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PLANNING FOR INTERRUPTIONS: THE SCIENCE OF MANAGING THEIR EFFECT

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How often have you been in the following situation? You have an important project to complete, but day after day ends with you muttering, "I didn't get anything done today." Usually this muttered complaint can be translated more accurately as, "I didn't make any progress today on my important project because of the frequency of *also* important, and even necessary, interruptions."

This article brings to light the amazing delaying power of too-frequent interruptions, and shows that their effect can be much more devastating than intuition alone would allow us to conjecture. A model is presented for use in assessing the time lost when certain interruption patterns prevail; simple remedies to increase effective use of time are suggested.

One purpose of our model is to confirm the obvious — the fact that we pay a high price in wasted time, if we attempt projects that require an uninterrupted time span longer than the average length of time between interruptions. The other, more ambitious, purpose is to provide convincing evidence that the effect of interruptions can be controlled through organization. Busy people who set aside time for planning, who organize their lengthy projects into a sequence of shorter subtasks, are amply rewarded for their investment in "interruption planning."

The Parable of the Watchmakers

The cost of interruptions is perhaps most dramatically illustrated in a tale of two watchmakers attributed to Herbert A. Simon [1969]. These two, aptly named Hora and Tempus, both produced very fine watches which came to be in great demand. Their workshop phones began to ring frequently, bringing orders from new customers. Hora prospered while Tempus became poorer and poorer and finally lost his shop.

Both men made watches that consisted of about 1000 parts. Each time an interruption occurred — for example, to answer the phone — the pieces currently being assembled fell apart and had to be reassembled from scratch. Hora's secret of success was that he had designed his watches so that he could put together components of about 10 parts. These 10-part components, once completed, were "stable" and could be set aside for later use as a unit. Ten of these components were then assembled into a larger stable sub-system. Later the assembly of the ten larger sub-systems constituted the whole watch. Tempus, on the other hand, had no stable sub-systems and lost much more than Hora in response to each interrupting phone call.

STATISTICS—PATTERN ANALYSIS; SIMULATION

If, for either watchmaker, the probability of interruption, while any part is being added to the assembly, is $p = .01$, then, using the model that we develop below, we can estimate that the cost of interruptions to Tempus is about 39,000 times their cost to Hora.

Formalization of the Interruption Problem

Let us suppose we have a project or task whose completion requires a sequence of A uninterrupted time units. In the watchmaker tale, we can identify a time unit as the length of time required to add an additional part to an assembly. Thus, for Hora $A = 10$, and for Tempus $A = 1000$. Other tasks, such as the writing of a report, may require time intervals such as three uninterrupted hours. Three uninterrupted hours may be designated also as 180 uninterrupted minutes or 18 uninterrupted 10-minute blocks. The problem context may dictate one choice of unit as preferable.

In this analysis, we assume that interruptions are devastating in their effect. That is, we must return to the beginning of our project — no matter how much progress has been made — and start again from scratch after an interruption has occurred. Thus, if our project is a report which we have already thought of in terms of distinct chapters which can be worked on independently, then the length of time required for a chapter (not the whole report) determines our value of A. Although this assumption of the devastating effect of interruptions is a bit more rigid than what may occur in practice, it is frequently a reasonable one. It is in exactly those cases where interruptions are approximately devastating that their effect causes a problem.

To calculate the expected effect of interruptions requires a probability estimate. We let p denote the probability of an interruption, occurring at random, during any specific time interval. Alternately, $1/p$ is the average number of time units between interruptions. Ability to estimate p may affect our choice of units in describing A. For example, if we wish to get a three-hour task completed without interruption and we can estimate the average time between interruptions as 20 minutes, then we might think of A as a sequence of eighteen 10-minute intervals, $A = 18$, with $1/p = 2$ and $p = .5$. Numerous other pairs of related A and p values also are possible.

In this model we also assume that the interruptions are independent. That is, each interruption has no effect on the pattern of subsequent interruptions. Where independence does not hold — i.e., in situations in which one has control over interruptions — they cause much less of a problem. They can simply be scheduled so as to allow for the needed uninterrupted time.

In summary, then, at this point we have a model in which:

- A is the number of noninterrupted time units required for a task
- p is the probability of an interruption during any single one of the A time units
- $1/p$ is the average number of time units between interruptions.

Furthermore, we have stipulated that interruptions are both *devastating* and *independent*.

