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Structure of action plans and the notion of temporal stops

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Abstract

Planning serves the purpose of constructing series of ordered actions by anticipation. Such anticipation must take into account that since time is irreversible and open to a future of multiple outcomes -- and thus involves uncertainty about the data related to a problem -- the plan may need correction during execution. But the cyclical nature of certain events reduces the effects of this uncertainty, enabling one to calculate the likelihood that the various possible "chronicles" will occur in the future. It is thus hypothesized here that plans for action are only flexible and adaptable by virtue of their rigid, precise temporal structure, which is based on the periodic (regular and predictable) repetition of certain facts. This hypothesis was tested by studying 2 x 264 daily schedules, planned and executed by 33 farmers. The results show that (1) events which can always be predicted to occur at a given time each day enable the farmers to make well-structured plans, and (2) "temporal stops", i.e. the time limits of these cyclical events, play a crucial role in controlling the execution of the plans by modulating the duration of the planned actions as they occur.

RESUME

La planification a pour fonction de construire par anticipation des séries ordonnées d'actions. Cette anticipation doit s'assortir d'une possibilité de correction du plan en cours d'exécution car, par son caractère irréversible et son ouverture sur un futur aux multiples possibles, le temps implique une incertitude sur les données d'un problème. Mais l'aspect cyclique de certains événements réduit les effets de cette incertitude en permettant le calcul des probabilités de réalisation des diverses "chroniques" que le futur propose. Nous faisons donc l'hypothèse que les plans d'action ne peuvent être flexibles, adaptables, que grâce à une structure temporelle rigide, précise, offerte par la répétition périodique (régulière et prévisible) de certains faits. Cette hypothèse est testée par l'étude de (2 x 264) plans journaliers prévisionnels et réalisés correspondants, construits et exécutés par 33 agriculteurs. Les résultats montrent d'une part que les événements qui sont prévisibles tous les jours à heure fixe permettent l'élaboration d'une structure précise des plans prévisionnels et, d'autre part, que les "butées temporelles", limites horaires de ces faits cycliques, jouent le rôle crucial de repères pour le contrôle du déroulement du plan grâce à la modulation des durées d'action prévues, en cours de réalisation.

Key words: Time, planning, mundane situations.

Mots clés : Temps, planification, situations quotidiennes.

INTRODUCTION

In order to define the characteristics of the temporal framework upon which planning is based, we studied a natural situation (Valax, 1986) in which the subjects, in our case independent farmers, are responsible for managing their own time. The "day" was the time unit chosen among those conventionally used to account for human activities, since one day is long enough for the cyclical events of interest here to occur, and (for this initial approach) this unit was easier to control experimentally than longer time periods.

This article will present one of the aspects of this research project: the study of the effect of the time limits of cyclical events, which shall be called "temporal stops", on activity organization.

If planning consists of constructing series of finalized actions (Schank & Abelson, 1977; Leplat & Savoyant, 1984) to be performed in the more or less near future (Hayes-Roth & Hayes-Roth, 1979), then to study it, we must face the problems involved in defining the finality (the goal of the action) as well as the difficulties inherent in time itself. Indeed, if time is the basis of all activity, then it is particularly crucial both in making predictions and adapting plans to fit the actual execution of the planned actions.

1. Time and planning

1.1. Properties of time and projection into the future:

Research on planning, while emphasizing the importance of the temporal aspect of goal attaining, is generally limited simply to the study of the chronology of the activities (e.g. Sacerdoti, 1977; Cohen & Feigenbaum, 1982; Schank & Abelson, 1977). In this perspective, the properties of time (duration, cycles, rhythm, temporal horizon) are hardly investigated, whereas in logic as well as in conventional studies on the psychology of time (since Fraisse, 1957; Grize, 1966; Piaget, 1946), these factors have become essential.

A comparison of the models proposed by Von Cranach (1982) and McDermott (1982) illustrates that there are currently two important lines of research in this field. There seems to be some incompatibility in these two approaches between the static and organizational study of goal representation and the temporal processing of activities.

