PROCRASTINATION DYNAMICS:
A STUDY OF DELAY TACTICS AND THEIR IMPLICATIONS

Wang Zhao, Khaled Gaafar

Procrastination Dynamics: A Study of Delay Tactics and Their Implications

Wang Zhao, Khaled Gaafar

European Master in System Dynamics, University of Bergen, Norway

Abstract - In dealing with compulsory or voluntary task, a common phenomenon always experienced by students is procrastination. Procrastination causes not only substandard quality in outcome, but also results in tiredness and high stress levels which is unfavourable to mental well-being. In this paper, procrastination is modelled through a system dynamics perspective to understand its underlying mechanisms behind it. The model is based on Sterman's (2000) "Managing Your Workload" problem, as well as the authors' own experience with procrastination. It capitalizes on the concepts of perception delays, utility cost-based decision-rules, and crisis management techniques procrastinators employ, with the goal of unravelling such processes and misperceptions therein. The paper concludes that repeated misperception of an extra utility cost for starting work results in procrastination, that such misperception is related to workload of the task, and that physical limit holds procrastinator from working as fast as anticipated. We then move to recommend policies to overcome the wicked problem that touches many people's lives adversely.

***Keywords* – System Dynamics, Procrastination, Expectation Formation, Decision Making.**

I. INTRODUCTION

Procrastination derives from the two Latin words 'pro' and 'crastinus' which translate to 'in favour of' and 'tomorrow' respectively. It thus takes a form of affinity to putting off a prescribed task, or a series of tasks to a later date. In the information age, Moore's law dictates that every 18 months we are bombarded with more and more alluring distractions that could impair us from consistent performance over a specific task-horizon. It is easy to fall victims of procrastination. It has been argued that some people procrastinate due to fear of failure, concerns about ability, excessive work pressure (Tucker-Ladd 2006), fear of success (being handed more tasks and the resulting increased workload) without sufficient reward, or perfectionism which leads to procrastination (Seo, 2008). This paper examines an unintentional, or at least unconscious type mainly in the academic context. It is assumed that those people, even procrastinating, can perceive the rewards of the tasks they are postponing, and still willing to take action for it. However, such effort to take actions keeps failing for some reason, i.e. they *de facto* do nothing until the deadline draws very close. Researching such prevalent phenomenon, it is worth noting that some university counselling services distribute pamphlets addressing procrastination, which makes it a worthy topic of study and analysis.

II. PROCRASTINATION IN OBSERVATION

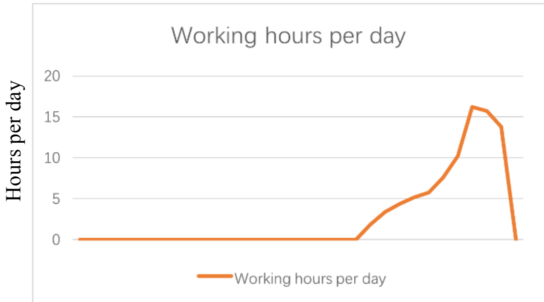
A typical procrastination starts with undertaking a task. The task doesn't necessarily need to be compulsory. Although in most cases tasks are attributed by some degree of compulsion, people also procrastinate with voluntary plans. For instance, diet, exercise, or even the mission to stop procrastination. Procrastination in tasks with deadline is easier to identify, but this doesn't mean there is no procrastination in continuous tasks. Participants in both kinds of tasks could be subject to procrastination (Akerlof, 1991).

High-achievers can also be procrastinators, and not rarely so. It may be argued that procrastination pays off, judging against mainstream academic standards (Onwuegbuzie, 2004). Despite social stigma against procrastination, the outcome can be 'very good' which explains why some students invest the absolute minimum time and effort, to maximize the output, which would give a feeling of triumph over the system. The drawback of cramming is, however, that it impairs true learning achieved by more sustainable, methodological approaches to studying (McIntyre & Munson 2008).

Procrastinators tackle a task by simply 'doing nothing', or it at least it seems so from an external perspective as they may be mulling over the problem to solve. But as long as the task is undone, or still not given up as in the case of voluntary personal initiatives, the person will knowingly decide to postpone it again until the very end a recurrent decision-making process aimed at maximizing benefit and minimizing perceived cost.

