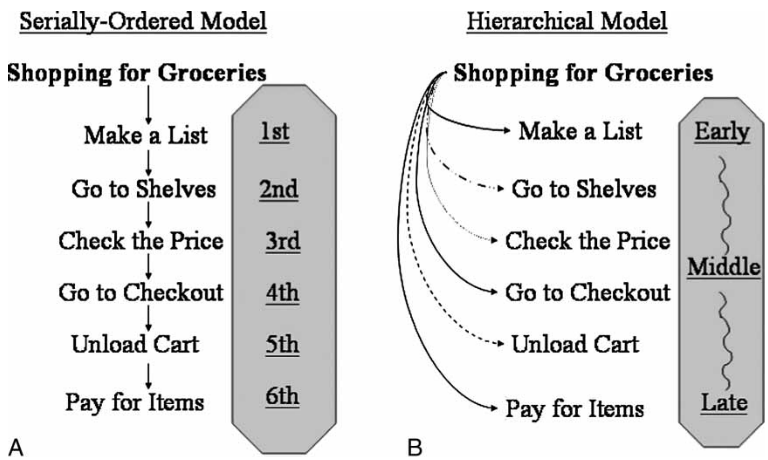

Figure 1. Comparison of a hierarchical model with a serially ordered model of routine memory. In the serially ordered model (a), actions are organised and accessed according to the order in which they take place in the routine. Temporal information for actions is coded according to the position of the action in the routine. In the hierarchical model (b), temporal information is coarsely coded. For example, the labels early, middle, and late could be assigned to the actions, but the actions are not organised or accessed temporally. A darker line would represent a stronger connection between the routine and the action.

measured as either a faster response time in judging the temporal relation between two actions that are close to one another in a script, or as some bias towards recalling the actions from scripts in a sequential order.

An alternative hypothesis is that temporal information is only coarsely coded with an action's general position. For example, actions could be classified as taking place early, midway, or later in a routine. Based on this model, coarse temporal codes become assigned to actions from a routine but do not influence the organisation of routine memory (i.e., the actions are not necessarily organised sequentially; see Figure 1b). According to this model, the actions are organised hierarchically, with ones that are most important and/or most frequently encountered in a specific routine being more strongly associated with the routine and easier to access (Black & Bower, 1980; Rumelhart, 1977). If this were the case, then different types of behavioural effects would be expected compared to a model based on inter-item associations. For example, given a task to decide which of two actions occurs earlier in a routine, participants would be faster when the actions occur farther apart. This ''distance effect'' would be due to the greater discriminability of the temporal codes for pairs of actions farther apart in the sequence (Banks, 1977; Moyer, 1973). Also, when asked to generate actions from a routine, participants would tend not to report the actions sequentially. Rather, they would list actions based on some other feature such as centrality, which would be exhibited as a tendency to generate the most important actions from the routine. While these two representational schemes are often pitted against each other, there is evidence that information for routine events is organised both temporally and by properties such as centrality.

Evidence for the hierarchical organisation of event memory was provided by Galambos and Rips (1982). In one experiment, participants were asked to decide which of two actions came either earlier or later in a routine. The distance between the actions was manipulated, such that for the routine of going to a restaurant, *sitting at the table vs paying the check* would have a greater distance than *looking at the menu vs ordering food*. Participants were faster to respond when there was greater distance between the pair of actions; this we call a distance effect. This was interpreted as evidence against a strict serial ordering of the actions in memory. Nottenburg and Shoben (1980) reported the same type of distance effect in an experiment with a similar task and materials. Galambos and Rips (1982) also used a number of other tasks to indicate that centrality, or the importance of an action to a routine, guides the organisation of event memory. For example, they showed that participants are faster to identify a single action or a pair of actions as belonging to a specific routine based on centrality rather than on the temporal position of the actions within the sequence.

Despite these findings that support a hierarchical organisation of routine memory, some work suggests that actions may be organised in memory by their temporal position in the routine.

Haberlandt and Bingham (1984) examined these two models by comparing actions presented in a forward order to those in a backward order. They found that participants were faster to categorise pairs of actions as belonging to a particular routine when presented in the forward order. This indicates that the processing of routines is facilitated when actions are presented in the order in which they take place in the routine, suggesting that a representation may exist that is organised temporally, with a forward ordering of actions in time. Galambos and Rips (1982) did not distinguish between forward and backward pairs in their analyses. It is possible that they might have found different results had they considered the direction of the actions along with distance. Since it may be difficult to scan backwards through a routine, their distance effect might have been more strongly influenced by the backward pairs than by the forward pairs. Therefore, the distance effect reported may not necessarily be indicative of a general processing strategy across all trial types.

