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Effects of Concurrent Temporal and Spatial Allocation of Water Delivery on Water-Seeking Behavior in Rats

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We evaluated the effects of varying temporal and spatial parameters on behavioral transitions within a water-seeking situation. Subjects were 8 experimentally-naïve male Wistar rats divided into 2 groups of 4 rats. For both groups, 2 independent schedules of water delivery were simultaneously available in two different locations of the experimental chamber. For Group 1, water was delivered with a fixed periodicity (fixed-time schedules). For Group 2, water was delivered randomly in time, but the average length of time between deliveries was constant (random-time schedules). Water deliveries were independent of the rat's behavior. In successive phases of the study, the frequency of water delivered in one location increased while the frequency of water delivered in the second location decreased, so that the total number of water deliveries was constant. Rats under fixed-time schedules spent more time in the location where water was initially provided. For rats under the random-time schedules, time spent at each location was close but not equal to the proportion of water delivered at each site. Results are discussed in terms of the divergences with matching and optimization models, emphasizing that apparently simple behaviors in a relatively simple environment may not be understood in terms of a single, overall encompassing concept.

Keywords: constancy, variation, adaptation, concurrent schedules, rats, time allocation

Studies of foraging behavior using the methodology of operant conditioning have privileged experimental situations involving concurrent or concurrent-chained schedules of reinforcement (Abarca & Fantino, 1982; Baum & Rachlin, 1969; Fantino & Abarca, 1985; Houston, Sumida, & McNamara, 1987; Lea, 1979). In this situation, usually rats or pigeons are exposed to two options of response, either in a single operandum and a change-over operandum (lever or key) or in two separate operanda, both adjacent to the food or water dispenser. The dispenser is the only source of food or water in the situation, and the effective response is restricted to a fixed location. The only variation is in the requirement established by the schedules of reinforcement to choose between two options of food or water delivery, either in terms of delay, response effort, amount, or quality. Schedules involved in the choice situation are usually variable-interval schedules, because other schedules, such as ratio or differential rate schedules, do not induce changes between available response options. Simple linear models such as optimization or matching, predict, not always successfully, foraging behavior in terms of the relation between choice and response frequency.

Ribes-Iñesta et al. (Ribes-Iñesta & Torres, 2000; Ribes-Iñesta, Torres, Correa, & Montes, 2006) assessed the effect of response-independent water deliveries on the spatiotemporal distribution of rats' behavior in a modified two-panel operant chamber. In contrast to mainstream studies, response-independent water reinforcement was provided concurrently in two opposite locations, in such a way that water presentation varied by location and time in different experimental conditions. Response location was defined as time spent in seven different areas of the experimental chamber.

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In an early study, Ribes-Iñesta and Torres (2000) evaluated the effects of water deliveries at regular intervals on the location of rats in a modified standard operant chamber. The experimental chamber contained two water dispensers, each located on opposite walls. Water was delivered according to concurrent fixed-time (FT) schedules. In the first experiment, the total number of water deliveries was kept constant while, in different conditions, the proportion of water delivered in Dispenser 1, relative to Dispenser 2, varied in the proportions of 1/0, .75/.25, .50/.50, .25/.75, and 0/1. In the second experiment, the proportion of water delivered in each dispenser was kept constant at 0.67 and 0.33 for Dispensers 1 and 2, respectively, while the total number of water deliveries varied between conditions. In both experiments, the percentage of time that the rats spent with its head in each water dispenser was a direct function of the percentage of water deliveries in each water dispenser. However, time allocated in areas near the water dispensers did not vary symmetrically with the proportion of water deliveries. This last finding did not coincide with the reports of other studies (e.g., Baum & Rachlin, 1969; Pear, 1985; Pear & Rector, 1979) regarding the direct relation between proportion of behavior located near the dispensers and the frequency of reinforcement delivery in those dispensers. According to Ribes-Iñesta and Torres (2000), the differences in the results could be explained by the fact that, in some studies, reinforcement delivery was contingent on the subjects' permanence only in one particular zone of the experimental chamber (e.g., Baum & Rachlin, 1969) and to the different schedules of reinforcement used, dependent or independent of behavior at fixed or variable intervals.