The *cost* of an interruption is the number of time units that become wasted time because of the interruption. In the watchmaker parable, Hora pays an average cost of five time units per interruption. For Hora the random interruptions can occur at any time during his assembly of 10 parts and these uniformly distributed values have a mean of 5. For Tempus, on the other hand, the average number of parts assembled without interruption is $1/p = 100$, and this figure gives the cost, to him, of an interruption. In general, if $A/2 \leqslant 1/p$, the average interruption cost is $A/2$. In cases where $A/2 > 1/p$, the average interruption cost is $1/p$ time units. Summarizing these two cases, with C denoting the expected cost of an interruption, we have

$$C = \text{Min}\ [A/2,\ 1/p].$$

The probability that an interruption will not occur during any specified time interval is given by $(1-p)$. Using the assumption of independence, we may calculate the probability of *no* interruptions during A consecutive time intervals to be $(1-p)^A$. This quantity may also be interpreted as the ratio of the number of completed tasks to the number of starts. For Hora, $(1-p)^A = (.99)^{10} \approx .9$. In other words, as our intuition also suggests, Hora will complete, without interruption, an average of 9 out of each 10 assemblies that he starts. For Tempus, $(1-p)^A = (.99)^{1000} \approx .000043$. Tempus will complete, without interruption, only 43 starts in 1 million — or about 1 in 23,000. The reciprocal of the ratio of the number of complete tasks to the number of starts is also of interest. This value, which we denote by N, gives an estimate of the number of starts per completed task. We have

$$N = \frac{1}{(1-p)^A}.$$

For Hora, $N_H \approx 1.1$ starts per completed assembly, and for Tempus, $N_T \approx 23{,}000$ starts per completed assembly.

The probability that an interruption *will* occur during one of the A consecutive time intervals is $1-(1-p)^A$. Multiplying this by the average cost C of each interruption gives the expected time lost per start, which we denote by S. We thus have

$$S = C\ (1-(1-p)^A).$$

For Hora, the average time lost for each assembly started is $S_H \approx .48$ time units. For Tempus, $S_T \approx 100$ time units.

All of the preceding has been developed to set the stage for estimating the *total time* that we can expect to lose in the course of a project *because of interruptions*. The total time lost per assembly is the product of the time lost per start and the number of starts per completed assembly. If this total interruption time is denoted by I, then we have

$$I = SN.$$

Substituting the formulas for S and for N yields

$$I = C(1-(1-p)^A)\ \frac{1}{(1-p)^A}.$$

Finally, substitution for C, from above, gives

$$I = \frac{(\text{Min}\ [A/2,\ 1/p])\ (1-(1-p)^A)}{(1-p)^A}.$$

Applying this last formula we can calculate the total time lost per assembly for our watchmakers Hora and Tempus and obtain:

$$I_H = \frac{5 \times (1-(.99)^{10})}{(.99)^{10}} \approx .53 \text{ time units;}$$

$$I_T = \frac{100 \times (1-(.99)^{1000})}{(.99)^{1000}} \approx 2{,}300{,}000 \text{ time units.}$$

(For our calculations for Tempus and Hora to be comparable we must recall that for Hora the cost is .53 time units for each of 111 subassemblies of 10 parts each, and thus Hora's actual time loss due to interruptions is $111 \times (.53) \approx 59$ time units.) Thus Tempus pays about 39,000 (2,300,000/59) times as much time in interruption costs as Hora.

The total time, which we will denote by TT, required to complete a project is the sum of the uninterrupted time required and the time lost to interruptions. For Hora, this sum is $TT = 1110 + 59 = 1169$. In general, if there are n subtasks, each requiring A units of uninterrupted time, and if there is an interruption pattern which costs I units of time for each subtask, the formula is

$$TT = n \times (A+I) = (n \times A) + (n \times I).$$

An Example Illustrating Use of the Model

In developing our model we have indicated its application to the Tempus-Hora situation; perhaps a realistic example will be more convincing.

Let us suppose that Assistant Vice President X is trying to find time to write a first draft of a report which she estimates will take her three uninterrupted hours. Because this report requires a tight logical development and intense concentration, she feels that any interruption will be devastating; that is, after an interruption, three *more* uninterrupted hours will be required to complete the draft. Although she has never kept track of the frequency of her interruptions she is, after a few moments reflection, able to estimate that the average time between interruptions is 30 minutes. If we measure time in 10-minute blocks, then the expected number of time intervals between interruptions is $3 = 1/p$, and $p = 1/3 \approx .33$. The project thus requires $A = 18$ consecutive uninterrupted intervals (supposing the interruptions to be independent).

Using our model, since $A/2 > 1/p$, we have $C = 3$. Then

$$S = 3\,(1-(2/3)^{18}) \approx 3 \text{ time intervals lost per start,}$$

$$N = \frac{1}{(2/3)^{18}} \approx 1478 \text{ starts,}$$

and the time wasted on interruptions is

$$I = SN \approx 4434 \text{ 10-minute intervals.}$$

Of course, this cost figure is a ridiculous one and confirms what we might have believed at the start — that is, that Vice President X will probably *never*, under the stated circumstances, find time to get her report written.

Let's consider some variations on the problem of Vice President X. Suppose the average time between interruptions is 60 minutes; then $p = 1/6 \approx .167$.

In this case,

$$S = 6\,(1-(5/6)^{18}) \approx 5.77 \text{ time intervals lost per start,}$$

$$N = \frac{1}{(5/6)^{18}} \approx 26.62 \text{ starts,}$$

$$I \approx 153.60 \text{ 10-minute intervals,}$$

which is still much too high a price to pay.

