Extension of a theory of predictive behavior in young children to the effects of intertrial interval duration [1]

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Twenty-five 4- and 5-year-old children predicted the next event in a 100-trial single alternation sequence. Each child received a different 50:50 random sequence of long and short intertrial interval durations. A model based on a theory emphasizing attention and short term memory processes gave a detailed quantitative description of the data. Transition relative frequencies across long and short intertrial intervals were interpreted theoretically as revealing greater guessing rates following long intervals, thus confirming the hypothesized role of a fallible short term memory subject to decay or interference effects.

Assume that a young child's prediction of the next event in a single alternation sequence passes a trace t_r of that predictive response (PR) to a short-term memory store which holds only the most recently passed trace. The next event may elicit attending to and encoding of that event, passing an event trace t_e to the store and removing the t_r. At any time a Distractor may pass a null trace t_0 to the Store. Finally, occurrence of the cue to make the next PR transfers the Store's contents to a Generator which applies a transformation rule to t_r or t_e and a guessing rule to t_0. The information in the Generator then passes to a Predictor which produces the PR.

The Attender and Encoder are both included since behavioral evidence suggests that young children can attend to an event without encoding it. The notion of a Generator with rules permits extension of the theory to prediction of other recurrent, noncontingent, or conditional frequency event schedules.

Assume Generator rules such that transfer of the trace of one PR results in the Predictor emitting an alternate PR, transfer of an event trace results in prediction of the alternate event, and transfer of t_0 results in unbiased, random guessing. Then, if α, β, and γ are respectively the constant probabilities that a t_e, t_r, and t_0 are passed to the Generator, the sequence of correct responses and errors will be a two-state first order Markov chain with stationary transition probabilities $p_{cc} = 1 - \gamma/2$, $p_{ce} = \gamma/2$, $p_{ec} = \alpha + \gamma/2$, and $p_{ee} = \beta + \gamma/2$, where p_{ij} is the conditional probability of a response of type j on trial $n+1$ given a response of type i on trial n (Bogartz, 1966).

This model applies well to prediction of a single alternation sequence by preschool children (Bogartz, 1966). Extension of the theory to varying intertrial interval durations and a test of the extension will now be given.

Table 1. Mean Performance Curve in 20-Trial Blocks

Block	1	2	3	4	5
Obs.	.796	.788	.788	.754	.712
Pred A	.751	.758	.758	.758	.758
Pred G	.758	.770	.770	.770	.770

If t_0 is any content of the memory other than a t_r or t_e, it is natural from either an interference or a decay point of view to assume that the longer the intertrial interval (ITI), the greater the probability that a t_0 will enter the store. Consider the case where two ITIs, long (L) and short (S), are presented in a 50:50 random sequence. There will be two sets of transition probabilities, one for each interval. That is, we obtain the matrices

$$
\begin{array}{c|cc}
 & c_{n+1} & e_{n+1} \\
\hline
c_n + L & 1 - \gamma_L/2 & \gamma_L/2 \\
e_n + L & \alpha_L + \gamma_L/2 & \beta_L + \gamma_L/2
\end{array}
\qquad
\begin{array}{c|cc}
 & c_{n+1} & e_{n+1} \\
\hline
c_n + S & 1 - \gamma_S/2 & \gamma_S/2 \\
e_n + S & \alpha_S + \gamma_S/2 & \beta_S + \gamma_S/2
\end{array}
$$

and

wherein, as before, α_k, β_k, and γ_k ($k = L, S$) are the probabilities of a t_e, t_r, and t_0 being passed to the generator following an ITI of type k.

These assumptions and the 50:50 random sequence of L and S ITIs imply that the sequence of correct responses and errors will be a two-state Markov chain with transition probabilities $p_{ij} = (p_{ijL} + p_{ijS})/2$, where p_{ijL} and p_{ijS} are the corresponding entries in the displayed transition matrices. Thus the data can be initially analyzed without consideration of the ITI variation, providing a test of the Markov chain model for alternation prediction. Also, sensitivity to variation in ITI duration can be assessed using the observed transition relative frequencies corresponding to the matrices above. Finally, a new set of sequential statistics, described below, can be compared with predicted values, testing the detailed applicability of the extension to ITI variation.

Table 2. Relative Frequency of 3-Tuples

3-Tuple	ccc	cce	cec	cee	ecc	ece	eec	eee
Obs.	.530	.107	.085	.046	.107	.026	.046	.053
Pred A	.529	.103	.080	.048	.109	.026	.051	.055
Pred G	.523	.109	.076	.056	.111	.023	.057	.042

Method

The Ss were 25 four and five year old preschool children. Each was taken to an experimental room and seated at a table, opposite E. On the table was a stack of 102 4 x 6 file cards concealed behind a small black box which could hold the entire stack. Centered on each card was a 1.5 x 2.0 in. rectangular patch of red and green tape. The colors in the stack alternated (RGRG... or GRGR...). The S was shown the first two cards in the stack, one after the other, after being asked to name the colors on the two cards. Following correct naming of the two colors, a 6 V buzzer was sounded briefly and the child was told that each time he heard the buzzer he was to guess quickly the next color in the stack.