Procrastinators finally become active in doing the task when there's no more room for maneuvering around the deadline. The logic is quite the opposite of Parkinson's Law (Parkinson & Osborn, 1957) by assuming that *work contracts to get done within the time left for its completion!* This could involve "pulling an all-nighter" to get the task done, compromising quality. Tasks without deadline or a supervisor may fade into the background, and are thus more difficult to observe. This suggests a 'turning-point', motivated primarily by the deadline that shifts the attitude towards working and forsaking procrastination.

From the perspective of an external observer, the two most obvious indicators of one's progress in task completion are 'working hours per day' and 'how many tasks are left untouched'. Suppose there is a task with deadline of 6 days, a typical behaviour may be observed below:



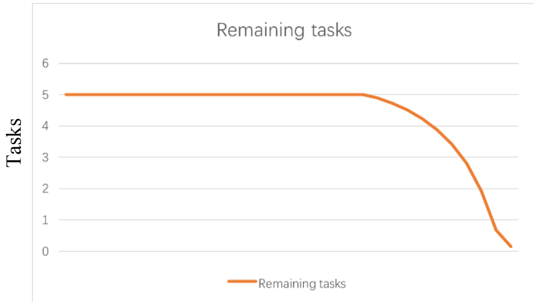


Figure 1 (left): Procrastinators always start late, and cannot maintain a constant productivity

Figure 2 (right): Tasks get solved just before deadline.

Obviously, procrastination does harm. Not only those who will make use of procrastinators' outcome, but also procrastinators themselves recurrently experience high stress levels (McIntyre & Munson 2008), which generates a strong motivation to alleviate it, if not to completely overcome it. We believe that a thorough diagnosis of the problem root-causes is the prerequisite of taking action, and we chose system dynamics modelling for this purpose.

System dynamics is developed by Jay Forrester as a tool to understand complex systems and design policy (Forrester, 1961). Meadows et al.(1972) see system dynamics as a useful method to help people focus more on the connections among pieces in addition to pieces themselves. It supposes that all systems have common elements including accumulation, feedback, and delay (Beall et al., 2011), from which growth, decay, and oscillation can be generated (Ford & Ford, 2009). It also enables people to reproduce all these patterns by building quantitative model, so that they could devise and test policies to mitigate the problematic behaviour. Therefore, it is a perfect means for studying complex systems, both as a diagnostic and a prescriptive tool. It provides the platform for integrating theory and empirical evidence to explore key leverage points for policy design.

III. PROCRASTINATION IN MODEL

Empirical findings enable us to formalize the mental model quantitatively. Following a typical system dynamics approach, we define variables that can be captured from a frozen frame (paused state) of the system - stocks. First, we assume a person who usually procrastinates has nothing but one assignment composed of a number of tasks to finish within a specific period of time. Submission after the deadline will not be accepted, and all tasks are of the same difficulty. Assume there are multiple tasks in the assignment, 'tasks remaining' could certainly be one stock, while the factor affecting it – namely 'how many tasks the person does in one day' could not be a stock but a flow. Moreover, given these two factors, it's also possible to calculate how much time is still needed for all remaining tasks.

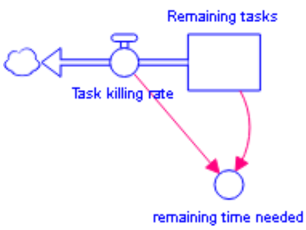


Figure 3: People estimate time needed for task based on "how many tasks left" (remaining tasks)

When a person works long hours they begin to experience tiredness, and this tiredness reduces the hours worked per day as the person finds it hard to focus for long hours. The assumption is if a person works for up to 10 hours, no effect will be observed; but once exceeding, then hours worked per day will begin to decline due to tiredness, the more the person spends beyond that point (10 hours in this case) the more tired they will get, until completely stopping at 18 hours. Then they will have to rest. Tiredness results in another effect: lowered quality hours. This means that when one is tired, the time they spend on a task is not as effective as when they are less tired.