Von Cranach defines "goal-directed action" as a behavior directed towards a planned, intentional, and conscious goal. He goes further to define "goal" as the imagined state desired as the outcome of an action; the term goal refers to a "representation" whose content is located in the future and which guides behavior; a "plan" is the outline of the action, and consists of the anticipated representation of some of the characteristics of its means of execution. He proposes a

breakdown of the "action" into a "complex system" with three levels of organization defining the goal, the strategic stages, and the operational means implemented (the "acts"). This breakdown enables Von Cranach to set up hierarchical observation levels, and to propose an application for his theory. In explaining how he processed his experimental example, he diagrams (p. 55) the possible behaviors (the action) as a network within which the initial state evolves towards a goal via actions (acts), shown as arrows, that enable the actor to reach subgoals (nodes). Further on, however, the illustration made of his own observations does not treat the "arrowing" as a dynamic element, and the typologies mentioned account for sets of behaviors viewed as blocks that are disconnected from their temporal context.

Mc Dermott proposes a "temporal logic" to account for human activity. He does not explicitly situate himself with respect to the philosophical or psychological literature on time, but uses the main notions employed therein. Indeed, he bases his axioms on the notion of causality, continuous change, and the persistence of facts; he stresses the originality of the future, characterized by its openness to multiple uncertainties, as first proposed by Prior (1967). To illustrate his model, Mc Dermott uses a "tree of chronicles" (p.107) in which the states or "instantaneous snapshots of the universe" are organized into chronicles whose parallel paths account for the "openness of the future". The "date line" accounts for the "continuity of time", and allows for the establishment of relationships between the "states" located along the various chronicles. This diagram, which may be compared in an interesting manner to Von Cranach's model (the "states" correspond to the "nodes" or subgoals), does not enclose the chronicles within one goal; although it does not include arrows, it is entirely oriented by the date line. This initial conception allows Mc Dermott to "stage" the "facts" (sets of states), which are ever-changing, and to introduce the notion of "event", which refers to the "time during which the facts change". Previously developed logic systems (those proposed before his own) could only talk about a change in situation "as a succession of two different static situations".

The time element of human activity poses the problem of the synchronization of uncertain facts. For Mc Dermott, it is not possible to consider *all* future outcomes, nor only *one* outcome. The solution is to "bet" on a real future using a logic that assumes the contrary (p. 150). In this perspective, reasoning is thought to be based on a map of time that "determines the significant facts", locating the relative positions of the initial and final boundaries. This structured representation is thought to serve as a framework for the flexible organization of less probable facts, which are linked to the preceding facts by the "before", "after", and "during" relations (Charniak & Mc Dermott, 1985).

These fixed points are thought to serve the purpose of reducing the problems brought on by continuity and uncertainty. The transformation of continu-

ous time into discrete time would make it possible to organize processing by providing reference points for verifying the execution of the plan, which requires adaptation of the planned schedule to the (knowingly) unplanned facts (the basis of the "bet").

These two models seem to oppose the realistic application (Von Cranach) of the study of behavior, which is limited to its structural aspects, and the construction of a metric theory of time (Mc Dermott), which has yet to be applied to experimentation involving not only computer programs, but also human subjects. Wouldn't an attempt to define the "fixed facts" enable us to apply the "tree of chronicles" to the study of behavior?

1.2. Periodicity and cycles in the experience of time:

The cyclical aspect of time that Barreau (1982, 1985) called "cosmo-bio-social time" has been the subject of much research, such as that done on biological rhythms (Fraisse, 1980; Queinnec & Devolvé, 1986), social rhythms (Grossin, 1985), and conventional rhythms -- the calendar -- (Friedman, 1982, 1983, 1984). These studies have shown that "cyclical facts" allow for the structuring of activities by means of time scanning, which creates landmarks from which rhythms are constructed.

For Michon (1979) and Friedman (1983, 1984), such cyclical facts are the object of imaged representations (linear or circular) for comparing intervals, ordering facts, and determining reference points for verifying the unfolding of activities in time. An example of the "crucial role played by the weekend in the process of temporal orientation" was given by Shanon (1979): he showed that response time when naming today, tomorrow, or yesterday was shorter at the beginning and end of the week than in the middle of the week. In addition, his subjects justified their responses by stressing the importance of the evocation of "events" that occurred, or were to occur, during the to-be-identified day.