In a second study, Ribes-Iñesta et al. (2006) examined the effect of independent-water deliveries at irregular intervals on the spatial distribution of behavior in rats. The apparatus and procedure were similar to the one used by Ribes-Iñesta and Torres (2000, Experiment 1), with the exception that Ribes-Iñesta et al. (2006) used random-time schedules (RT), instead of FT schedules. It was found that time allocated to the two water dispensers and the adjacent areas varied according to the percentage of water delivered in each dispenser. However, space allocation was not symmetrical in both dispensers: Rats spent more time in the dispenser and adjacent area in which a higher water proportion was delivered in the first condition (a primacy effect). It is possible that in this study, unlike the former one, rats spent more time in areas adjacent to the dispensers because water that was delivered at irregular intervals induced increases in the spatial variation of behavior of rats because they did not spend a large proportion of time inside the dispenser.

The findings of our previous experiments suggest the importance of taking into account spatial parameters in the patterning of foraging behavior when concurrent schedules are used. In order to evaluate the effects of an increased distance between water delivery locations and the continuous space allocation of rats' behaviors, we designed a study replicating our previous studies with FT and RT schedules of water delivery. Experiments were run in a larger modular chamber with video-digital continuous recording of rats' behaviors during the complete session. We used an experimental chamber of approximately 1 m^2, in which rats were able to move around freely. Some foraging behaviors do not require specific manipulative behavior, as is demanded in many instances of predating. Foraging in such cases consists of exploring and locating the food or water sources available in a given environment. If needed, specific operanda may be additionally included. A situation like this may involve at least two water or food dispensers (or one of each) located on different walls of the chamber. These dispensers, in the simplest conditions in which food or water need only to be located, operate concurrently. Concurrence may involve strict simultaneity in providing food or water, asymmetry in the delivery intervals, or a combination of both temporal contingencies. The use of FT or RT schedules may allow for local variations in the availability of food or water in each and both dispensers. In this way, a simple open space situation with two concurrent FT or RT schedules may be used to evaluate the occurrence of flexible behavior patterns and environmental variation in time and space parameters, and may be used to identify possible dynamic changes involved in foraging in natural habitats.

Method

Subjects

Subjects were eight experimentally-naïve, male Wistar rats, between 3 and 4 months old at the beginning of the study. All rats were maintained under a daily schedule of 22.5 hours of water deprivation with 1 hour of free access to water per day. Subjects had free access to food in their home cages. Sessions were conducted 6 days per week, from 8:00 am to 6:00 pm.

Apparatus

An enlarged-experimental chamber was used (Coulbourn Instruments, Model E14-05). The dimensions of the chamber were 92 cm × 92 cm × 38 cm (see Figure 1 for a diagram of the experimental chamber and the different areas in which it was divided to allocate rats' behaviors). The four walls of the chamber were made of removable aluminum panels supported by a hard plastic frame. The floor was an aluminum mesh located on top of a steel floor. The chamber was illuminated by four lights of 28V that were turned on during sessions, each light located on the corner of each wall. Each panel had a drop-type liquid dispenser, 2 cm above the chamber floor, and a water tray below it (MED-ENV-200R3BM); only the liquid dispensers at the front and rear panel of the chamber were operative. Water dispensers delivered a 0.3 cm^3 drop of water. Once delivered, the water remained available in the tray until consumed. Each water delivery was signaled by a 3-s, 28-V light located inside the water dispensers.

