CONDITIONING OF WITHIN-TRIAL PATTERNS OF KEY PECKING IN PIGEONS¹

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The possibility of conditioning systematic patterns of responding during brief discrete trials was studied by requiring hungry pigeons to key peck and then pause or to pause and then key peck in order to gain access to food. These schedules were highly effective in promoting decelerated and accelerated rates of responding, respectively, within individual trials; indeed, performance was quite similar to that observed when explicit external stimuli were correlated with "peck" and "pause" portions of the daily trials. Finally, schedules of reinforcement that did not selectively reinforce peck-pause or pause-peck patterns neither generated these patterns nor maintained them at the previous high levels. The results, therefore, confirm Shimp's (1976) proposal that organized groupings of discrete responses may function as operants—even in the absence of strict response-reinforcer contiguity.

Key words: response differentiation, response patterning, response-reinforcer contiguity, temporal control, key peck, pigeons

Usually, the definition of an operant entails a class of discrete responses that enters into orderly functional relationships with reinforcing events (Schick, 1971). In a recent series of papers, however, Shimp (see the 1976 review) suggested that groupings or patterns of discrete responses may also be operants in the above sense, so long as the functional behavioral unit is retained at the moment of reinforcement.

To demonstrate that patterns of discrete responses may be modified by reinforcement operations, Hawkes and Shimp (1975) trained hungry pigeons during individual 5-sec trials to respond with either increasing or decreasing rates of key pecking for food reinforcement. Basically, their procedures involved making reinforcement dependent on within-trial patterns of key pecking that closely corresponded with computer-stored reference patterns. Thus, when pigeons were required to approximate a reference pattern

of 0, 1, 2, 3, and 4 key pecks per second during successive 1-sec subintervals of 5-sec trials, they showed accelerated rates of responding within individual trials; when the same pigeons were later required to approximate a reference pattern of 4, 3, 2, 1, and 0 key pecks per second during successive subintervals of the trials, they showed decelerated rates of responding.

These results support the proposal that behavioral units comprising several discrete responses may be subject to reinforcement. They also suggest that strict response-reinforcer contiguity is not necessary for conditioning, since the behavioral patterns involved discrete responses that often occurred several seconds before reinforcement. In this regard, the rate-increase schedule developed by Hawkes and Shimp is quite important; with the proper choice of schedule parameters, conjunctions of discrete responses and reinforcement can be prevented, while patterns composed of several discrete responses may be strengthened by reinforcement.

The present investigation pursued several questions raised by the interesting, but complex methods and analysis of Hawkes and Shimp (1975). Rate-increase and rate-decrease schedules of reinforcement were again studied; however, the within-trial patterns of responding were more simply defined. Here,

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individual 8-sec trials were divided into two successive 4-sec subintervals. In order to reinforce a decreasing rate pattern, the pigeon was required to key peck one or more times during the first 4 sec of the trial, and then not to key peck during the remainder of the trial. In order to reinforce an increasing rate pattern, the pigeon was required not to key peck during the first 4 sec of the trial and then to peck the key one or more times during the remainder of the trial. In either case, correct performance produced food reinforcement at the end of the 8-sec trial. These procedures are easily scheduled with either computer or conventional programming equipment. Furthermore, these schedules allow one quite easily to determine the occurrence of particular patterns of key pecking by merely considering the relative frequency of the four possible temporal sequences of responding (R) and not responding ($\bar{R}$) during the trial subintervals: RR , $R\bar{R}$, $\bar{R}R$, and $\bar{R}\bar{R}$. Lastly, the present reinforcement schedules were stricter than those of Hawkes and Shimp, in the sense that 4-sec periods were scheduled in which no key pecks were permitted on trials involving reinforcement, thus precluding any possibility of key peck-food conjunctions under the rate-decrease schedule.

Other experimental conditions were studied for comparison purposes. To see whether the specific patterns of within-trial key pecking were due to the presentation of food reinforcement at the end of brief discrete trials, a third schedule was investigated. It required one or more key pecks any time during the 8-sec trial. Thus, this schedule was the same as the two selective reinforcement schedules, in that the subject was required to key peck at least once per trial to receive reinforcement at the end of the trial; however, the exact time of occurrence of key pecking was unrelated to reinforcer presentation.