Evidence from Bower, Black, and Turner (1979) and Barsalou and Sewell (1985) also suggests that routines can have multiple organisational schemes and that a serial ordering of actions is one way in which these routines are organised. In a series of experiments, Bower et al. (1979) showed that when asked to recall actions from a routine in the order presented, participants tended to recall them in sequential order even if they were presented in a random order. Likewise, Bower et al. found a reverse-distance effect, in that reading time was faster for pairs of actions from a routine when they were temporally closer. This suggests an organisation similar to that shown in Figure 1a, in which activation spreads between temporally adjacent actions. In an experiment by Barsalou and Sewell (1985), participants were given 20 seconds to generate as many actions as possible from a routine under different instructions. Participants were fastest when the actions were to be generated starting from the beginning and proceeding towards the end, and significantly slower to generate actions based on centrality. This suggests that actions from a routine could be organised temporally, thus facilitating sequential retrieval. An organisational scheme based on centrality would predict that participants are fastest in naming actions according to their importance in the script. Likewise, rather than showing an initial burst when generating items, as is seen when generating category exemplars, participants generated actions at a constant rate. These data provide evidence that participants are likely able to scan through a script one action at a time based on temporal order.

It is possible that the apparently discrepant results reported in the literature could point towards a more general organising principle for routine memory. Yet little work has been devoted to identifying specific variables that influence the way in which temporal information is retrieved from memory. Some of these variables can be inferred based on work by Foss and Bower (1986) and Franklin and Bower (1988). These two studies used a similar paradigm in which participants had to answer true–false statements about the order of actions from routines. Franklin and Bower (1988) showed that participants were faster when the items were closer together temporally within the routine (a reverse-distance effect), while Foss and Bower (1986) showed that participants were faster when the items were farther apart within the sequence (a distance effect). One important difference between these studies (as discussed by Zacks & Tversky, 2001) has to do with the amount of testing done with the material. Franklin and Bower (1988) tested participants repeatedly with the same material, which could serve to facilitate coding of the actions according to their specific temporal position in the routine. Therefore, during testing, participants could utilise this sequential organisation and, via a scanning procedure, be faster for statements closer together in time within the routine. In contrast, the distance effect found by Foss and Bower (1986) could then be the result of their participants having only coarsely coded temporal information about the available routines. These results suggest that certain variables, such as familiarity, may influence the type of distance effect. Additionally, different types of distance effects become important when testing between competing theories.

THE PRESENT STUDY

Taken together these studies provide evidence that event memory may be organised by different properties and, as such, multiple strategies may be engaged that utilise these multiple organisational schemes. The present study aimed to identify variables that influence whether memory for routines is: (1) serially ordered based on inter-item associations and accessed via a scanning mechanism; or (2) hierarchically organised and accessed via an estimation mechanism that processes coarse temporal information. The present studies utilised similar tasks and materials as Galambos and Rips (1982). An estimation mechanism would be evident by distance effects in which participants are faster to make a judgement when the actions are farther apart. A scanning process would be evident through reverse-distance effects in which participants are faster for items that are closer together within the sequence.

We focused on how the following variables interact with distance between actions:

- *Familiarity*. The familiarity of a routine (how familiar participants are with the routines before beginning the experiment) may influence the type of distance effects, so we included routines of high and low familiarity. Specifically, we expected that more specific temporal information would be available for routines of high familiarity, which would increase the chance of finding reverse-distance effects. In a similar fashion, we expected a distance effect for routines of low familiarity, because only coarsely coded temporal information would be available.
- *Practice.* The results of Franklin and Bower (1988) and Foss and Bower (1986) discussed above suggest that amount of exposure to the test stimuli may influence the type of distance effect. We examined trials from the first half (blocks 1 and 2) and second half (blocks 3 and 4) of the experiment to see if the distance effect changes as a function of participants becoming more familiar with the task and routines included. We expected distance effects for the first half of the experiment, and reverse-distance effects for the second half as participants become more exposed to the routines and constituent actions.
- *Stimulus position.* Whether the trial contains an action in the first or last position in the routine (an endpoint item), or contains only middle actions, could influence the type of distance effect. Because coarse temporal information from endpoint actions would likely be sufficient when making an order judgement, we expected trials containing endpoints to show distance effects. More fine-grained information would be necessary to discriminate between middle actions, so these items might exhibit reverse-distance effects.
- *Direction.* We were interested to see if differences would emerge for actions presented in a forward versus a backward order. Actions were presented side by side, and those trials in which the earlier action occurs on the left were labelled as forward trials, and trials in which the earlier action occurs on the right as backward trials. Haberlandt and Bingham (1984) indicated an advantage for actions presented in the forward direction. We expected that actions presented in the forward direction would be easier to scan and would produce reverse-distance effects, whereas actions presented in the backward direction might lead to distance effects. It should be noted that direction can also be thought of as "correctness". All forward trials are in the correct order and vice versa.