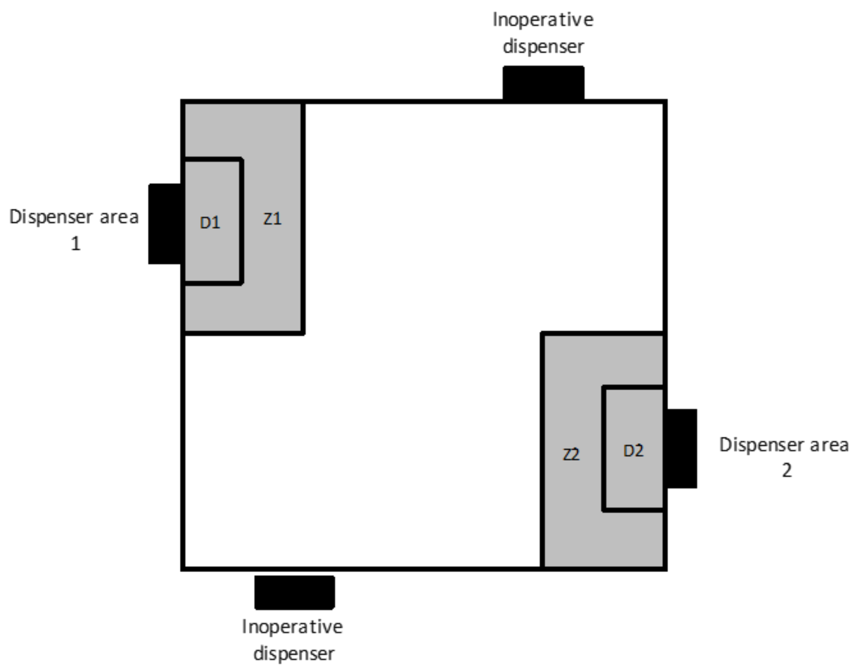

Figure 1. **Diagram of the experimental chamber and the different areas into which it was divided to allocate rats´ behaviors**.

The experimental chamber was housed in an isolated room. All programmed events were scheduled and recorded in an adjacent room using a 486-MED computing system with MED-PC 2.0 ® software. Rats' locations were recorded by a Panasonic® (RJ36) video camera located at the center of the experimental chamber, 1 m above it. The video camera was connected to a PC with Ethovision 2.1 ® software. The software recorded time (in seconds) spent by the rats in different locations in the experimental space. The locations were defined in terms of four categories: two corresponded to the location of the rat in the water dispensers or their adjacent areas (D1 and D2 in Figure 1), and two corresponded to surrounding zones, which could be covered by the rat's body (Z1 and Z2 in Figure 1).

Procedure

Subjects were divided in two groups of four rats. Subjects in both groups were exposed to five phases in the same order. For both groups, two schedules of water delivery were simultaneously available (concurrent schedules), the first schedule was programmed in Dispenser 1 and the second schedule in Dispenser 2, independent of each other. For Group 1, water was delivered using concurrent FT schedules, and for Group 2 using concurrent RT schedules. Both schedules delivered water independently of a rat's behavior. FT schedules delivered water with a constant periodicity (e.g., every 30 s), while RT schedules delivered water randomly in time, but the average length of the schedule was constant. For the RT schedules, each water-delivery value was taken randomly from a uniform distribution ranging from x/2 to 3*x/2, where x was the mean value of the schedule.

The specific values of each schedule varied between phases. Table 1 shows the specific values for each FT and RT schedule for Groups 1 and 2. The mean value of the schedule in each phase was equivalent between groups. For both groups, the interval length of the FT or RT schedule for Dispenser 1 increased across phases from 30 s to extinction, while the interval length of the schedule for Dispenser 2 decreased from extinction to 30 s. Each phase lasted 20 sessions and each session lasted 30 minutes.

Table 1
Experimental Conditions of the Two Groups of Rats

Phase	Dispenser 1	Dispenser 2	Number of water deliveries per session (D1/D2)	Proportion of water deliveries in D1
1	30 s	Extinction	60/0	1.00
2	40 s	120 s	45/15	0.75
3	60 s	60 s	30/30	0.50
4	120 s	40 s	15/45	0.25
5	Extinction	30 s	0/60	0.00

Note. FT- or RT-schedule values for each water dispenser, number of water deliveries per session, and proportion of water deliveries associated with Dispenser 1 for each phase of the study.

Results

Results describe group and individual time allocation measures in different zones under FT and RT schedules in every experimental phase. Figure 2 displays the mean percentage of time allocation in each dispenser and frontal area in the different experimental phases for Groups 1 and 2. The top panel of Figure 2 corresponds to Group 1 under a FT schedule whereas the lower section corresponds to Group 2 under a RT schedule. The figure shows the relative differences in time allocation in each dispenser given different proportions of water delivery in the same experimental phase. Group 1 showed a limited increase in the percentage of time allocation (from almost 0% to around 20%) with increments in the proportion of water delivered in Dispenser 2 (from 0.0 to 1.0). There was an increase in time allocation in this dispenser with increases in water deliveries, but the percentage of time allocation was far below the proportion of water being provided. Percentage of time allocation in Dispenser 1 was not symmetrical to changes in the proportion of water delivered. Time allocation in Dispenser 1 and its frontal area showed a decrease with decrements in the proportion of water deliveries (from almost 60% to 20%) during the first four phases, but in the last phase (extinction), time allocation increased to 30%.