Also, to determine how strongly the patterns of key pecking were controlled under the rate-increase and rate-decrease schedules, other pigeons were exposed to the same schedules of reinforcement, but with discriminative stimuli correlated with the subintervals of individual trials. Providing such external discriminative stimuli could markedly improve the extent of differential responding

during the trial subintervals (Ferster and Skinner, 1957).

Finally, the effect of a schedule of reinforcement requiring a key peck in each subinterval of the trial was studied after subjects were trained under the rate-increase and rate-decrease schedules. Here, the aim was to see how durable the within-trial response patterns would be under conditions that ought to reduce or eliminate such patterns of key pecking.

METHOD

Subjects

Twenty experimentally naive, adult homing pigeons, reduced to 80% of their free-feeding weights, were individually housed with water and grit constantly available in the home cages and were tested daily when their weights did not exceed the 80% value by more than 10 g.

Apparatus

Four, three-key pigeon conditioning chambers were used. In each, only the center key was used to signal trial presentation and to record key pecks. The 1.9-cm diameter clear plastic key required a force of at least 0.05 N for activation and was positioned 9.4 cm above the solenoid-operated grain feeder and 4.9 cm below the houselight. The key could be transilluminated with green or red light by a miniature display projector (IEE Series 10, 28-V dc, CM 1820 bulb). A small bulb (ESB 24) illuminated the food tray (LVE No. 114-10). The houselight (28-V dc, CM 1820 bulb) was encased in a black metal housing that continually directed light toward the ceiling during experimental sessions. The interior walls of the box and the response panel (which contained the response keys, houselight, and food tray) were constructed of aluminum. Masking noise was continuously provided to the experimental room. In an adjoining room, scheduling and data collection were performed by an 8K DEC PDP 8/I computer, using the SKED software system (Snapper, Stephens, and Lee, 1974) and a relay interface.

Procedure

Preliminary training. The pigeons were trained in a single session to eat grain from

the lighted magazine when it was briefly activated. The next day, key pecking was conditioned by the autoshaping procedure (see Hearst and Jenkins, 1974 and Schedule R-Independent below). Illuminations of the key for 8 sec preceded access to grain for 3 sec on each of 40 daily trials. The onset of successive trials was equiprobably set at 38, 68, or 98 sec. Subjects remained on the autoshaping procedure until they pecked the key on 90% or more of the trials in a daily session. The assignment of key colors during autoshaping was the same as that described below during Phase I.

Phase I. During this phase of training, different subjects were exposed to schedules of reinforcement designed to produce increasing and decreasing rates of within-trial key pecking, as well as to a control schedule of reinforcement that should have neither of these two effects. These schedules of reinforcement, as well as those used in later phases of training, are shown in Table 1, which indicates those patterns of key pecking within trial subintervals that produced food reinforcement at the end of the trial. For example, for subjects on the $R\bar{R}$ schedule, one or more key pecks during the first 4 sec of an 8-sec trial and then no key pecking during the remainder of the trial resulted in a 3-sec access to grain at the end of the trial ($R\bar{R}$); no other pattern of key pecking resulted in food delivery (RR , $R\bar{R}$, or $\bar{R}\bar{R}$).

Three groups of four subjects each were administered Schedules $R\bar{R}$, $\bar{R}\bar{R}$, and Any-R corresponding with rate-decrease (Group 1), rate-increase (Group 2), and control (Group

3) procedures, respectively. For these 12 birds, the key was illuminated with the same color for the full 8 sec of each daily trial. For half of the subjects (numbers 1-1, 1-2, 2-1, 2-2, 3-1, 3-2), the keylight was red; for the other half (numbers 1-3, 1-4, 2-3, 2-4, 3-3, 3-4) it was green.

Two other groups of four subjects each were also exposed to Schedules $R\bar{R}$ and $\bar{R}\bar{R}$ (Groups 4 and 5, respectively). For these eight birds, however, the key was differently colored during the two 4-sec subintervals of daily trials. For half of the subjects (numbers 4-1, 4-2, 5-1, 5-2) the keylight was red during the first subinterval and green during the second; for the other half (numbers 4-3, 4-4, 5-3, 5-4) the keylight was green during the first subinterval and red during the second. Phase I training continued for 28 days.