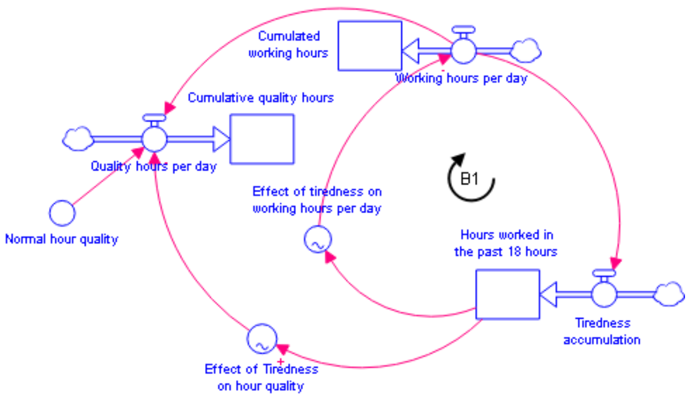
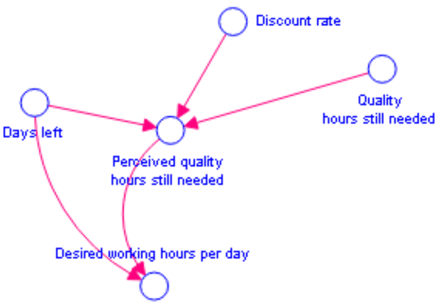


Figure 4: Tiredness and its implications on number of hours worked and hour quality



In determining how many quality hours should a person spend on the task, an underestimation mechanism results in the procrastinator always desiring to work less hours than what is needed. The method chosen to model this is adopted from Present worth analysis used in accounting (i.e. net present value, NPV). There is a discount rate which determines the degree of underestimation he employs, over the time horizon of days left as shown in Figure 5.

Figure 5: Underestimation of needed quality working hours to finish a task

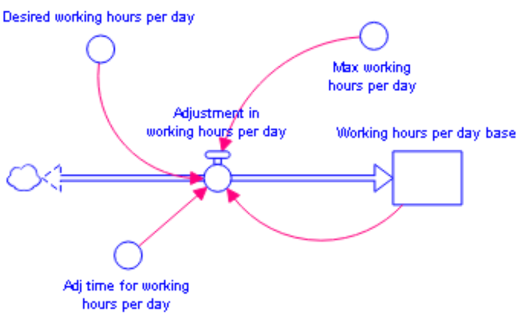


Figure 6: Goal-seeking mechanism of working hour adjustment to meet desired level

The procrastinator works based on a goal seeking loop, always comparing how many hours he worked with the desired working hours he perceives he needs to work. however, this will not exceed the maximum possible working hours per day, which was chosen to be 18 hours. This resonates with the previously explained rule of halting all work after 18 hours of work the previous day.

The more the person works, the less tasks are left to finish, and this adjusts the hours still needed (see Figure 7), but at a delay as previously mentioned in figures 5 and 6. Below is the main balancing loop that aims to accomplish the assignment.