Experiment 1 was run to verify that the routines, constituent actions, and the order of these actions based on the norming study by Galambos (1983) are still applicable to the present college-aged sample. In Experiment 2 we presented participants with two actions from a routine and asked them "Are the items in the correct order?". This instruction varied from the Galambos and Rips (1982) instruction of "Choose the earlier/later action". We decided to probe memory for order with this more general "correct order" instruction, as the latter type of instruction may bias participants towards a more discriminative strategy.

EXPERIMENT 1

Method

Participants. A total of 40 participants were run in this experiment (26 female, 14 male, mean age = 20.9).

Stimuli. The stimuli were taken from Galambos (1983). We chose eight routines each consisting of 12 actions.

Procedure. Participants were first presented with the eight routines (see Table 1) and asked to rate the familiarity of the routines on a scale from 1 to 10, with 10 being very familiar and 1 not familiar at all. Then, for each of the eight routines

TABLE 1
Routines used, familiarity ratings, *SD*, and position rating *SD* as collected by Galambos (1982)

Header	*Familiarity*	*SD*	*Position rating SD*
Buying a Car	4.56	2.48	1.31
Going to Movies	9.06	1.43	0.95
Making New Clothes	4.50	3.42	0.63
Pitching a Tent	4.67	2.06	1.01
Playing Some Tennis	4.72	3.46	0.67
Shopping for Groceries	8.94	1.92	0.29
Starting a Car	9.00	1.19	0.86
Writing a Letter	9.06	1.21	1.03

participants were presented with the 12 actions in a random order, and were required to place the actions in the correct order by placing a number next to each of the actions. The order of routines was counterbalanced across the participants, and each participant saw a different random order of the 12 actions.

Results and discussion

In Tables 1 and 2 we present the mean familiarity ratings and standard deviations for each of the eight routines as reported by Galambos (1983) and the current study, respectively.

Also included in Table 2 is the average standard deviation associated with participants' position ratings for the 12 actions for each of the eight routines. A higher number means that there was greater discrepancy in participants' ratings of the order of the actions for the given routine. Table 3 presents the average position ratings and standard deviations for each of the actions for the eight routines.

A comparison of our norming data with those of Galambos (1983) (see Tables 1 and 2) indicates no significant difference for either familiarity ratings, $t(7) = 0.88$, $p = .41$, two-tailed, or the average standard deviation of position rating, $t(7) = 2.00$, $p = .09$, two-tailed. While there is a trend indicating that our participants have a slightly more difficult time putting the actions from these eight routines into the correct order, overall this difference is not statistically significant. Likewise participants' familiarity ratings did not significantly differ from Galambos (1983). Therefore, we proceeded with Experiment 2 knowing that participants are able to place the actions from the eight routines into the correct order and that the familiarity of the routines from Galambos (1983) are similarly rated by our sample of college-aged participants.

TABLE 2
Routines used, familiarity ratings, *SD*, and position rating *SD* as collected in Experiment 1

Header	*Familiarity*	*SD*	*Position rating SD*
Buying a Car	3.60	2.60	1.37
Going to Movies	8.44	0.88	0.88
Making New Clothes	2.49	2.52	0.96
Pitching a Tent	3.30	2.70	1.47
Playing Some Tennis	5.11	2.92	1.05
Shopping for Groceries	8.37	0.91	0.57
Starting a Car	8.21	1.61	1.48
Writing a Letter	6.78	2.33	1.33

EXPERIMENT 2

Method

Participants. A total of 22 participants were tested in this experiment (8 male, 14 female, mean age = 20.2).

Stimuli. The stimuli were taken from a study by Galambos (1983), which collected norms for everyday activities. We used eight routines, picking four of high familiarity (mean familiarity = 7.95, $SD = 0.78$) and four of low familiarity (mean familiarity = 3.62, $SD = 1.09$; see Table 1 for a list of routines used). Each of the routines consisted of 12 actions. In the study by Galmbos and Rips (1982), three distances of two, five, and eight were used. We used an equal number of action pairs that were either four or seven steps apart. Since it was only possible to have five of the seven-step pairs, our stimulus set was limited to 10 unique pairs of actions from each of the eight routines, yielding a total of 80 trials. The direction of the actions was counterbalanced across participants such that half of the participants saw the same pair of actions, but on the opposite side of the screen. A total of 20 practice trials were taken from five additional routines (washing your hair, sending a gift, brewing some tea, throwing a party, and taking a photograph). Two four-step, and two seven-step actions were chosen from each of these routines.