Phase II. In Phase I, three of the eight subjects on the rate-decrease ($R\bar{R}$) schedule so seldom emitted the $R\bar{R}$ pattern of responding required for reinforcement that key pecking ceased. Furthermore, two pigeons in each of Groups 1 and 2 emitted the RR pattern of key pecking more than any of the other patterns. Therefore, in order to increase the level of key pecking of the former three subjects (by autoshaping) and to decrease it for the latter four subjects (by reinforcing not key pecking), Phase II training involved reinforcement of $R\bar{R}$ patterns for all subjects in addition to reinforcement of all those patterns of responding that were reinforced in Phase I. Subjects in Groups 1, 2, 3, 4, and 5 were thus trained for 14 days on Schedules $R\bar{R}/\bar{R}\bar{R}$, $\bar{R}\bar{R}/\bar{R}\bar{R}$, R-Independent, $R\bar{R}/\bar{R}\bar{R}$, and $\bar{R}\bar{R}/\bar{R}\bar{R}$, respectively (see Table 1).

Phase III. During the 14 days of Phase III, the subjects were returned to the schedules of reinforcement that were in force during Phase I.

Phase IV. Finally, subjects in Groups 1 and 2 were trained for 21 days in Phase IV under Schedule RR shown in Table 1. Here, only RR patterns of key pecking were reinforced in order to see how persistent the patterns of responding engendered by prior procedures would be under a schedule that required key pecking during both of the trial subintervals.

The sequence of reinforcement schedules for each group during each phase of training

Table 1
Schedules of Reinforcement

Schedule Name	Response Pattern			
	RR	$R\bar{R}$	$\bar{R}\bar{R}$	$\bar{R}\bar{R}$
RR	+	—	—	—
$R\bar{R}$	—	+	—	—
$\bar{R}\bar{R}$	—	—	+	—
$R\bar{R}/\bar{R}\bar{R}$	—	+	—	+
$\bar{R}\bar{R}/\bar{R}\bar{R}$	—	—	+	+
Any-R	+	+	+	—
R-Independent	+	+	+	+

Note. Response is denoted by R, food reinforcement is denoted by +, and nonreinforcement is denoted by —.

Table 2
Summary of Experimental Conditions

Group	Phase			
	I (28 days)	II (14 days)	III (14 days)	IV (21 days)
1	RR	RR/RR	RR	RR
2	RR	RR/RR	RR	RR
3	Any-R	R-Independent	Any-R	—
4 ^a	RR	RR/RR	RR	—
5 ^a	RR	RR/RR	RR	—

^aThese groups received different key colors during the first and second subintervals of the daily trials.

is given in Table 2. Training phases lasted for 2, 3, or 4 weeks with 40 trials per session. Changes in a procedure were made when visual inspection of performances during the preceding five days indicated that systematic changes were absent in most subjects.

RESULTS

All pigeons pecked the response key during trials within the first two days of autoshaping. At most, four sessions were necessary for subjects to reach the 90% criterion. On the last day of autoshaping, all subjects responded most often with the RR pattern of key pecking, except Bird 5-4, which pecked most often with the RR pattern.

Key-pecking performance during Phases I and II is shown in Table 3. This table depicts the number of trials of the last 200 in a phase that involved the RR, RR, RR, and RR patterns for each subject.

Phase I. With the inception of Phase I, the RR pecking pattern was not followed by food for subjects in Groups 1, 2, 4, and 5. Correspondingly, response rates fell until the RR or RR pecking patterns occurred sufficiently often to offset experimental extinction. However, three birds (1-1, 4-1, and 4-4) exposed to the rate-decrease (RR) schedule eventually stopped key pecking.

Over the last five days of training in Phase I, the birds that did respond tended to key peck in accord with the prevailing schedules of reinforcement. Subjects in Group 3, exposed to the control (Any-R) schedule of reinforcement, all responded most often with the RR pattern of key pecking. The five birds

Table 3
Performance of individual birds during the last 200 trials of Phases I and II.