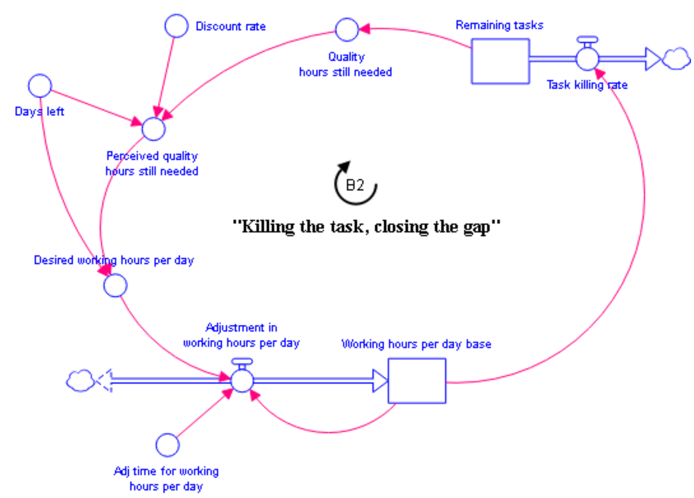


Figure 7: Goal-seeking mechanism of working to finish the assignment

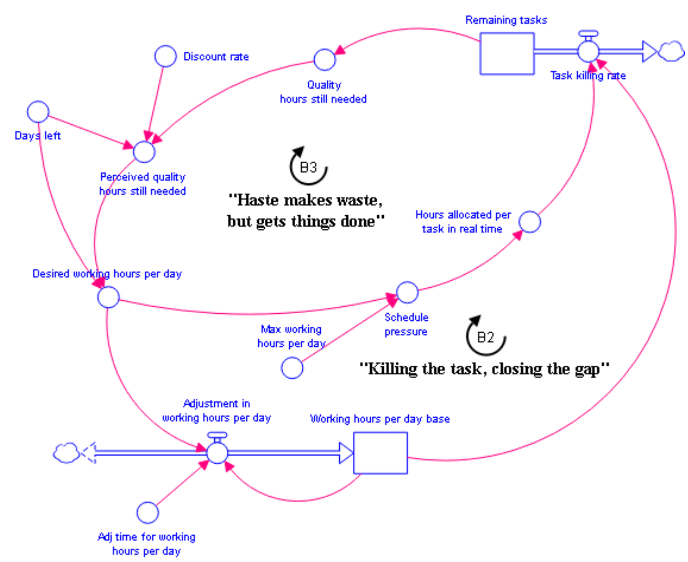


Figure 8: Balancing loops that aim to kill remaining tasks

The procrastinator begins to feel anxious as he is disillusioned with his estimate of how many hours are needed to finish the task. This anxiety is modelled here as schedule pressure, and as it rises it results in a compromise to get things done.

This is accomplished through lowering the number of hours allocated per task, thus lowering quality of the output, but increasing task killing rate, which reduces tasks remaining and accordingly adjusts the perception of quality hours still needed (see Figure 8). Stress or anxiety of the procrastinator were not modelled explicitly here, yet their effects are clearly witnessed in both the structure and behaviour, see Analysis section.

The two loops B2 and B3 both aim to kill remaining tasks, yet B3 has less delays and thus short-circuits B2, as it acts faster, when schedule pressure is high enough.

The core mechanism underlying the problem dynamics is the decision rule upon which a procrastinator starts working.

The decision rule is Boolean (yes-or-no) and based on Akerlof's (1991) utility cost model of procrastination (see Figure 9). If the perceived utility cost of starting to work today exceeds the perceived utility cost of starting tomorrow, the person will always choose to postpone the work to the next day, i.e. to procrastinate. The utility cost could be considered as a kind of 'bother' or 'consumption of energy in a tedious way'. In this algorithm it is a function of time left to complete the work, perceived quality hours still needed to complete the task, and a salience factor.

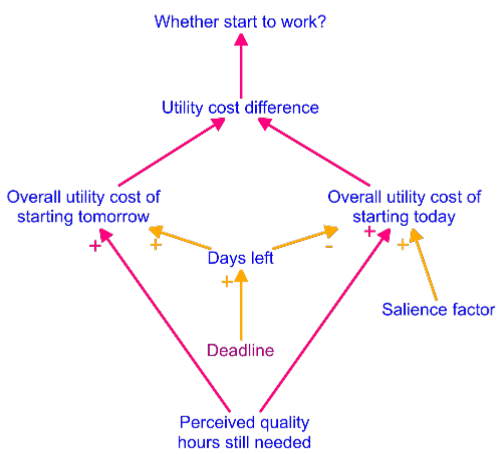


Figure 9: Decision-making mechanism on whether to start working or keep on procrastinating

Salience factor reflects the key idea of Akerlof (1991), and thus plays a central role in his decision-making mechanism. It is based on an observation: people tend to attach extra importance (salience) to affairs closer to them, in (including but not limited to) spatial and temporal senses. For instance, advices from a close friend affect decision more than those from a stranger, a misfortune happening right tomorrow makes people feel worse than one happening 10 years later. Akerlof termed such phenomenon as 'time-inconsistent behavior', and believed that utility cost (or more precisely, perceived utility cost) of doing a task right away hassles a person more than utility cost of doing the same task tomorrow, because the former one is more immediate and deserves more concern. In equation, such 'over-perceiving' is modelled by multiplying the utility cost with a salience factor – which therefore only exists in the equation for starting today (see Figure 10).