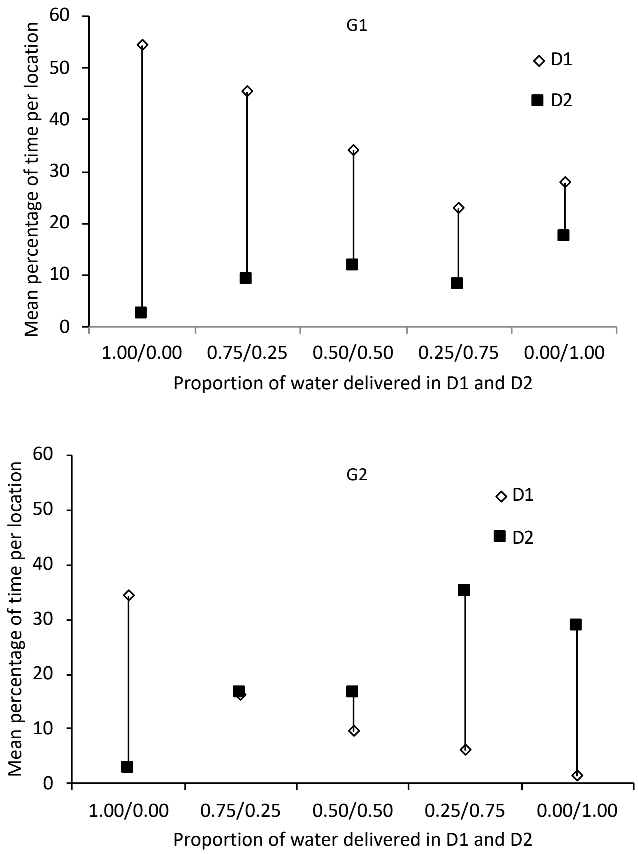

Figure 2. **Mean percentage of time allocation in Dispenser 1 and Dispenser 2 and its respective frontal areas in the different experimental phases for Groups 1 (G1) and 2 (G2).**

Percentage of time allocation in each experimental phase did not match the percentage of water delivered in each dispenser. Time allocation was always lower than the proportion of water provided in each dispenser. The reversal in the proportion of water being delivered in each dispenser did not produce equivalent percentages of time allocation in each dispenser. Furthermore, in the last condition, there was a larger percentage of time allocated to Dispenser 1 under extinction than to Dispenser 2, in which all the water was being provided. Group 2 (Figure 2, bottom panel), under a RT schedule, showed an irregular increase in time allocation in Dispenser 2 and its frontal area with increments in the proportion of water deliveries (from 0%, to two conditions below 20%, and the last two conditions with almost 40% and 30%). Time allocation in Dispenser 1 and its frontal area showed a systematic decrease in time allocation with decrements in the proportion of water deliveries, especially from the first condition (100%) to the second (75%). In this group, no matching was found between the percentages of time allocation in each dispenser and the water deliveries provided. Nevertheless, differences in time allocation in both dispensers and their frontal areas were lower than for Group 1.