On each of 100 trials, following each buzz, S made his prediction, E removed the top card from the stack, turned it color side up in front of S for about 1 sec, and then placed it color side down in the box. The buzzer sounded for .3 sec every 8 sec, except when the E depressed a foot switch which opened the buzzer circuit. If this occurred, the interbuzz interval was increased from 7.7 sec to 15.7 sec. A different random sequence of long and short intervals was used with each child; thus, approximately half the intervals were long and half short.

Results

The initial analyses, which do not involve the ITI variation, are presented in Tables 1, 2, and 3. The observed statistics are averaged individual values. The $Pred_G$ values were obtained by using one set of parameters for the entire group of Ss. The $Pred_A$ values are the averages of the predicted values obtained with individual parameter estimation for each S. Table 1 shows the mean relative frequency of correct responses in successive blocks of 20 trials. Table 2 shows the relative frequencies with which the eight possible 3-tuples occurred in the 25 100-trial protocols. Table 3 shows the observed and predicted mean values of r_j, the number of error runs of length j, and C_k, the number of joint occurrences of two correct responses k trials apart. These results not only replicate the detailed fit of this model

Table 4. Observed and Predicted Relative Frequency of the 3, 2-Tuple

3,2-Tuple	Obs.	$Pred_A$	$Pred_G$	3,2-Tuple	Obs.	$Pred_A$	$Pred_G$
c S c S c	.156	.166	.164	c L c S c	.137	.133	.130
c S c L c	.123	.133	.130	c L c L c	.114	.108	.103
c S c S e	.016	.012	.013	c L c S e	.006	.010	.010
c S c L e	.054	.045	.047	c L c L e	.031	.034	.037
c S e S c	.009	.009	.008	c L e S c	.032	.030	.028
c S e L c	.011	.009	.008	c L e L c	.033	.029	.030
c S e S e	.004	.005	.006	c L e S e	.018	.019	.023
c S e L e	.004	.005	.006	c L e L e	.021	.020	.021
e S c S c	.025	.030	.030	e L c S c	.030	.030	.032
e S c L c	.027	.022	.024	e L c L c	.025	.023	.025
e S c S e	.003	.003	.002	e L c S e	.004	.003	.003
e S c L e	.011	.010	.009	e L c L e	.009	.009	.009
e S e S c	.011	.011	.014	e L e S c	.013	.013	.013
e S e L c	.011	.013	.015	e L e L c	.011	.013	.014
e S e S e	.016	.015	.012	e L e S e	.014	.013	.011
e S e L e	.014	.013	.011	e L e L e	.008	.013	.010

presented in a previous report, but yield values of the statistics surprisingly close to those found in that previous study (Bogartz, 1966).

To evaluate the ITI effects, the relative frequencies of transitions across L and S intervals were obtained. These were

	c_{n+1}	e_{n+1}
$c_n + L$	.734	.266
$e_n + L$	.594	.406

and

	c_{n+1}	e_{n+1}
$c_n + S$	.926	.074
$e_n + S$	.555	.445

Recalling the theoretical matrices, we estimate the group mean probability of a t_0 being passed to the generator after a long ITI by $2p_{ceL} = .532$ and the corresponding value for a short ITI by $2p_{ceS} = .148$. Thus, the expected effects of the ITI variation on the parameter reflecting the guessing probability were obtained, indicating that guessing increases with greater opportunity for trace decay or interference to occur.

To further evaluate the fit of the extended model, the observed and predicted mean relative frequencies of the 32 possible 3, 2-tuples were obtained (Table 4). A 3,2-tuple is defined as the occurrence of a specified 3-tuple of responses on three consecutive trials in conjunction with a given pair of ITIs separating the three responses. The results in Table 4 provide additional evidence supporting the extension of the theory to variation in the ITI.

References

Bogartz, R. S. Test of a theory of predictive behavior in young children. *Psychon. Sci.*, 1966, 4, 433-434.

Note

Table 3. Observed and Predicted Mean Values of r_j, the Number of Error Runs of Length j, and C_k, the Number of Joint Occurrences of Two Correct Responses k Trials Apart

	$Pred_G$	$Pred_A$	Obs.		$Pred_G$	$Pred_A$	Obs.
r_1	7.78	8.28	8.88	C_1	62.90	63.17	63.00
r_2	3.28	2.67	2.00	C_2	58.99	60.25	60.32
r_3	1.38	1.07	1.40	C_3	57.56	58.82	58.12
r_4	.58	.50	.68	C_4	56.76	57.87	57.96
r_5	.25	.26	.12	C_5	56.11	57.11	56.84