2. The notion of temporal stop

2.1. Temporal stops as obstacles:

In research on the organization of mundane activities (Theureau, 1981), we come across the notion of temporal stop used to qualify certain activity time limits. These time limits are the boundaries of punctual events such as waiting for a doctor (Theureau, 1981), care of animals (Cellier & Marquié, 1984) or preparing for an examination, etc. They are considered to be "constraints" or annoyances in the organization of time, which then becomes restricted before (and by) the expected event.

2.2. Cyclical facts and temporal stops as stakes:

But if, thanks to the experience the subject has of certain cyclical facts, he/she integrates the possible occurrence of such events, the temporal stops become unstressing consequences of the scheduling; they become positive insofar as they aid in structuring future time and controlling how the activity actually unfolds. They could be considered as landmarks, which are to mundane activities what subgoals are to goal attaining in problem solving, i.e. they are the stakes, or temporal subgoals for marking off the unfolding of time, thus contributing to how the subject orients him/herself in time.

3. General hypothesis

In the context of the irreversibility of time and the openness of the future, the planner is faced with a difficulty: since action plans are built from partially defined data, the planner must foresee the need to make possible corrections to the plan during execution without questioning its validity, even though such corrections are liable to lead him/her to challenge that validity by desynchronizing the foreseen future events.

For an action plan to be valid, it must take an active part in controlling its own execution. The inherent cost of such control leads us to favor the idea that such plans are based on a cyclical representation (Mc Dermott) rather than on a linear representation (Von Cranach).

Plans based on a linear, arrowed representation which endows each goal with a specific sequence of actions would require verification of each successive fact. Moreover, this type of representation would in itself be a source of unpredictability, in that the execution and control of activities would interfere with each other by simultaneously requiring contradictory cognitive resources.

Plans based on a cyclical representation, which defines a precise temporal structure that can be used by a given class of goals, and which is constructed according to the predictability (probability of occurrence and time of occurrence) of facts whose cyclical nature is known (by experience), enable the discontinuous checking of the validity of the plan, thus limiting the cost of control and the sources of disturbance.

METHODOLOGY

1. Subjects and observation method

Thirty-three men (independent farmers) were asked on two occasions to account for their time for a period of four consecutive days by filling out "time budgets" (Guilbert et al., 1965), i.e. grids marked off in quarter hours. The time budgets were first elaborated during an individual interview held the day before

the first day in each set of four days: these were the "planned schedules" (PS). Then for the next four days, the subjects filled out the grids (alone) by indicating the tasks actually performed: these were the "actual schedules" (AS).

We thus obtained 2 x 264 time schedules in all, including both planned and actual schedules (PS and AS).

2. Hypotheses and variables

Hypothesis A: If the planning process develops around periodic facts, all planned schedules should have the same structure for a given time unit, regardless of the characteristics of that time unit. By opposition, if the process of planning depends on a series of facts specific to the goal to be obtained, the planned schedules should have a distinct structure for each unit of time considered.

To test hypothesis A, we varied the times at which data was collected according to the "demand level" of the time periods being observed. By demand level, we mean the imperativeness of the tasks that must be performed in addition to the usual activities (considered as being of the lowest demand level).

Accordingly, it is the seasons that determine the various levels of demand for farmers. For example, ripe vegetables lead to additional harvesting tasks. Similarly, Sunday does not have the same social status as the other days of the week with respect to farming tasks. The times chosen in our experiment for recording the schedules were thus as follows:

- * The two seasons that are the most representative of agricultural activity in southwest France were chosen: (1) summer (end of June, beginning of July), the high season (HS) where activity is intense, and (2) autumn (end of November, beginning of December), the low season (LS).

- * For each season, a series of four consecutive days (from Saturday to Tuesday) were chosen for observation. Sunday, where the demand level is low compared to weekdays, was thus included in the study.

Four levels of demand were defined by crossing the time-schedule recording conditions (Figure 1). Although two of these levels were easy to rank: the maximum demand level (rank 1) for weekdays in high season, and the minimum demand level (rank 4) for Sundays in low season, the intermediate levels (weekdays in low season and Sundays in high season) could not be considered equivalent. If the weather is perceived as more imperative than the social habits favoring weekend family activities, then weekdays in low season are most likely less "constraining" than Sundays in high season. The demand levels of the days studied were thus ordered as shown in Figure 1.

If the action plans constructed for the different days are based on a common temporal structure, then the time limits of the cyclical events (the temporal stops) in the planned schedules (PS) should be identical, regardless of the demand level involved.