Group	Bird	Trials of Each Pattern							
		Phase I				Phase II			
		RR	RR	RR	RR	RR	RR	RR	RR
1	1	7	1	6	186	20	174	4	2
	2	80	62	31	27	41	63	29	67
	3	114	75	7	4	30	124	9	37
	4	3	163	0	34	15	166	1	18
2	1	111	10	72	7	45	20	76	59
	2	72	2	114	12	0	6	19	175
	3	26	0	171	3	53	0	142	5
	4	160	0	40	0	158	0	42	0
3	1	186	2	11	1	121	32	28	19
	2	185	4	8	3	155	15	23	7
	3	81	65	30	24	65	71	30	34
	4	197	0	2	1	196	0	1	3
4	1	4	0	4	192	33	149	3	15
	2	25	86	11	78	1	65	1	133
	3	22	72	23	83	3	32	11	154
	4	1	0	1	198	7	146	2	45
5	1	40	0	159	1	0	0	48	152
	2	27	1	172	0	49	1	150	0
	3	1	0	194	5	4	0	167	29
	4	1	7	28	164	0	2	0	198

Note. Italicized numbers indicate those patterns of responding that involved food reinforcement.

(1-2, 1-3, 1-4, 4-2, and 4-3) exposed to the rate-decrease (RR) schedule that responded, performed the RR pattern much more often than the RR pattern. And, the eight birds (Groups 2 and 5) exposed to the rate-increase (RR) schedule performed the RR pattern much more often than the RR pattern.

No major differences were seen between those subjects given schedules of reinforcement involving external discriminative stimuli correlated with the trial subintervals (Groups 4 and 5) and those subjects given schedules without signalled subintervals (Groups 1 and 2). However, two birds in each of Groups 1 (1-2, 1-3) and 2 (2-1, 2-4) key pecked most often with the RR pattern; no bird in Group 4 or 5 did so.

Phase II. Phase II training added reinforcement on trials when key pecks did not occur (RR) in an attempt to recondition the responding of Birds 1-1, 4-1, and 4-4, and to decrease the responding of Birds 1-2, 1-3, 2-1, and 2-4. Of the former subjects, all three increased key pecking and of the latter subjects, three of four decreased key pecking (the ex-

ception was Bird 2-4). Most of the remaining subjects evidenced a decrease in the rate of key pecking (see Table 3).

Phase III. Because all subjects continued to respond throughout Phase III, this part of the experiment provided the best evidence of stable performance under the rate-increase, control, and rate-decrease schedules of reinforcement.

One measure of temporal control by the schedule of reinforcement is the percentage of total key-peck responses occurring during the last 4 sec of each trial. These percentages (which minimize the influence of individual differences in rates of key pecking), based on performances during the last five days of Phase III, are numerically shown in Figure 1 for each subject (values in parentheses). Subjects in Groups 2 and 5, exposed to the rate-increase ($\overline{RR}$) schedule, all made more than 89% of their key pecks during the last half

of the trial, whereas subjects in Groups 1 and 4, exposed to the rate-decrease ($R\overline{R}$) schedule, all made less than 37% of their key pecks during the last half of the trial. As for the groups with and without signalled trial sub-intervals, considerable overlap in the scores of individual subjects occurred between Groups 2 and 5 and between Groups 1 and 4. However, the individual scores of control subjects in Group 3 (range: 39% to 69%) did not overlap with the scores of any of the subjects trained under the rate-increase or rate-decrease schedules (Groups 1, 2, 4, and 5).

A more detailed picture of the time course of key pecking within trials is shown by the percentage of total key pecks during successive 1-sec bins of the trials. The solid lines in Figure 1 give this function (which also minimizes the influence of individual response-rate differences) for individual subjects in the four groups. Figure 1 illustrates that

Fig. 1. Percentage of total key pecks occurring during successive 1-sec bins of the last 200 trials in Phase III (solid lines) and Phase IV (dashed lines) for individual subjects. The parenthetical scores next to the subject numbers indicate the percentage of total key-peck responses occurring during the final 4 sec of the last 200 trials in Phase III. Note the different ordinate scales for the different subjects.

Group 1 subjects exposed to Schedule $\overline{RR}$ evidenced decelerated patterns of responding within trials, whereas Group 2 subjects exposed to Schedule $\overline{RR}$ evidenced accelerated patterns. Control subjects in Group 3, trained under Schedule Any-R, evidenced generally inconsistent trends of within-trial key pecking with the exception of Bird 3-4, which showed a trend for responding to increase throughout the trial. Subjects in Groups 4 and 5 responded quite similarly to subjects in Groups 1 and 2, respectively.