Procedure. The sequence of events on a trial was as follows: Participants were presented with a fixation point for 1500 ms. The name of the routine, then appeared on the screen for 1000 ms, followed by the two actions from the routine, until a response was detected. The actions were

TABLE 3
Actions, mean position ratings, *SD* for each routine, as collected by Galambos (1983) and in Experiment 1

	Experiment 1 sequence		*Galambos (1983) sequence*	
	Mean	*SD*	*Mean*	*SD*
Making New Clothes				
Select the Pattern	1.46	0.87	1.19	0.75
Buy the Material	1.98	0.52	1.94	0.25
Buy the Thread	2.66	0.85	2.94	0.25
Lay out Fabric	4.27	0.67	4.00	0.37
Pin on Fabric	6.46	1.55	5.50	0.63
Cut the Material	5.22	1.01	5.50	0.63
Thread the Needle	6.51	0.87	7.06	0.57
Sew Pieces Together	7.88	0.68	8.13	0.50
Try on Garment	10.95	1.16	9.69	1.08
Put Buttons on	9.56	0.87	9.88	1.03
Adjust the Hems	9.95	1.22	10.37	0.96
Iron the Garment	11.10	1.22	11.81	0.54
Shopping for Groceries				
Make a List	1.00	0.00	1.00	0.00
Enter the Store	2.09	0.30	2.00	0.00
Get a Cart	2.90	0.30	3.00	0.00
Go to Shelves	4.00	0.00	4.00	0.00
Reach for Items	5.46	0.50	5.31	0.48
Check the Price	5.58	0.77	5.94	1.18
Load the Cart	7.34	1.25	6.94	0.25
Go to Checkout	8.07	0.51	8.06	0.44
Pick Shortest Line	8.804	0.40	8.81	0.40
Unload the Cart	10.39	0.77	9.94	0.25
Pay for Items	10.97	0.79	11.06	0.25
Load up Bag	11.29	1.28	11.94	0.25
Playing Some Tennis				
Reserve a Court	1.61	0.89	1.38	0.62
Get the Equipment	1.68	0.61	1.69	0.48
Go to Courts	3.05	1.24	2.94	0.25
Choose a Side	4.24	0.83	4.06	0.25
Warm up Volley	4.98	0.57	5.19	1.05
Start a Game	6.05	0.92	6.00	0.37
Serve the Ball	7.34	1.09	7.13	0.34
Run for Shot	8.68	0.88	8.56	0.89
Make the Return	9.15	0.99	8.81	0.54
Keep the Score	9.85	1.33	9.94	1.44
Retrieve the Balls	9.73	2.42	10.50	1.41
Congratulate the Opponent	11.68	0.88	11.81	0.40
Starting a Car				
Unlock the Door	1.10	0.30	1.06	0.25
Open the Door	2.20	1.12	1.94	0.25
Get into Auto	3.80	2.32	3.00	0.00
Adjust the Seat	4.80	1.35	4.13	0.50
Lock Seat Belts	5.95	1.50	5.37	0.62
Key in Ignition	5.61	1.55	6.44	1.03
Check the Mirrors	7.05	2.06	7.19	1.97
Shift into Neutral	8.66	1.09	8.06	1.61
Turn the Key	6.93	1.25	8.63	0.81
Check the Traffic	10.24	2.33	10.81	0.75
Depress the Accelerator	10.95	1.99	10.37	1.63
Shift into Drive	10.27	0.98	11.00	0.89
Going to Movies				
Check the Newspaper	1.27	0.63	1.31	0.70
Pick a Show	1.85	0.48	2.13	0.34
Find out time	2.98	0.35	3.25	0.45

Table 3 (*Continued*)

	Experiment 1 sequence		*Galambos (1983) sequence*	
	Mean	*SD*	*Mean*	*SD*
Go to Theatre	4.20	0.64	4.38	0.62
Stand in Line	5.95	1.18	5.37	0.72
Buy the Tickets	6.32	0.91	6.38	0.72
Enter the Theatre	6.49	1.72	7.31	1.25
Give Usher Tickets	8.49	0.78	8.00	0.73
Watch the Previews	10.51	1.86	8.50	4.34
Buy Some Popcorn	8.02	0.96	9.38	0.96
Find a Seat	9.88	0.87	10.00	0.63
Leave the Theatre	11.98	0.16	12.00	0.00
Writing a Letter				
Get some Paper	1.02	0.16	1.13	0.34
Put on Date	3.02	1.60	2.63	1.09
Put on Salutation	3.88	2.14	3.31	0.70
Compose the Message	3.66	0.73	3.69	1.01
Sign Your Name	5.05	0.71	5.31	0.60
Put on Postscript	7.61	2.71	6.25	1.65
Get an Envelope	6.05	2.25	6.25	2.32
Fold the Paper	7.29	1.31	8.13	0.89
Address the Envelope	9.49	1.33	9.31	1.40
Put Into Envelope	8.78	1.08	9.63	0.72
Seal the Envelope	10.34	1.04	10.81	0.75
Put on Stamp	11.49	0.98	11.56	0.89
Pitching a Tent				
Find Good Location	1.02	0.16	1.00	0.00
Prepare the Site	2.32	1.59	2.00	0.00
Unpack the Canvas	3.44	1.03	3.33	0.72
Get the Stakes	5.34	2.10	4.93	1.16
Unfold the Canvas	4.95	1.58	5.67	1.54
Get out Ropes	6.34	1.89	5.67	1.59
Pound Stakes in	7.41	1.97	7.07	1.83
Put up Poles	6.93	1.40	7.07	1.71
Raise the Top	9.02	1.64	8.93	1.03
Tighten the Ropes	9.51	1.29	9.67	0.98
Check for Stability	10.88	1.72	11.07	0.70
Tie Back Flap	10.76	1.32	11.60	0.83
Buying a Car				
Look at Advertisements	1.24	0.43	1.06	0.25
Select the Model	2.32	0.82	2.44	1.03
Look at Engine	4.15	1.57	3.25	0.45
Take Test Drive	3.95	1.00	4.13	0.72
Bargain About Price	5.59	0.92	5.31	0.60
Arrange the Financing	5.80	1.66	6.56	1.67
Sign Sales Contract	7.83	1.07	7.75	1.48
Get Temporary Licence	7.39	3.51	8.63	3.12
Pay the Money	9.12	1.40	9.06	1.39
Get Title Transferred	9.02	1.49	9.13	1.45
Get the Keys	9.76	2.07	9.13	2.71
Drive it Home	11.85	0.48	11.56	0.89