Figure 1. Definition of demand levels by season and by day.

		SEASON	
		Summer	Autumn
DAY	Weekday	Demand level	
		+	-
	Sunday	-	
		+	+
		1	3
		-	+
		2	4

Figure 1. Définition des niveaux d'exigence en fonction des saisons et des jours.

Hypothesis B: Both the verification of a plan's validity and the handling of necessary corrections should depend on the coherency between prediction and execution within the temporal framework: this implies that the planned schedules and the actual schedules have a common structure. In the opposing case, i.e. when the succession of events takes priority over the periodicity of the facts during verification, the planned schedules and the corresponding actual schedules need not have a common temporal structure.

Hypothesis B was tested by comparing pairs of schedules (PS and AS) produced by each subject for each of the 8 days under consideration. We expected the cyclical fact time boundaries (the temporal stops) to be identical on both types of schedules.

3. Data analysis

Sixty-one different activities were specified by the farmers on their schedules. To facilitate processing, these activities were grouped into 7 categories: animal care, work in the fields, cleaning and maintenance, management and sales, family life, social life, miscellaneous.

Only the data concerning cyclical facts will be dealt with here, i.e. those activity categories likely to create "temporal stops" for the subjects.

The percentages calculated for each category were based on the total number of waking hours. The significance of the observed differences was assessed either by Student's *t* test or by the Wilcoxon test.

RESULTS

Analysis of the time schedules showed that there were indeed periodic facts whose boundaries formed "temporal stops" (cf. §1.1). We were thus able to

study the variations in the temporal stops for each of the defined observation conditions (Hyp. A, cf. §2; Hyp. B, cf. §3).

1. Evidence of the existence of temporal stops

In the time schedules recorded (planned and actual), farmers systematically marked certain activities at set times of the day. These activities pertained both to animal care and breaks for family life (see Table 1).

TABLE 1. Proportion of recorded activities involving animal care and family life on the planned and actual schedules (PS and AS).

		PS	AS
Animal care	Morning	95.83	91.28
	Evening	83.33	79.54
Family life	Midday	92.80	91.29
	Evening	95.45	93.18

TABLEAU 1. Pourcentages des citations des activités concernant les soins aux animaux et la vie familiale sur les plans prévisionnels (PS) et réels (AS).

Since the proportion of other activities scheduled at set times of the day never exceeded 43%, we can consider the above two activities as the "cyclical facts" upon which the action plans were based. The time boundaries of these cyclical facts are thus the "temporal stops" whose variations we have set out to study.

Table 2 lists the seven "temporal stops" observed, in chronological order.

TABLE 2. Description of "temporal stops".

Time of day	"Periodic" facts	Boundaries of the "periodic" facts	Stop N°
Morning	A - Animal care	beginning of A	1
		end of A	2
Midday	B - Family break	beginning of B	3
		end of B	4
Evening	C - Animal care	beginning of C	5
		end of C (= beginning of D)	7
	D - Family break	beginning of D (= end of C)	7
		end of D	7

TABLEAU 2. Identification des "butées temporelles".

Since each subject produced 8 planned schedules (PS) and 8 actual schedules (AS) (2 seasons x 4 days in each case), the following comparisons concern the 56 PS stops (7 stops per schedule; §2) or the 112 PS + AS stops (§3).

2. Variation of the planned schedule temporal stops by demand level

2.1. Evidence of the overall stability of the temporal stops:

Figure 2. Planned schedules and actual schedules for performing mundane tasks, by day (weekday vs. Sunday) and by season (high activity vs. low activity).