Consider a different approach. (Here we return to $p = 1/3$.) Vice President X estimates that if she can find one uninterrupted hour she can organize her thoughts sufficiently so that the report can be written in six additional half-hour segments. She arrives at work one hour early to do this. After she has invested the hour of organizational time, she has reduced A from 18 to 3. For each of the six subtasks, the interruption costs may be calculated:

$$S = (3/2)\,(1-(2/3)^3) \approx 1.06 \text{ time intervals lost per start,}$$

$$N = \frac{1}{(2/3)^3} \approx 3.4 \text{ starts per half-hour segment,}$$

$$I \approx 1.07 \text{ time intervals lost per half-hour segment,}$$

Total interruption costs are thus $6I \approx 21.48$ 10-minute intervals (just over 3½ case hours). This figure is still not good but represents a significant improvement.

On the other hand, if $p = 1/6$, we have:

$$S = (3/2)\,(1-(5/6)^3) \approx .63 \text{ time intervals lost per start,}$$

$$N = \frac{1}{(5/6)^3} \approx 1.7 \text{ starts per half-hour segment,}$$

$$I = 1.07 \text{ time intervals lost per half-hour segment.}$$

Total interruption costs are thus $6I \approx 6.42$ 10-minute intervals (just over one hour). Of course, the extra organizing hour must not be neglected in calculating total time costs.

The strategy of working early or late to cut interruption costs is frequently used by busy people in responsible positions who must juggle their time to meet two types of requirements — to find time both for uninterruptible reflective types of activity and also time for the unscheduled interruptions from which the essential fabric of dealing with people and process is woven.

While in many cases interruptions themselves cannot be controlled, some planning can enable us to gain control of their *effect*. It is not necessary for busy people to extend their working days excessively — as some do — to *avoid* interruptions. What is required, however, is that a limited amount of time be set aside for organizing lengthy projects into subtasks, so that the time available between interruptions can be well utilized, and the effect of interruptions thus controlled. Below we present some figures and formulas that can be useful in planning — in restructuring lengthy tasks to avoid paying too high a price for our interruptions.

Average Time Lost to Interruptions

It is difficult to gather good data on the actual time lost on a lengthy project because of interruptions that required a return to the start. Since the interruptions are necessary, individuals have tended to view whatever effects they have observed as also necessary and have tried to cope with such a situation rather than analyzing and managing it.

Controlling the Effect of Interruptions

When $1/p \approx A$ and $p < 0.5$, the interruption costs are approximately A. It is reasonable to use this to establish a practical limit on the amount of time we will ever allow ourselves to lose to interruptions. That is, a task should never be attempted without adjustment of A and/or p so that $A < 1/p$.

If we require that interruption costs shall not exceed a fixed percentage of A, then we can derive a relationship between A and p. In particular, if we wish total interruption costs not to exceed $k \times A$ (where $0 < k \leq 1$), then from the equation

$I \leqslant k\,A$ we can obtain the following constraint on p and A:

$$p \leqslant 1 - \frac{1}{(1 + 2k)^{1/A}}$$

If a task requiring A time units is subdivided into n subtasks, each requiring A_n $(= A/n)$ time units, the number of time intervals, I_n, then lost on interruptions is given by

$$I_n = \frac{n\,(\mathrm{Min}\,[A_n/2,\ 1/p])\,(1 - (1-p)^{A_N}).}{(1 - p)A_n}.$$

Using the formulas provided as a basis for calculations, tables may be simply prepared to read off:

(a) Average time lost to interruptions for ranges of A and p
(b) Maximum interruption probabilities for ranges of A and k
(c) Expected interruption time losses (for a range of p) which result from breaking down a large task into varying size subtasks.

In general, the following rule of thumb (rather than calculations) may prove most useful: if the time wasted because of interruptions is not to exceed the total noninterrupted time a project will require, then A and p must be related by $A < 1/p$. Any situation in which $A > 1/p$ causes excessive waste of time and, when $A < 1/p$, the greater the difference the better.

Assessing Trade-offs

Ability to organize tasks to keep interruption costs to a minimum is an art rather than a science. Since organization time will be required to reduce to subtasks, the trade-off between organization time and interruption time should not be ignored. For example, when $p = 0.2$, if one hour of organizational time is required to subdivide a 20-time-unit project into 10 subtasks of duration 2 time units each, and if significantly more organizational time would be required to subdivide the project into 20 subtasks, this latter subdivision may not be worthwhile.

Conclusion

There is no such thing as a project that requires A uninterrupted time units — where A is large. The truth is more like this: without an initial investment of time to organize the project, it will require A uninterrupted time units. Unstated, when we estimate the requirement of A uninterrupted time units, is an unwillingness to invest organizational time to restructure the project into a number of subtasks of shorter duration. We see clearly the cost in time we must invest in organization and avoid facing the time costs of our interruptions. Generally speaking, in such a case, we are trading a molehill for a mountain. We are trusting our project completion to luck, and the probabilities are not on our side.

The Tempus-Hora parable did not tell the whole story. The beginning was omitted. Sometime, long before we entered the picture, Hora invested some organizational time in which he designed his assembly process for watches in terms of small stable substructures. His investment, perhaps great, in organization time, paid off because it provided him with low interruption costs.

Go thou and do likewise!

REFERENCE

Simon, Herbert A., 1969, *The Science of the Artificial*, MIT Press.