presented side by side. Participants were instructed to press the "1" key with their left hand if the items were in the correct order, meaning that the item on the left preceded the item on the right within the routine, and the "0" key with their right hand if they were in the incorrect order. For example, given the header *Going to a Restaurant*, two actions could be *Read the Menu* on the left and *Tip the Waiter* on the right. In this case, the participant would respond "correct". Participants were instructed to respond as quickly as possible while maintaining a high level of accuracy. Before the experimental trials began, participants went through 20 practice trials to ensure that they understood the task. The experiment was divided into four blocks of 20 trials with a rest between blocks.

Results and discussion

Data were trimmed on an individual-participant basis for trials that exceeded 1.5 times the interquartile range. This resulted in a loss of 4.3% of the data. Only correct trials were analysed. Table 4 displays mean reaction time and accuracy for each of the variables of interest: distance, familiarity, direction, position, block.

Accuracy data. While we have included accuracy data in the table, we were primarily interested in reaction times, since the speed of processing should be more informative regarding distance effects. Therefore we performed analyses for reaction times only. Since it appeared as though a possible speed–accuracy trade-off might have been occurring for the distance variable (overall participants were faster in the four-step compared to seven-step trials, but more accurate in the seven-step compared to four-step trials), the correlation between errors and reaction times was analysed, producing a slightly positive correlation ($r = .13$, $p = 0.01$). This indicates that participants were slower on error trials and not trading speed for accuracy.

Reaction time data: Main effects. There was no significant main effect of the distance manipulation, $F(1, 21) = 0.443$, $p = .519$. Overall participants were only slightly faster (by 5 ms) when the actions were closer together. There was a main effect of familiarity, $F(1, 21) = 5.483$, $p = .029$, with the mean reaction time 89 ms faster for actions that were taken from more familiar routines. There was no significant difference in reaction time to pairs of actions that contained endpoint items vs middle items, $F(1, 21) = 0.454$, $p = .509$. There was a main effect of direction, $F(1, 21) = 5.483$, $p < .001$, with the mean reaction time 90 ms faster for actions that were in the forward direction (i.e., the correct order). There was no significant effect of block, $F(1, 21) = 2.138$, $p = .159$.

TABLE 4
Mean reaction time (ms), *SD*, and accuracy for each variable of interest

	RT	*SD*	*Accuracy*
Distance			
Four	1900	252	0.842
Seven	1905	482	0.892
Familiarity			
High	1858	473	0.876
Low	1947	530	0.858
Direction			
Forward	1864	490	0.824
Backward	1951	496	0.920
Block			
First Half	1872	508	0.859
Second Half	1933	497	0.875
Position			
Middle	1909	502	0.857
Endpoints	1889	515	0.883

Interactions: Position × distance. There was a significant two-way interaction between position and distance, $F(1, 21) = 10.635$, $p = .004$ (see Figure 2). For trials containing middle items, participants were faster when the actions were closer together, $F(1, 21) = 3.825$, $p = .064$, showing a marginally significant reverse-distance effect. For trials with endpoint items, participants were faster when actions were farther apart, $F(1, 21) = 7.055$, $p = .015$, showing distance effects.

Familiarity × distance. Likewise there was a significant interaction between familiarity and distance, $F(1, 21) = 12.6$, $p = .002$ (see Figure 3). Reverse-distance effects were seen for routines of high familiarity, $F(1, 21) = 7.089$, $p = .015$, and distance effects were seen for those routines of low familiarity, $F(1, 21) = 5.558$, $p = .028$.

Block × distance. There was an interaction between block and distance, $F(1, 21) = 8.975$ $p = .007$ (see Figure 4), with participants showing a trend towards reverse-distance effects in the second half, $F(1, 21) = 3.568$, $p = .073$, and showing a distance effect for the first half, $F(1, 21) = 5.512$, $p = .029$.