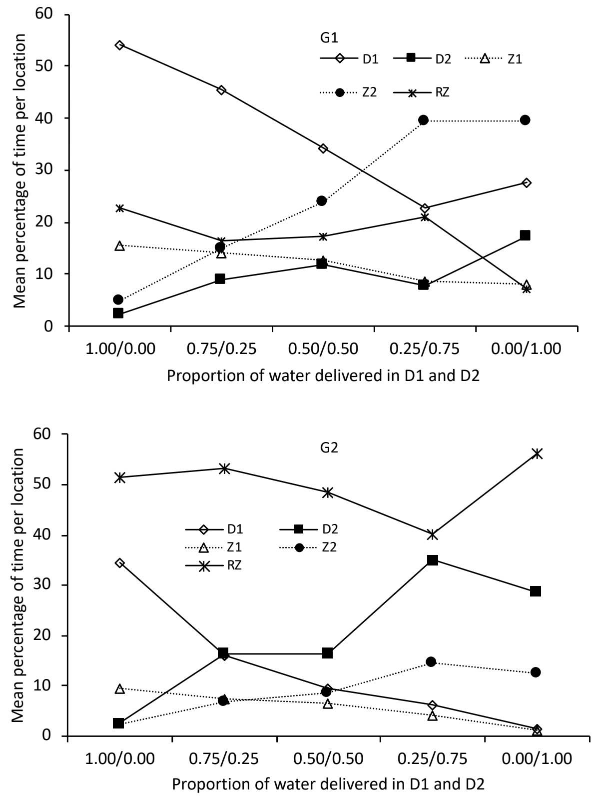

Figure 3. **Mean percentage of time allocation in the two dispensers and frontal areas (D1, D2), their two surrounding areas (Z1, Z2), and the remaining zone in the experimental chamber (RZ) in the different experimental phases for Groups 1 (G1) and 2 (G2).**

Figure 3 shows the mean time allocation in the two dispensers and frontal areas, their two surrounding areas, and the remaining zone in the experimental chamber (RZ), as a function of the corresponding proportion of water deliveries in each dispenser during the five experimental phases. The top panel of Figure 3 shows the data for Group 1 under a FT schedule. The percentages of time allocation in both dispensers and their frontal areas are the same as described in Figure 2. Time allocation in Z2, the area surrounding Dispenser 2, increased in proportion to the increments in water deliveries in that dispenser, except for the last phase, in which despite the fact that Dispenser 2 provided 100% of water, time spent in its surroundings remained the same (40%) as the previous phase with fewer deliveries. Time allocation in Z2, added to that spent in the dispenser, represented only 60% of the total time of the sessions in that condition. Time allocation in Z1, the area surrounding Dispenser 1, decreased along decrements in the proportion of water deliveries in that dispenser, except for the last condition in which time allocation increased 10% in comparison to the previous phase, despite the fact that no water was provided by Dispenser 1. In general terms, time allocation was always higher in the surrounding areas than in the corresponding dispensers and their frontal areas. Time allocation in RZ, involving areas other than the dispensers and its surroundings, remained relatively constant across conditions with ranges between 10% and 25%. The bottom panel of Figure 3 shows time allocation for Group 2, under a RT schedule in the same five areas, as described in Figure 2. In this group, time allocation in both dispensers and frontal areas was higher than in their corresponding surrounding areas. Time allocation in any of both surrounding areas, Z1 and Z2, never scored beyond 15%. In contrast, time allocation in RZ, those areas other than the dispensers and its surroundings, ranged from 45% to 60% of time allocation, the latter score in the last experimental condition.

Tables 2-5 depict the accumulated presence of rats in the water dispensers and their frontal adjacent and surrounding areas. Allocation is represented as the mean accumulated time in seconds per session, for each experimental phase (total number of seconds per phase divided by number of sessions). The highest mean time allocation per subject per phase is highlighted in bold.

Table 2 shows the allocation of every rat in Group 1 in the areas related to each water dispenser. In the five experimental conditions, all rats spent more time in Dispenser 1 and its frontal area, in which water was initially provided. The only exception was R4 during Phase 5, although this rat had a higher permanence in Dispenser 1 during the rest of the phases. Preference for Dispenser 1 occurred despite the fact that frequency of water delivery was matched in Phase 3 for each dispenser, or was higher in Dispenser 2 during Phases 4 and 5. In Phase 1, the four rats stayed only 35 s to 57 s in Dispenser 2 (under extinction), with mean accumulated times ranging from 749 s to 1250 s per session in Dispenser 1 and its frontal area. In Phase 2, during which one of every four deliveries was provided in Dispenser 2, rats showed mean accumulated times ranging from 479 s to 1074 s in Dispenser 1 and from 116 s to 219 s in Dispenser 2. In Phase 3, with simultaneous concurrent deliveries in both dispensers, rats showed mean accumulated times ranging from 396 s to 791 s in Dispenser 1 and from 170 s to 245 in Dispenser 2. In Phase 4, during which the proportion of water deliveries was the inverse of Phase 2, rats showed mean accumulated times ranging from 311 s to 494 s in Dispenser 1 and from 8 s to 196 s in Dispenser 2. Finally, in Phase 5, during which water deliveries were restricted to Dispenser 2, rats (excluding R1 who died at the end of Phase 4) showed mean accumulated times ranging from 136 s to 955 s in Dispenser 1 and from 202 s to 404 in Dispenser 2. Rats consistently spent more time in Dispenser 1, the first dispenser that delivered water, although in Phases 3 and 4, Dispenser 2 provided the same or larger percentages of water. In the last phase, only one rat spent more time in Dispenser 1 (under extinction) compared to Dispenser 2. Nevertheless, in contrast to the first phase in which rats practically did not visit Dispenser 2 under extinction, in Phase 5, three rats spent a significant amount of time in Dispenser 1 that did not provide water.