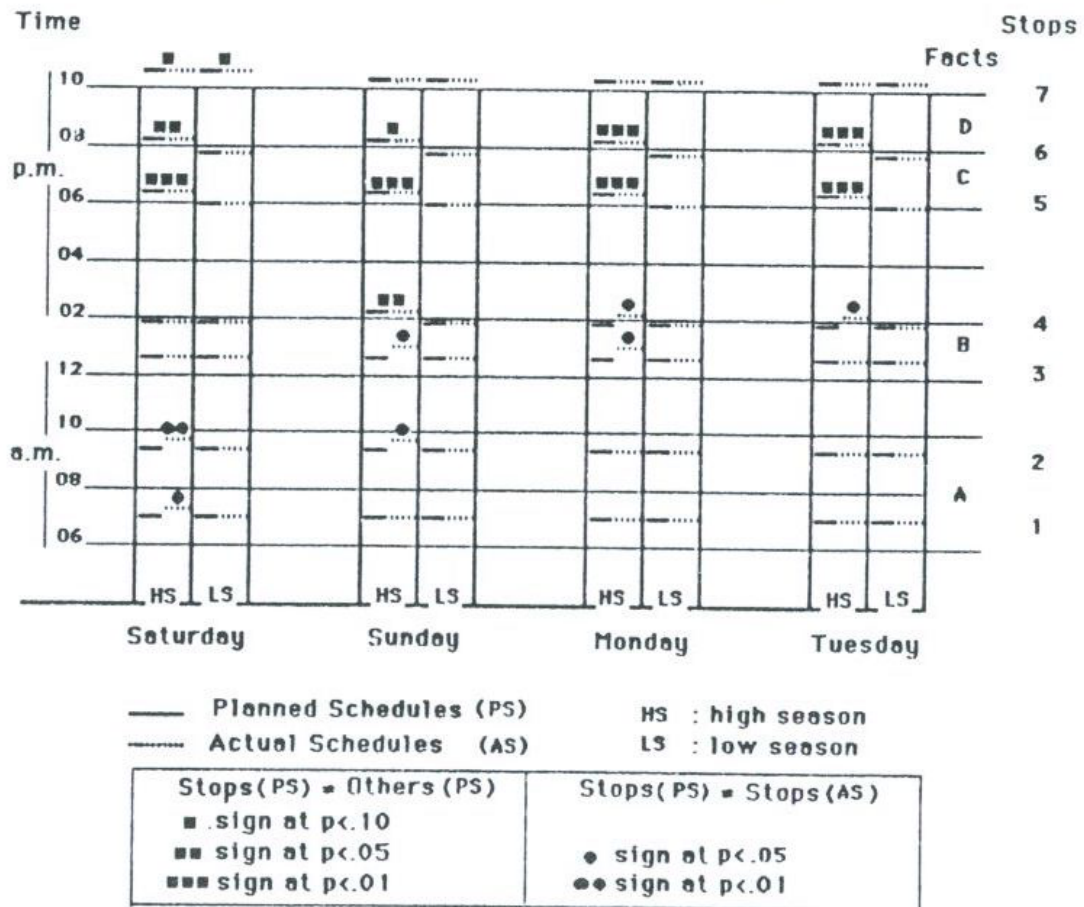


Figure 2. Horaires prévus et horaires de réalisation des tâches quotidiennes en fonction des jours (semaine versus dimanche) et périodes (creuses versus d'activité intense).

Figure 2 presents the subjects' planned and actual schedules. The 11 significant deviations observed between the various planned schedules (PS) only pertain to one particular time of day. Close analysis of these deviations indicates that they are consistent with a precise overall framework.

2.2. Meaning of the observed deviations:

a) If we compare the planned schedules (PS) of the two seasons studied, we can see that the "temporal stops" that delimit animal care in the afternoon were delayed during the high season as compared to the low season. Table 3 gives the details.

The weather conditions of the seasons in question differ as to the duration of daylight and environmental temperature, both of which are at a maximum during the high season and at a minimum during the low season. The observed differences may thus be the cumulative effect of the increase in work load during the active season (work in the fields, for example) and incentive to work later on outside tasks due to the weather.

TABLE 3. Seasonal differences in temporal stops (Student's t and significance of the differences).

	"Summer schedule > Autumn schedule"			
	Saturday	Sunday	Monday	Tuesday
Stop 5	5.12 p < .01	5.84 p < .01	4.60 p < .01	4.61 p < .01
Stop 6	2.21 p < .05	1.90 p < .10	4.70 p < .01	3.41 p < .01

TABEAU 3. Différences des butées temporelles entre saisons (valeurs des t de Student et signification des différences).

b) If we compare the temporal stops of the planned schedules (PS) for a given day to the planned schedules (PS) of the other days, we can see that there is very little variation. Existing variations pertain only to the end of family breaks on the weekend. Table 4 gives the details.

TABLE 4. Daily differences in temporal stops (Student's t and significance of the differences).