Direction × distance. There was only a trend towards an interaction between direction and distance, $F(1, 21) = 2.618$, $p = .121$. This implies no significant relation between the actions being in a forward or backward order and the distance effects seen.

The present results failed to find an overall distance effect like that reported by Galambos and Rips (1982). Rather, the results of the present experiment suggest that distance effects are contingent on a number of variables. First, whether a trial contained an endpoint or not had an effect

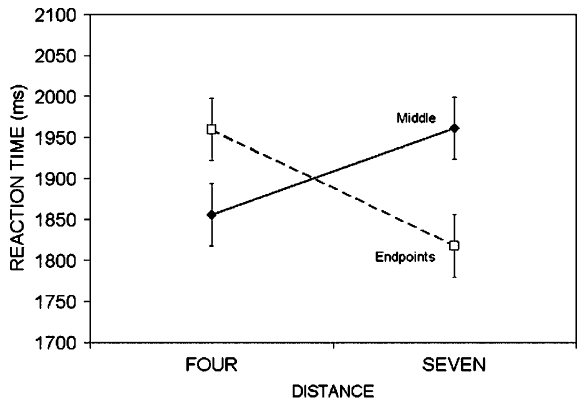

Figure 2. The interactions of position and distance. Error bars displayed are 1 SE.

on the type of distance effect. When participants encountered an endpoint item they were faster when the other action was farther away within the routine (a distance effect). This implicates an estimation strategy for trials with endpoint items rather than a serial search through the routine. In contrast, for middle items, participants were faster when the actions were closer together temporally in the routine (a reverse-distance effect), which implicates a scanning strategy. These distance effects were also influenced by the block of the experiment. Participants showed distance effects for the first half of the experiment and reverse-distance effects for the second half of the experiment. The distance by familiarity interaction demonstrates that participants are estimating for low-familiarity routines and scanning for high-familiarity routines. While the difference between our ‘‘correct order’’ instruction and Galambos and Rips' (1982) ‘‘choose the earlier/later action'' instruction may account for some of the differences between our results, it is possible that had Galambos and Rips (1982) investigated the same variables as in the present study (i.e., stimulus position, routine familiarity, and experiment block), similar interactions with distance might have emerged.

These results support the notion that it is possible to obtain reverse-distance effects. This suggests that besides the coarse coding of temporal information, memory for everyday routines is also represented serially according to inter-item associations, and that participants are able to scan through this representation.

GENERAL DISCUSSION

Nottenburg and Shoben (1980) and Galambos and Rips (1982) showed that distance effects occur in sequencing tasks of routine memory. These distance effects have been taken as support for a hierarchical model of routine memory (see Figure 1b). The results of the present experiments differ from these studies in finding evidence that participants sometimes find it easier to compare actions that are closer together within the routine. This reverse-distance effect implies a serial search or scanning mechanism in addition to an estimation mechanism likely responsible for the distance

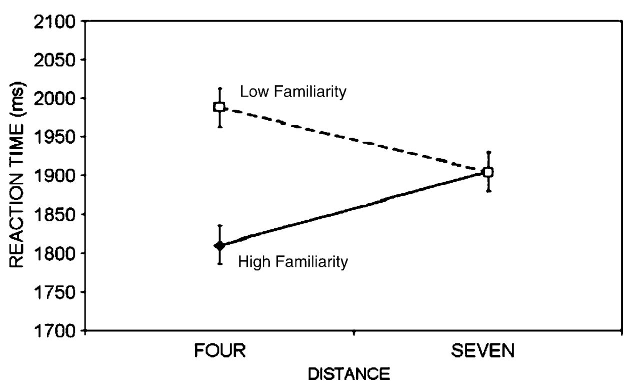

Figure 3. The interactions of familiarity and distance. Error bars displayed are 1 SE.

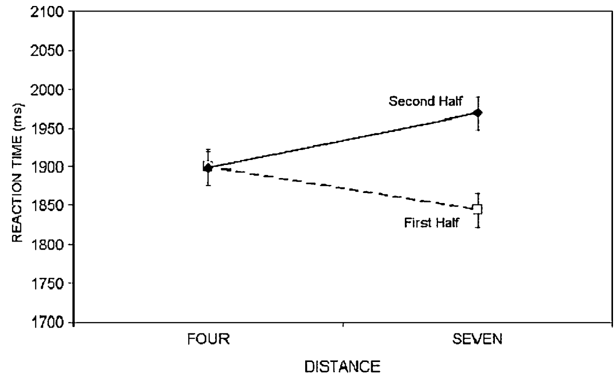

Figure 4. The interactions of block and distance. Error bars displayed are 1 SE.

effects. The variables that influence the type of distance effects are position, familiarity, and experimental block.