Table 2

Mean Time Allocation in Dispenser 1 and Dispenser 2 per Phase for Each Rat in Group 1

	Phase 1		Phase 2		Phase 3		Phase 4		Phase 5	
	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2
Rat 1	1160	36	864	219	791	240	432	8	-	-
Rat 2	1250	35	1074	164	666	245	406	196	955	202
Rat 3	749	57	861	116	669	193	494	177	408	336
Rat 4	749	36	479	140	336	170	311	191	136	404

Table 3 shows the time spent in the surrounding area of each dispenser. This measure does not covary necessarily with the time spent in each dispenser and its frontal area. During Phases 1, 4, and 5, the time spent by rats in the surrounding areas of each dispenser corresponded to the percentage of water deliveries provided by each one. Nevertheless, in Phase 2, R1 and R2 spent more time in the surroundings of Dispenser 2 with a lower frequency of water deliveries. In Phase 3, all rats spent more time in the surroundings of Dispenser 2, despite the fact that both dispensers delivered the same frequency of water deliveries simultaneously. These data suggest that moving around the dispensers was not correlated with the time spent in each dispenser but probably with the effective immediate contact with the delivery of water.

Table 3

Mean Time Allocation in Zone 1 and Zone 2 per Phase for Each Rat in Group 1

	Phase 1		Phase 2		Phase 3		Phase 4		Phase 5	
	Z1	Z2	Z1	Z2	Z1	Z2	Z1	Z2	Z1	Z2
Rat 1	156	80	224	344	257	483	149	817	-	-
Rat 2	167	80	142	310	139	467	150	822	123	392
Rat 3	453	105	351	193	262	365	127	610	174	823
Rat 4	348	89	301	236	254	415	198	595	134	915

Table 4 shows the mean time allocation in seconds per session in each phase for every rat in Group 2. Time allocation is computed for both water dispensers and their adjacent frontal areas. In this group, rats were exposed to the delivery of water under concurrent RT schedules, matching the frequency of deliveries to Group 1 under FT schedules. In Phase 1, time spent in Dispenser 1 and its frontal area ranged from 445 s to 824 s and from 29 s to 64 s in Dispenser 2 and its frontal area. In Phase 2, time spent in Dispenser 1 ranged from 186 s to 369 s and from 273 s to 328 s in Dispenser 2. In Phase 3, time ranged from 122 s to 224 s in Dispenser 1 and from 355 s to 552 s in Dispenser 2. In Phase 4, time spent in Dispenser 1 ranged from 99 s to 127 s and from 552 s to 766 s in Dispenser 2. Finally, in Phase 5, time spent in Dispenser 1 ranged from 17 s to 41 s and from 452 s to 591 s in Dispenser 2. In Group 2, total time allocations in each dispenser and their frontal areas were lower than in Group 1. In contrast to Group 1, only during Phase 1, rats in Group 2 spent more time in Dispenser 1 than in Dispenser 2. Nevertheless, the time spent in the only dispenser providing water was higher in Phase 5 than in Phase 1.