	High season	Low season
Stop 7 Saturday > other days	1.95 p < .10	1.79 p < .10
Stop 4 Sunday > other days	ns	2.22 p < .05

TABEAU 4. Différences des butées temporelles entre journées (valeurs des t de Student et signification des différences).

The slight shifts in stop 7 on Saturday and stop 4 on Sunday may indicate that the daily time schedules do not exactly correspond to the "physical day". These shifts lead us to assume that "psychological Sunday" begins during the family break in the evening of "physical Saturday" and ends on "physical Sunday" after the midday break. The lack of shift in stop 4 on summer Sundays supports our assessment of the demand levels (§2).

3. Shifts in temporal stops on the actual schedules (AS) as compared to the planned schedules (PS)

3.1. Evidence of the overall stability of the temporal stops:

Comparing the planned schedules to the actual schedules on a quarter hour basis, we can see that only 58% of the quarter hours have a similar content on both types of schedules. (Since the activities are grouped into categories, this proportion is in fact an overestimation.) Cyclical activities take up 43.7% of the time on the planned schedules, and 42.87% on the actual schedules. Cyclical activities thus account for 74% of the congruence between the planned schedules and the actual schedules. This high percentage shows us that it is indeed important to compare the time boundaries for these activities, i.e. to study the differences between PS stops and AS stops.

3.2. Meaning of the observed differences:

a) No difference between PS stops and AS stops was observed for the low season. The differences found pertain only to the high season stops. Table 5 gives the details.

TABLE 5. Shifts in AS stops from their PS position (Wilcoxon test values and significance of the differences).

	"Only in High Season, AS schedule > PS schedule"			
	Saturday	Sunday	Monday	Tuesday
Stop 1	2.39 p < .05	ns	ns	ns
Stop 2	2.86 p < .01	2.03 p < .05	ns	ns
Stop 3	ns	2.27 p < .05	1.99 p < .05	ns
Stop 4	ns	ns	2.31 p < .05	2.31 p < .05

TABLERAU 5. Décalages des butées temporelles des plans réels (AS) par rapports aux plans prévisionnels (PS) (valeurs au test de Wilcoxon et significations des différences).

The existence of deviations on high season Sundays (consistency with § 2.2.b) again indicates that Sunday becomes more commonplace in summer. The increase in demand level seems to affect the accuracy of the plan, and for the situation studied, the weather (daily or seasonal) takes priority over social habits (day of the week).

b) All deviations represent delays in execution of the planned schedule: the 7 PS stops that were shifted all occurred later than the corresponding AS stops. It looks as though the subjects only change their execution schedules in light of events that are added to those already planned (additional tasks or work that takes longer than expected), while they never anticipate execution of a "periodic" task, and thus do not modify (in advance, thus deliberately) the organization of their day.

c) Whenever an AS stop was shifted from its PS stop position, the shift was not carried over to affect the entire day, but was absorbed by the end of the next activity. It appears that each time a subject "notices" a shift in the time at which a stop occurs, he/she modifies the predicted durations as the following activity is being performed.

GENERAL DISCUSSION

The scheduling of an activity in time implies that action plans are adaptable. In order for a plan to preserve its validity despite the multiple possibilities the future holds, it must be based on a precise temporal structure, and not on a series of successive facts, as the alternative hypothesis postulates (cf. §1.3). The building of such a structure is made possible through the subject's experience of cyclical facts, which delimit time intervals and thus provide subgoals within the to-be-planned time period.