$$\textit{Overall utility cost of starting today} = \left(\frac{\textit{Perceived quality hours still needed}}{\textit{Days left}}\right)^2 \times (\textit{Salience factor} + \textit{Days left})$$

$$\textit{Overall utility cost of starting tomorrow} = \left(\frac{\textit{Perceived quality hours still needed}}{\textit{Days left} - 1}\right)^2 \times (\textit{Days left} - 1)$$

Figure 10: Utility cost equations

Because of the salience factor, utility cost of starting today will always exceed that of starting tomorrow. Therefore, a person pursuing maximum overall utility will always choose to start tomorrow – and this is a decision just for today. When tomorrow comes, the same process will happen again, and the same decision will be made again. The more time a procrastinator has, the less costly it appears to start work tomorrow versus today. However, there must be one day (always very close to the deadline), on which even taking salience factor into consideration, the utility cost of starting tomorrow is higher than starting today, due to drastic increase in 'work per day' caused by decrease in 'days left'. Then it is time for procrastinator to start working. As a further move based on Akerlof (1991), the salience factor in this study is interpreted to be a function of the size of the assignment, the larger it is, the more burdensome it is perceived by the person.

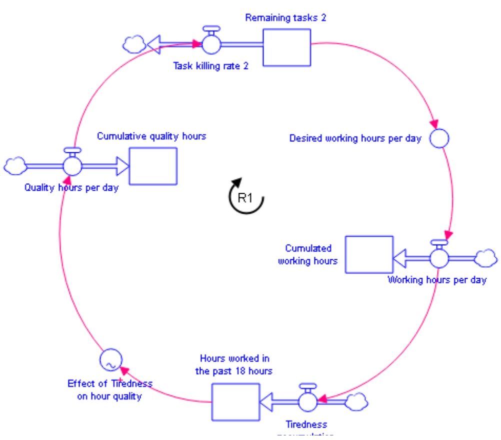


Figure 11: Reinforcing effect of tiredness on task killing

As the deadline draws near, the perception of the actual needed quality hours increases as it approaches its real value rather than the underestimated magnitude (due to the discounting mechanism, see Figure 6 above). As soon as the work finally gets started, a crisis management mode is entered, whereby the procrastinator suddenly drops everything else and realizes the immense cost of further procrastination, thus decides to work.

The last important mechanism to point out is a result of working long hours and the fatigue ensuing. It operates to lower working hours the more tired the person gets. As working hours are reduced, task killing rate drops which raises the desired working hours. This pushes the person to work for more hours, seeking the goal of 'desired working hours', which in turn accumulates more tiredness. It is thus a reinforcing loop as seen in the aggregated diagram to the left.

Based on these observations, the story may be summarized as a conditional goal seeking behaviour aimed at accomplishing the assignment only when the costs of further procrastination exceed the cumbersomeness of working on the assignment. This is compounded by the fact that the procrastinator underestimates the time sufficiency to complete the assignment, thus waits longer. Once the person starts working, if time is insufficient he will start spending less time per task by lowering the quality of the output. Moreover, the more hours he spends per day leads to tiredness and hence a competition arises between the reinforcing loop R1 as well as B1 against the balancing loops B2 and B3 (see Figure 12). Exogenous inputs are coloured yellow. A stock-flow diagram representing the full-scale model is included in the documentation

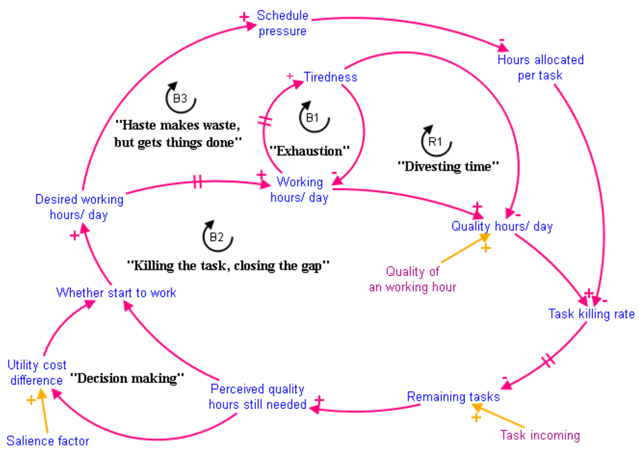


Figure 12: Aggregate causal loop diagram for the proposed theory.