These findings have a number of implications for how memory for everyday routines is organised, as well as how that information is accessed when participants make decisions about the order of actions in a routine. Figure 1a provides one framework for describing this organisation. Under this model, routines are represented as a set of actions that are organised sequentially starting from the beginning of the routines. This model would explain the reverse-distance effects because actions that are close to one another should be easier to access. However, this model alone cannot account for both scanning and estimation effects. The implication of the distance effect is that events from a routine are not simply coded by inter-item association. There must be some additional types of temporal codes that allow for a faster comparison when there is greater temporal distance and hence greater discriminability between actions.

Figure 5 shows a hybrid of the hierarchical and serial-ordered models of routine memory that could help explain the results of the present experiments. According to this model, temporal information from routines is represented both hierarchically and serially. The hierarchical representation consists of temporal codes that are initially coarse and become more specific at lower levels. When participants have sufficient information to make the comparison (i.e., each of the actions has a distinct code), a decision is made. This explains why participants are sometimes faster when actions are farther apart. Accessing more fine-grained temporal information takes time because that information is available only

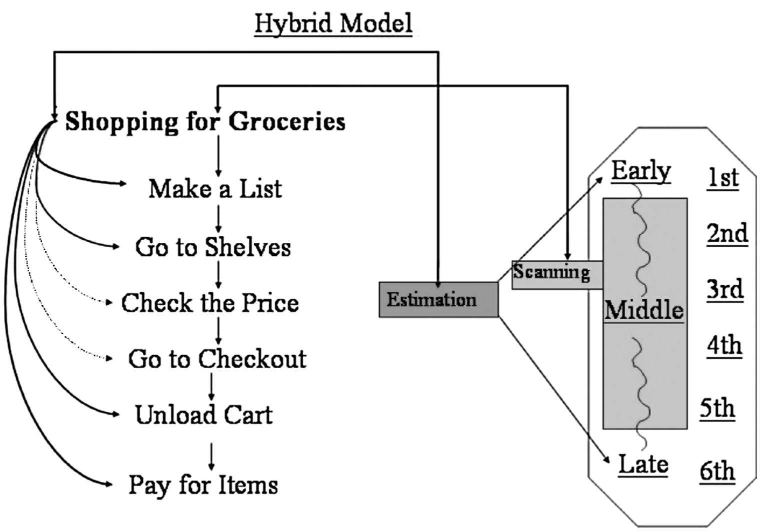

Figure 5. A hybrid model of routine memory. According to this model, temporal information is coded both by position and by coarse codes. Scanning occurs for middle items and for highly familiar routines, and makes use of positional information. Estimation occurs for endpoint items and less familiar routines using coarse codes.

at lower levels. Information about routines can also be coded such that each action is uniquely coded by its temporal relation to other adjacent items in the routine. This information is accessed through a scanning mechanism that goes through the actions serially from early to later. Under this mechanism participants would be faster when actions are closer together in time.

Together, the results from this study support the assumption that there are multiple organisational schemes and mechanisms for accessing temporal information. One effect that supports this assumption is the significant interaction of position by distance. This interaction implies that participants are scanning for the trials with only middle actions, and estimating for trials containing endpoint actions. This suggests that on all trials, participants are making use of coarse temporal information. The endpoint actions are distinctly tagged as beginning or end items and have a special status. When an endpoint action is encountered, participants use an estimation mechanism and are facilitated by the greater discriminability between distant actions.

In trials with middle actions, the actions are all coded as ''middle items'', and thus there would be no benefit from using this coarse-coded information. Assuming that more fine-grained temporal position information is available for the routine, a scanning mechanism could be engaged starting from the first action presented. Since we found similar distance effects on backward trials, it is plausible that participants must first locate the earlier item and then scan forward, which would take longer on backward trials.

The two other variables that interact with distance, familiarity, and block, can also be understood in the context of the proposed model. Because participants see only 10 trials taken from each of the eight routines, it is likely that over the course of the experiment, specific position information becomes more available. As Zacks and Tversky (2001) suggest, greater practice with the routine could result in scanning through the routine. This would explain why, in the second half of the experiment, participants are more likely to use a scanning strategy. The interaction of distance and familiarity could be due to the fact that routines with which participants are more familiar before beginning the experiment are more likely to be represented by specific position information. The low-familiarity routines are more likely to be coarsely coded.

This hybrid model is similar to the representation of scripts discussed by Abbott, Black, and Smith (1985). Based on participants' inferences while reading descriptions of various routine events, Abbot et al. (1985) developed a model in which everyday routines are represented both hierarchically and serially. In their model each routine is organised hierarchically, in that there is a representation of the routine name (e.g., going to a restaurant), various scene headers (e.g., enter, order, etc.), as well as the actions within these scenes (e.g., open door, go to table, sit down). In addition to this hierarchical arrangement, each of the scene headers and actions within the scenes are connected serially. Since the various scene headers take place at discrete times in the routine, these likely have distinct coarse codes, i.e., early, middle, and late. This would lead to different predictions when comparing our hybrid model and the model of Abbott et al. (1985). Their model predicts reverse-distance effects when comparing scene headers, since the scene headers are proposed to be organised serially, whereas our data suggest that scene headers have distinct coarse codes and therefore would be processed by an estimation mechanism yielding distance effects.