Table 4

Mean Time Allocation in Dispenser 1 and Dispenser 2 per Phase for Each Rat in Group 2

	Phase 1		Phase 2		Phase 3		Phase 4		Phase 5	
	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2
Rat 5	445	48	186	274	131	355	99	552	32	496
Rat 6	512	64	242	273	122	529	102	596	41	452
Rat 7	694	29	354	304	224	499	120	605	17	591
Rat 8	824	43	369	328	208	552	127	766	17	520

Table 5 shows the mean accumulated time per session per phase spent by every rat in Group 2 in the surrounding area of each dispenser. Results were similar to those related to time spent in each dispenser and its frontal area. In Phase 1, rats spent more time in the surrounding area of Dispenser 1. However, from Phase 2 on, rats spent more time in the surroundings of Dispenser 2, except R5 during Phases 2 and 3. In the same fashion, the total amount of time spent in both surrounding areas was lower for this group than for Group 1 under an FT schedule of water delivery.

Table 5
Mean Time Allocation in Zone 1 and Zone 2 per Phase for Each Rat in Group 2

	Phase 1		Phase 2		Phase 3		Phase 4		Phase 5	
	Z1	Z2	Z1	Z2	Z1	Z2	Z1	Z2	Z1	Z2
Rat 5	145	59	192	127	215	113	79	260	24	249
Rat 6	163	44	76	81	25	141	44	268	31	175
Rat 7	128	31	152	152	161	238	106	365	21	242
Rat 8	240	21	119	129	61	135	64	162	9	230

Discussion

The results of this experiment show that time allocation of water seeking and consuming did not match the different relative frequencies of water delivery. The two groups of rats in this study received the same frequency and amount of water, independently of their behavior, but nonetheless differed in the time allocated to the two concurrent dispensers and their surrounding areas. When water was delivered in constant cycles (FT), rats showed what could be identified as a primacy effect. This effect consisted of a preference for the first dispenser in which rats obtained water in the experimental space (Dispenser 1). Rats spent more time in this dispenser and its frontal and surrounding areas than in the alternative dispenser (Dispenser 2) during the whole experiment. This took place despite changes in the frequency of water deliveries in each dispenser. While during the first two phases, water was more frequent in Dispenser 1, in the intermediate and last two phases, water was delivered as frequently or more frequently in Dispenser 2. In the last phase, the primacy effect of Dispenser 1 persisted in two of the three rats (as the fourth was lost), in spite of the fact that all water was provided in Dispenser 2. The primacy effect was observed both in relation to time spent in the dispenser and frontal area as well as in the area surrounding the dispenser. Rats did not match the time they spent regarding the water source with the frequency of water obtained from it. This is especially surprising becasue rats tended to spend more time where less or no water was delivered. This means that, becasue rats spent more time in the areas where water was provided in lower proportion, they traveled longer distances than those required to obtain the water being delivered in both dispensers, especially in the last two experimental phases. Note that water was presented independently of rats' behaviors and that in three of the five experimental phases there were two alternative sources of water. Both sources, when being asymmetrical or symmetrical in delivery, coincided in one of three or in all water presentations, in such a way that, at the same moment, two deliveries occurred in different places (i.e., in each dispenser). Nevertheless, because water remained available, rats could consume both drops successively.

The primacy effect was not observed when water was delivered at random times, and interval constancy was lost. Even though the number of water deliveries provided by the dispensers was the same as under the FT schedule, their distribution in time varied. The breakdown of periodicity in water delivery produced results opposite to those observed in Group 1. In this situation, when water was provided by the two dispensers, some rats spent more time in the dispenser recently operating, although it provided the same or fewer drops of water than the first dispenser providing water. The preference for Dispenser 2 and its frontal and surrounding areas increased with the increase in frequency of water delivered by that dispenser. Nevertheless, time allocation in both dispensers and their frontal and surrounding areas was lower when water was delivered at random intervals than when it was presented according to fixed intervals. Temporal variation was accompanied by an increment in traveling and behaviors different to being close to any of the dispensers.

In both groups, time allocation varied despite the fact that water drops remained available in the dispenser after their delivery.