Finally, control by the prevailing schedules of reinforcement was assessed by considering the most frequently performed pattern of key pecking during the last 200 trials of Phase III. These data are shown in Table 4 together with the absolute number of key peck responses in 1-sec bins corresponding to relative response functions summarized in Figure 1. It can be seen in Table 4 that seven of eight pigeons trained with Schedule $\overline{RR}$ (Groups 1 and 4) responded most with the $\overline{RR}$ pattern, six of eight pigeons trained with Schedule $\overline{RR}$ (Groups 2 and 5) responded most with the $\overline{RR}$ pattern, and all four subjects

trained with Schedule Any-R (Group 3) responded most with the RR pattern.

Phase IV. During Phase IV, only RR patterns of key pecking produced reinforcement for Groups 1 and 2. Data from this phase of training are shown in Table 5 (which follows the format of Table 4) and in the dashed curves of Figure 1 (which are based on the response-frequency scores shown in Table 5). With the exception of Bird 2-4, exposure to Schedule RR led to increased key pecking (see Table 5). Furthermore, as shown in Figure 1, the skewness of the individual temporal response functions was reduced by the end of Phase IV (dashed lines) by comparison with performances at the end of Phase III (solid lines). For all eight pigeons, Table 5 shows that the RR pattern was the most frequent pattern during the last five days of Phase IV.

Despite the reduction in the temporal control over responding by Schedule RR, there was still no overlap in the scores of individual subjects in Groups 1 and 2 in terms of the percentage of total key pecks made during the last half of the trial over Days 17 to 21 of Phase IV: 59%, 58%, 55%, and 27% for

Table 4
Performance of Individual Birds during the Last 200 Trials of Phase III

Group	Bird	Total Key Pecks during 1-sec Bins								Trials of Each Pattern			
		1	2	3	4	5	6	7	8	RR	$\overline{RR}$	$\overline{RR}$	$\overline{RR}$
1	1	179	319	42	16	11	9	10	4	27	<i>158</i>	3	12
	2	32	55	56	49	30	23	24	18	43	<i>74</i>	22	61
	3	31	43	33	7	7	9	13	18	12	<i>81</i>	29	78
	4	302	128	22	7	5	9	15	8	30	<i>161</i>	1	8
2	1	0	2	10	8	27	122	220	220	16	0	<i>167</i>	17
	2	0	0	0	0	1	8	32	101	0	0	<i>98</i>	102
	3	0	2	5	70	179	297	311	354	58	1	<i>137</i>	4
	4	0	51	55	88	191	407	537	540	138	0	<i>62</i>	0
3	1	3	177	213	120	67	73	83	106	<i>136</i>	<i>43</i>	15	6
	2	31	119	101	76	77	39	93	222	<i>130</i>	<i>37</i>	25	8
	3	23	84	60	73	101	102	64	41	<i>89</i>	<i>39</i>	56	16
	4	16	177	328	452	509	553	556	520	<i>197</i>	0	3	0
4	1	229	271	26	1	4	4	2	2	10	<i>189</i>	0	1
	2	23	123	51	10	3	0	3	7	6	<i>106</i>	4	84
	3	11	0	1	0	3	0	3	1	1	<i>11</i>	6	182
	4	87	254	71	6	0	0	0	0	0	<i>146</i>	0	54
5	1	0	1	0	0	52	183	265	366	1	0	<i>183</i>	16
	2	7	1	6	10	132	344	263	240	21	1	<i>175</i>	3
	3	3	0	0	1	60	169	193	181	4	0	<i>160</i>	36
	4	0	0	1	15	48	95	80	77	7	9	<i>146</i>	38

Note. Italicized numbers indicate those patterns of responding that involved food reinforcement.

Table 5

Performance of Individual Birds in Groups 1 and 2 during the Last 200 Trials of Phase IV

Group	Bird	Total Key Pecks during 1-sec Bins								Trials of Each Pattern			
		1	2	3	4	5	6	7	8	RR	RR̄	RR̄	RR̄
1	1	180	359	355	461	510	496	504	405	196	0	2	2
	2	48	69	88	117	113	120	106	104	155	11	31	3
	3	159	290	167	114	130	239	276	247	195	2	2	1
	4	389	356	318	285	210	161	81	37	160	40	0	0
2	1	3	29	90	104	119	195	303	274	133	2	64	1
	2	61	106	168	249	295	309	338	341	174	1	24	1
	3	12	168	180	227	274	375	474	603	146	0	53	1
	4	28	63	111	126	165	274	332	307	145	3	51	1

Note. Italicized numbers indicate those patterns of responding that involved food reinforcement.