Although not much recent work has been done studying memory for routines, a current study by Dean, Dewhurst, Morris, and Whittaker (2005) investigated mental representations underlying judgements of symbolic distance tasks of the sort studied by Moyer and Landauer (1967). This study provides further evidence that commonly found distance effects across a range of comparison types need not require the generation of an image, since the distance effects remained intact after selective spatial and visual interference. The present work is consistent with these findings, in that it is unlikely that our distance effects are due to participants using an image of the actions within the routine. On the other hand, the reverse-distance effects may reflect a type of mental simulation of actions from a routine. This is consistent with current work on the topic of mental simulation, which suggests that understanding a description of an action involves a mental simulation of the action (Goldman, 2002; Hesslow, 2002).

Other research in the domain of number processing also relates to the present study. For example, work by Dehaene, Dupoux, and Mehler (1990) suggests that number comparison takes place by holistic processing of numbers on an analogue number line. This is applicable to the present study in which distance effects emerge from an estimation mechanism working with coarsely coded information. It is not yet clear if there is an analogue to the reverse-distance effects seen in the present experiment, although a recent study by Turconi, Campbell, and Seron (2006) suggests that different distance effects can be obtained in a number comparison task depending on whether the instruction focuses on order or magnitude.

While our study describes aspects of memory for routines *across* routines as a whole, much of the current work in this domain focuses on a finer-level discrimination *within* routines by studying event structure perception (e.g., see Zacks, Tversky, & Iyer, 2001). This line of research suggests that routine events are organised hierarchically, similar to the model proposed by Abbot et al. (1985) discussed previously. By analysing routines from this perspective, the work on event structure makes contact with a number of domains including language processing, memory, planning, and action, all of which are thought to share a similar hierarchical structure (Zacks & Tversky, 2001). While we find evidence for different coding and retrieval processes across routines as a whole, the results do not directly offer insight into the above hierarchical models. This is largely due to the fact that the stimuli used in the present study (from Galambos & Rips, 1982) were constructed to look at distance across entire routines, not taking into account the lower-level structure suggested by the hierarchical models.

Even though our study does not provide information about the sub-structure of routines, the present work contributes to our gross knowledge of memory for routines and could inform research on the representation and processing of order information in memory. For example, in the domain of working memory, Marshuetz and colleagues (Marshuetz, 2005; Marshuetz, Reuter-Lorenz, Smith, Jonides, & Noll, 2006; Marshuetz, Smith, Jonides, DeGutis, & Chenevert, 2000) have studied how order information is represented. In their task, participants were shown five letters vertically on the screen for a brief period of time, followed by a delay, then were probed with two of the letters. Participants were required to decide if the letters were in the correct order or not. Results revealed distance effects, such that participants were faster to make a decision when the letters were farther apart in the sequence. Since we also know that participants can scan through information in working memory, as evidenced by performance on forward and backward span tasks (for a review see Lewandowsky & Li, 1994), we now have evidence for both distance and reverse-distance effects in tasks that tap working memory for order information. It is possible that some of the variables discussed in this paper, including familiarity, practice, and the occurrence of endpoint items, could also play a role in the type of strategy participants use in these working memory tasks.

In addition, previous research has demonstrated that frontal patients have a deficit in sequencing information. For instance, given an everyday routine such as ‘‘going to a restaurant’’ frontal patients can name numerous actions that take place in the routine, but have difficulty in arranging the items in the correct temporal sequence (Sirigu et al., 1996). The present results dissociating distance and reverse-distance effects in order judgements could be useful in understanding the specific nature of this deficit as well as the neural mechanisms of order processing in healthy populations. While a number of neuroimaging studies in different domains (Dehaene, Piazza, Pinel, & Cohen, 2003; Marshuetz et al., 2000; Pinel, Dehaene, Riviere, & Le Bihan, 2001; Pinel et al., 1999; Pinel, Piazza, Le Bihan, & Dehaene, 2004) suggest that distance effects are mediated by the parietal cortex, there are no comparable brain-imaging data for reverse-distance effects. This is probably largely due to the scarcity of these effects in the literature. The significant reverse-distance effects from the present study make the task and manipulations used here a good candidate for investigating these aspects of order memory.

Conclusions

By finding evidence for distance and reverse-distance effects, the present study supports the idea that temporal information for routines is represented both serially, coded by inter-item associations, and hierarchically, based on coarse temporal codes. We have shown that participants tend to scan through the serial ordered representation for trials with middle items, for highly familiar routines, and for the second half of the experiment. An estimation mechanism makes use of the coarse codes and was seen for trials with endpoint items, for less familiar routines, and for the first half of the experiment.

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