LOOP	EXPLANATION
B1	Accumulated tiredness stops the person from working too many hours per day
B2	Closing the gap of remaining tasks by working more hours per day
B3	Closing the gap of remaining tasks by putting less hours into one task
R1	Accumulated tiredness reduces the quality of a working hour, making an hour's work yield less

Table 1: Explanation of CLD

IV. ANALYSIS

Can the model reproduce the reference mode of behaviour? If so, does such reproduction come from a structure sufficiently reflecting what happened in the real world? This chapter will discuss such issues through model analysis. It will link the behavioural outcomes of simulation with the structure outlined in Chapter 3. The first question asked in analysis is the model's validity. With building model being a continuous process, validation was considered in-progress from the very beginning of the modelling exercise.

Structure validation

Validation is first guaranteed by deliberate structure confirmation, where only the most convincing hypothesis would be accepted and kept in structure. Units were carefully checked for consistency. Economics-based decision rules are introduced in this model as a module to model a procrastinator's decision to start working. Not like in system dynamics field, people see a broader use of concepts such as cost or utility in the economic sphere, and system dynamics model runs into unit troubles from time to time in dealing with economic equations. Instead of forcing a modification on the equations, the authors documented all equations and the units that should be there, and made sure the output from such module to be with proper unit or to be unitless.

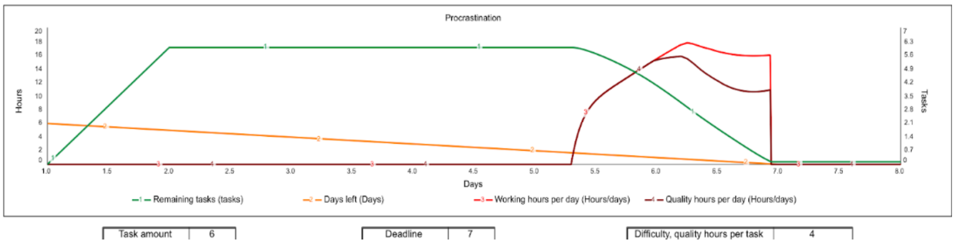
The model represents a clear boundary of settings: an assignment involving certain number of tasks to do, a deadline, and an overall difficulty for all tasks based on the average experimental results. Situations where tasks have heterogeneous difficulty are more often used to discuss order placement, or prioritization, among tasks (Brocas & Carrillo, 2001), therefore are not included herein.

Against the settings, the individual faced by an assignment is abstracted into 3 aspects: mental perception of tasks, productivity, and physical condition. Mental shift resulting from perception of workload triggers a procrastinator to work, i.e. to build up productivity (Akerlof, 1991). Working causes fatigue in the physical condition and in turn impairs productivity. Productivity affects how fast the tasks are processed, which consequently changes the person's perception of workload. All said structures have been made explicit in Chapter 2.

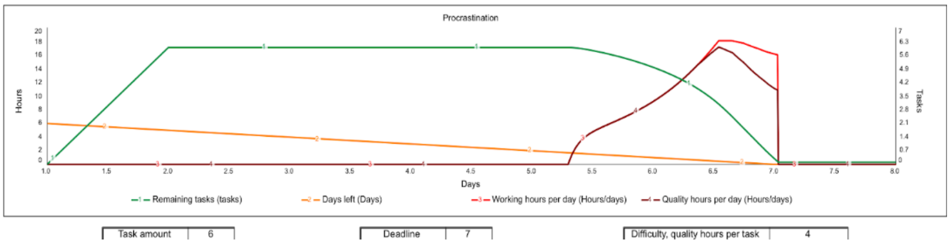
The model passed several structure tests including: extreme conditions test, integration error test, dimensional consistency test, structure verification test, boundary adequacy test, and parameter verification test.

Behaviour validation

There are basically 2 obvious 'problematic' patterns in the reference mode: starting to work right before the deadline, and unstable productivity. Both features can be found in a base run of the model, regardless of whether the procrastinator chooses to pursue a high productivity or to be reluctant to work until the very end.