Birds 1-1, 1-2, 1-3, and 1-4 respectively; and 80%, 69%, 75%, and 77% for Birds 2-1, 2-2, 2-3, and 2-4, respectively.

DISCUSSION

The present results agree with those of Hawkes and Shimp (1975) in showing that within-trial patterns of key pecking may be strengthened by positive reinforcement; peck-pause and pause-peck patterns of responding were conditioned under simply-defined schedules that made food reinforcement dependent on these patterns of key pecking in Groups 1 and 2, respectively. Furthermore, the results of Group 3 control subjects indicate that these patterns of responding were not the result of the presentation of food reinforcement at the end of brief discrete trials. These findings are thus consistent with Shimp's (1976) proposal that organized units of discrete response elements may function as operants.

Evidence collected in Phase IV under Schedule RR, which reinforced only the peck-peck pattern of responding, indicates that temporal control engendered by rate-increase and rate-decrease schedules can be reduced. However, after three weeks of training under this schedule, some residue of the prior patterns of key pecking in Groups 1 and 2 was still evident. Conditioned patterns of responding are thus quite resistant to modification.

Comparison of Groups 1 and 2 with Groups 4 and 5 provides yet another means of assessing how strongly controlled by the prevailing schedules of reinforcement were the decreasing and increasing patterns of key pecking. Surprisingly, most measures of performance

indicated that the temporal control of responding in subjects given unsignalled trial subintervals (Groups 1 and 2) was quite similar to subjects given signalled trial subintervals (Groups 4 and 5). Considerable temporal precision must then have been involved in the adjustment of key pecking in Groups 1 and 2 to the arranged schedules of reinforcement.

As pointed out by Zeiler (1977), the conclusion that a pattern of behavior is a functional response unit requires (a) that reinforcement be made dependent on the occurrence of the unit and (b) that the frequency of occurrence of the unit be increased as a function of the reinforcement dependency. Although the present experiment and that of Hawkes and Shimp (1975) meet these two requirements, other investigations that have been thought to demonstrate the differentiability of respond-pause and pause-respond patterns do not.

For example, Dews (1960) placed hungry pigeons on a free-operant schedule of reinforcement that required one key peck and then t sec of no key pecking; each key peck started a resettable timer that triggered food reinforcement when t sec had elapsed. Inspection of cumulative records revealed patterns of responding describable as "peck-pause". However, because reinforcer presentation was always preceded by one key peck and then t sec without key pecking, one cannot be sure that the frequency of peck-pause patterns had been differentiated from peck-peck, pause-peck, and pause-pause patterns.

As a second example, consider Staddon's (1972) work on "go/no-go" schedules. Here,

on a variable-interval 1-min schedule, a pigeon might receive reinforcement for key pecking up to 1 min since the last reinforcer; after a postreinforcer time of 1 min, not key pecking for at least 10 sec would lead to reinforcement. The problem with this type of schedule is that reinforcement was not actually dependent on completing a particular peck-pause pattern within a finite period of time. Up to postreinforcement times of 1 min, pigeons might receive reinforcement for both peck-peck and pause-peck patterns; with postreinforcement times in excess of 1 min, both peck-pause and pause-pause patterns might produce reinforcement. Thus, whereas Dews' (1960) experiment required peck-pause patterns for reinforcement, but did not permit evaluation of response pattern differentiation, Staddon's (1972) experiment provided greater information about pattern differentiation, but did not selectively reinforce one particular temporal pattern of key pecking.

It is hoped that Zeiler's (1977) two-part definition of functional response units will gain wider acceptance, since important theoretical questions require the surest empirical evidence for their evaluation. This concern is not limited to the present experimental question but is also germane to concurrent schedules of reinforcement (see Catania, 1971 for a two-key procedure sharing the same analytical problems as Dews' 1960 experiment).

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