Spatial variation may depend on two factors. One is the location of the dispensers on opposite walls, or even on opposite ends of the same wall. Another is directly related to the extension or area of the experimental space in which the animal may move around. The potential variation allowed by an extended space may alter the patterns observed within a smaller space under the same temporal schedules of water delivery. In the studies by Ribes-Iñesta and Torres (2000) and Ribes-Iñesta et al. (2006) previously cited, the standard operant conditioning chamber used was 11.5 times smaller than the experimental chamber used here (725 cm^2 versus 8464 cm^2). Despite the fact that those studies used similar concurrent FT and RT schedules of water delivery with dispensers located on opposite walls, spatial allocation of behavior was different to those observed in the present experiment. Results obtained in those experiments do not match present findings, suggesting the importance of the variation in behavior that may be allowed by the size of the experimental space. In the experiment with concurrent FT schedules, the time allocation of rats in each dispenser was proportional to the percentage of water drops delivered by each dispenser. However, this effect was not observed in relation to time allocation in the frontal and surrounding areas of the dispensers. In the study with concurrent RT schedules, time allocation of behavior in the dispensers and their adjacent areas varied according to the proportion of water delivered by each dispenser, but this effect was not symmetrical. Rats spent additional time in Dispenser 1, where water was initially delivered, in such a way that differences in time allocation did not correspond to differences in the percentage of water provided by each dispenser. In this case, the primacy effect involved both the dispenser and the adjacent area. Primacy consisted of a spatial bias, in that the percentage of time spent in Dispenser 1 and its adjacent area was higher than the percentage of water obtained in that dispenser. The discrepancies between these experiments and the present study, being that the rest of conditions were the same, may be due to the difference in the size of the experimental space. Future studies should explore this possibility.

In any case, these two studies pose some questions on the plausibility of general "laws" assuming maximizing or matching relations between behavior and its outcomes. It could be the case that these relations take place because of the effect of highly restricted conditions, both regarding environmental variables and behavioral possibilities.

A study by Ribes-Iñesta and Chávez (1988) strengthens this assumption. Two food-deprived rats were exposed to different FT schedules, varying every fourth session from 30 s, 25 s, 6 s, 15 s, and 30 s. The experiment consisted of twenty-one 15 min sessions. The experimental space was an 80 cm × 80 cm prototype chamber. Two manually operated-food dispensers were located on opposite walls and a bulb above them was lit when a piece of sweet cereal was delivered. Only one of the dispensers provided food. In the middle section on one of the lateral walls was located a dispenser, with water available all the time. The experiment used the same intervals employed by Skinner (1948) in his "superstition" experiment, and explored the occurrence of adaptive behavior patterns as described by Staddon and Simmelhag (1971) and Staddon and Ayres (1975), in terms of consummatory, interim, and facultative behaviors. The behavior of rats did not support the generality of the assumptions and findings of previous studies employing a small size experimental chamber with pigeons and rats. No systematic behavioral patterning, involving sequences of interim, facultative, and consummatory responses were observed. Rats also did not show any form of stereotypy during the different inter-food intervals. Although water was continuously available, no adjunctive drinking behavior was observed. Most behavior was allocated to the operative food dispenser or moving around the chamber. Contrary to assumptions regarding the adaptiveness of food seeking behavior, rats in this study spent less time in the dispenser when the interval of food presentation was shorter, in such a way that they did not consume all the food delivered during those sessions. Space size is not a static variable because it induces an increment in the variation and amount of behavior to be displayed, affecting also the actual intervals when stimulus objects are contacted in different locations.

Present and previous findings suggest that even apparently simple behaviors in a relatively simple environment may not be understood in terms of a single, overall encompassing concept, such as matching. Water and food seeking behaviors do not seem to be a simple matter of adjusting to an ideal or optimal ratio between amount and availability intervals of consumables and the effort involved in obtaining them. Natural and social habitats involve a diversity of relations among individual organisms of the same species and of different species, as well as changes in the functional properties of objects and events with which they interact. The experiment reported here involved a single organism, without any predetermined behavior required to produce changes in the environment, and an environment that only provided water in two different locations discriminated by different light stimuli. In spite of this apparent simplicity, the spatial extension of the environment, the opposite location of water dispensers, the changes in relative frequency of water deliveries, and the concurrency of water administration, unexpected transitions were found in the ways in which rats distributed their behavior in the different areas of the chamber.

It would be wise to put aside preconceptions and economic-based formal models about ecological behavior and to begin to systematically explore the complex transitions and functional relations that take place between individual organisms and environmental circumstances, including other organisms.

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