Mindset a) Eager to finish quickly



Mindset b) Reluctant to work fast

Figure 13: Outcomes from a base run of the model, same background settings with different mindsets.

Table 2: Parameter settings for base runs

RUN	TASK AMOUNT	DEADLINE	DIFFICULTY	MINDSET
Base1	6 tasks	7 days	4 hours/task	Once starts, work hard immediately
Base2	6 tasks	7 days	4 hours/task	Once starts, work hard gradually

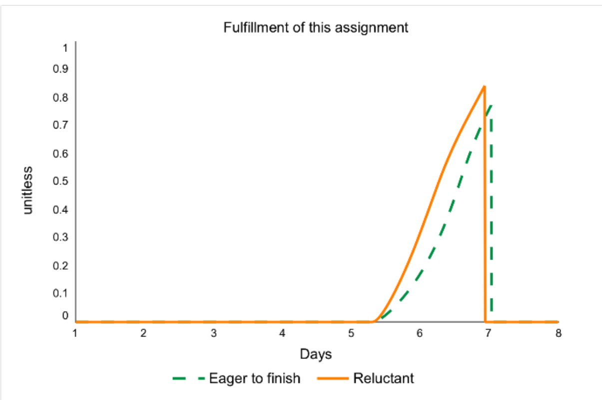


Figure 14: Assignment fulfilment between the 2 mindsets

If the procrastinator chose to pursue a high productivity after initializing the task completion process, before which no progress had been made, there would be a fast decline in remaining tasks. This productivity was closely linked to the 'Adjustment Time for working hours/ day'. The shorter the Adjustment Time, the faster he would be able to reach the goal of desired working hours per day. However, working hard for too long exhausted the person's mental faculties and lowered the quality of a working hour, as shown in Figure 13 (a). However, by doing this, the person could get his schedule pressure under control, avoid using too much the loop 'Divesting Time', and therefore got a higher fulfilment of the assignment.

On the other hand, a person reluctant to work fast may only exhausted in the very end, but at the same time he had to lower his work quality to get things done, resulting in a lower overall fulfilment as a cost. But for the purposes of this model, consequences of lower quality such as getting low grade were excluded from the scope.

Under both mindsets, the simulated person only managed to start working when close to the deadline, and not able to manage a steady productivity.

<u>Behaviour interpretation</u>

A closer examination of other variables helps to give more insights into the run. Taking the reluctant procrastinator for example, as shown below, we selected 8 important variables to interpret the dynamics of procrastination.

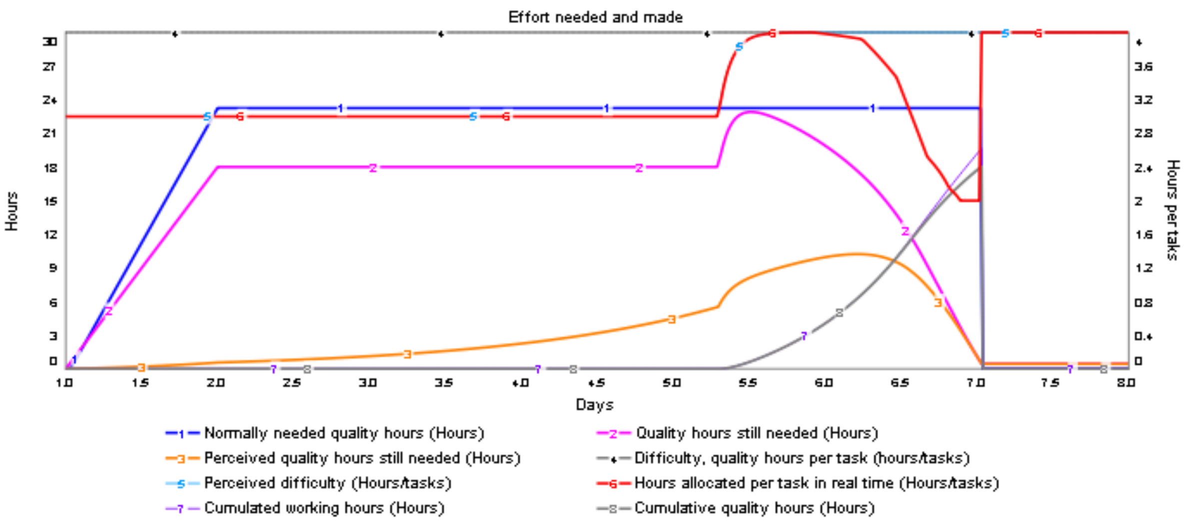


Figure 15: Behaviours produced by a base run of the model, same background settings with different mindsets