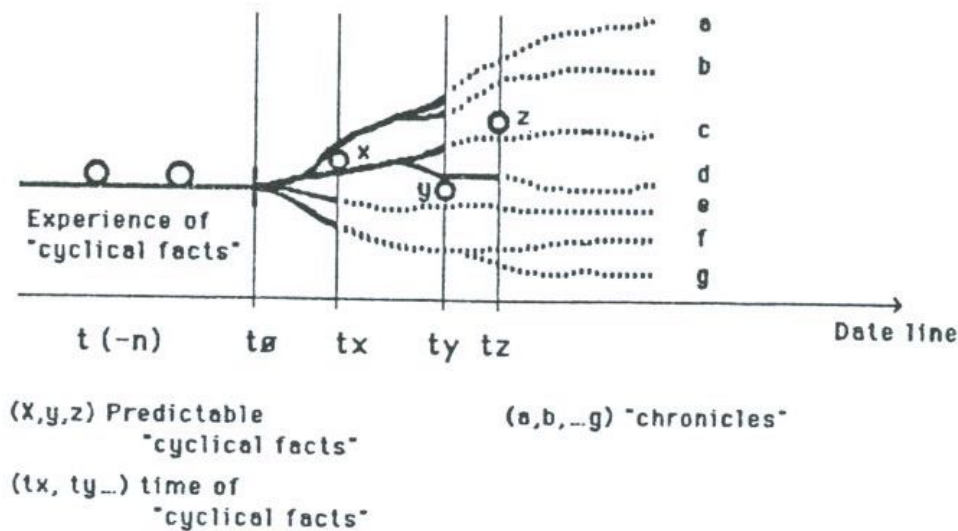
The temporal boundaries of these cyclical facts do indeed "stake out the time" in that they are the landmarks by means of which the subjects make corrections every time they check to see whether the planned schedule and the actual execution of the activity do in fact correspond to each other.

The rarity of the deviations between planned schedule and actual schedule, and the fact that such deviations are absorbed very soon after having been discovered, stress the importance to the subjects of the stability of the planned schedules. We might attempt to explain this stability.

By qualifying the "fixed facts" in Mc Dermott's (cf. §1.1) tree of chronicles as "cyclical facts", we are now able to propose an operational logic model for the study of behavior based on the scanning of ongoing time around subgoals that can be predicted by the planner. Figure 3 illustrates this proposal.

The distances between the marks on the date line can be attributed the role of temporal spans. This definition makes it possible to account for the main outcomes of our experiment, and to raise some questions concerning other situations which were not studied here.

Figure 3. Contribution of cyclical facts to the management of "chronicles" (cf. Mc Dermott, 1982) in planning.



If at time t_0 , the subject can indeed be confronted with a series of possible "chronicles" (a...g), the experience he/she has of the existence of cyclical facts makes it highly unlikely (dotted line) that a chronicle that does not integrate a cyclical and thus predictable fact (x, y, or z) will apply. Instead of an increase in the number of chronicles as time passes, there is a reduction in the probability of the "wrong" chronicles, and thus the tree is pruned *before* the beginning of execution: at time t_x , unlikely of the *efg* chronicles, which do not take x into account; at t_y , unlikely of *abcfg*; at t_z , unlikely of *abdefg*. The choices or constraints will depend on the distances between (t_0 , t_x), (t_0 , t_y), and (t_0 , t_z). The decrease in the number of possibilities varies by the time span under consideration at planning time: x may not be relevant to time span (t_0 , t_y); if both x and y, then what happens to chronicle e? If z, then x and y are not relevant.

Figure 3. Apport des faits cycliques à la gestion des "chroniques" (cf. Mc Dermott, 1982) pour la planification.

Accordingly, in our example, if z represents "animal care" and t_z , the time at which z occurs, is considered to be a given "time" (as in our calculations, Table 3), then we can see that there is a difference between autumn stops and summer stops: in order to be planned, different chronicles must be evoked for activities that take seasonal variations into account, like length of daylight, multiplicity of events (with their respective durations).

But if management of the date line is done according to landmarks other than the time on the clock, t_z could be "sundown \pm a few minutes"; if so, it is the distance (t_0 , t_z) that is modulated according to the season, and the same chronicle can handle the cyclical facts of any day in the year. In this case, the temporal stops of autumn and the temporal stops of summer are indistinguishable.

It is obvious with an example like this one that the cyclical facts defined depend on the type of subject chosen. An office worker planning for the same time "span" would not have the same cyclical facts as landmarks, nor would his/her date line be determined in the same way as the farmer's.

Perhaps the problems posed by the simultaneous execution of more than one task by the same subject, or those encountered in the execution of one task by several subjects, stem from difficulty in discovering the cyclical facts common to the tasks or (co-)operators, even if the importance of the social, external (calendar, clock, instructions, ...) determination of the date line cannot be neglected.

Similarly, could we account for the newness of an activity simply by the fact that the subject has not yet had the chance to set up landmarks based on the discovery of cyclical facts, regardless of the time span under consideration, for an activity of daily living or in solving a so-called well-defined problem? The discovery of such facts (that experience would render cyclical) may enable him/her to make an exact plan of the actions to be undertaken.

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