Initially, as the assignment was received, there was a steady increase in normally needed quality hours (line 1), indicating how many quality hours a person ideally needed to spend on the assignment. Because we can only get to know the exact difficulty of a specific task (line 4) by attempting to undertake it, if we estimate the quality hours needed to finish (line 2), it can only be calculated using an empirically ‘guessed’ difficulty, namely ‘perceived difficulty’ (line 5).

Human beings, students included, are usually subject to misperceptions due to which they attach less importance to less salient matters. Modelled through a ‘net present value’ algorithm, needed quality hours were perceived much lower by a procrastinator, than they were at the very beginning (line 3).

We assume procrastinators don’t proactively reduce their tasks’ quality, even if they tend to postpone a lot (and it is often the overestimation of how well a task should be done that holds procrastinators from starting (Seo, 2008). The approaching deadline ‘squeezes’ the overestimated part, thus brings the task quality down to reality, sometimes even less). Therefore, hours allocated per task in real time (line 6) kept identical to perceived difficulty (line 5) until it was forced to be lowered.

As time went by, the procrastinator perceived more needed quality hours (line 3), and as described before, at a turning point, he finally started to work. If there was any difference between the actual difficulty and the difficulty he perceived, he started to adjust his perception as soon as he started a task. This process was reflected as the goal-seeking behaviour of line 5 to line 4. Since line 6, line 2, and line 3 all based themselves on perceived difficulty (line 5), all of them saw an upward shift respectively.

After starting to work, cumulative working hours (line 7) started to rise, so did cumulative quality hours (line 8). They were coincided as hours allocated per task in real time (line 6) was still identical to perceived difficulty (line 5). However, as a cost of starting at a too low productivity, schedule pressure went uncontrolled in the final stage: even if the procrastinator worked at maximum working hours per day (which is 18 hours/day in this case), he couldn’t finish all tasks at a normal quality. From then on, hours allocated per task in real time (line 6) parted from perceived difficulty (line 5), resulting in a distance between cumulative quality hours (line 8) and normally needed quality hours (line 1) when deadline was finally approached. However, the procrastinator suffered less from physical fatigue: cumulative quality hours (line 8) was not much lower than cumulative working hours (line 7), indicating a very small loss in efficiency due to tiredness.

Scenario analysis and testing

Model robustness decides to what extent can the model be applied. The more robust the model is, the broader phenomenon it can be used to explain. It is worth noting that only rational conditions may be used to test extreme condition, i.e., we cannot give a 200-hour work load to a person within a one-week deadline, given the assumptions about difficulty, productivity and maximum hour/ day.

Analysis in this part is carried out on both the procrastinator side and the assignment side. We assume all procrastinators have the same physical condition and behaviour pattern toward schedule pressure, so the only 2 variables that would change across procrastinators is how much extra importance they attach to salient events, i.e. the salience factor, and their historical perception (experience) of difficult, based on which they form the estimation of this assignment even before they start investing time and effort in it.

Scenario 1: various workloads with constant salience factor = 2

Scenario 1 is designed to test the procrastinator's reaction to change in assignment. Salience factor is set to 2.

	ASSIGNMENT 1	ASSIGNMENT 2	ASSIGNMENT 3	ASSIGNMENT 4	ASSIGNMENT 5
DIFFICULTY	3 hrs/tsk	3 hrs/tsk	3 hrs/tsk	3 hrs/tsk	3 hrs/tsk
TASKS	1 tasks	3 tasks	5 tasks	7 tasks	9 tasks
QUALITY HOURS	3 hrs	9 hrs	15 hrs	21 hrs	27 hrs
DEADLINE DAYS	7 days	7 days	7 days	7 days	7 days

Table 3: various workloads

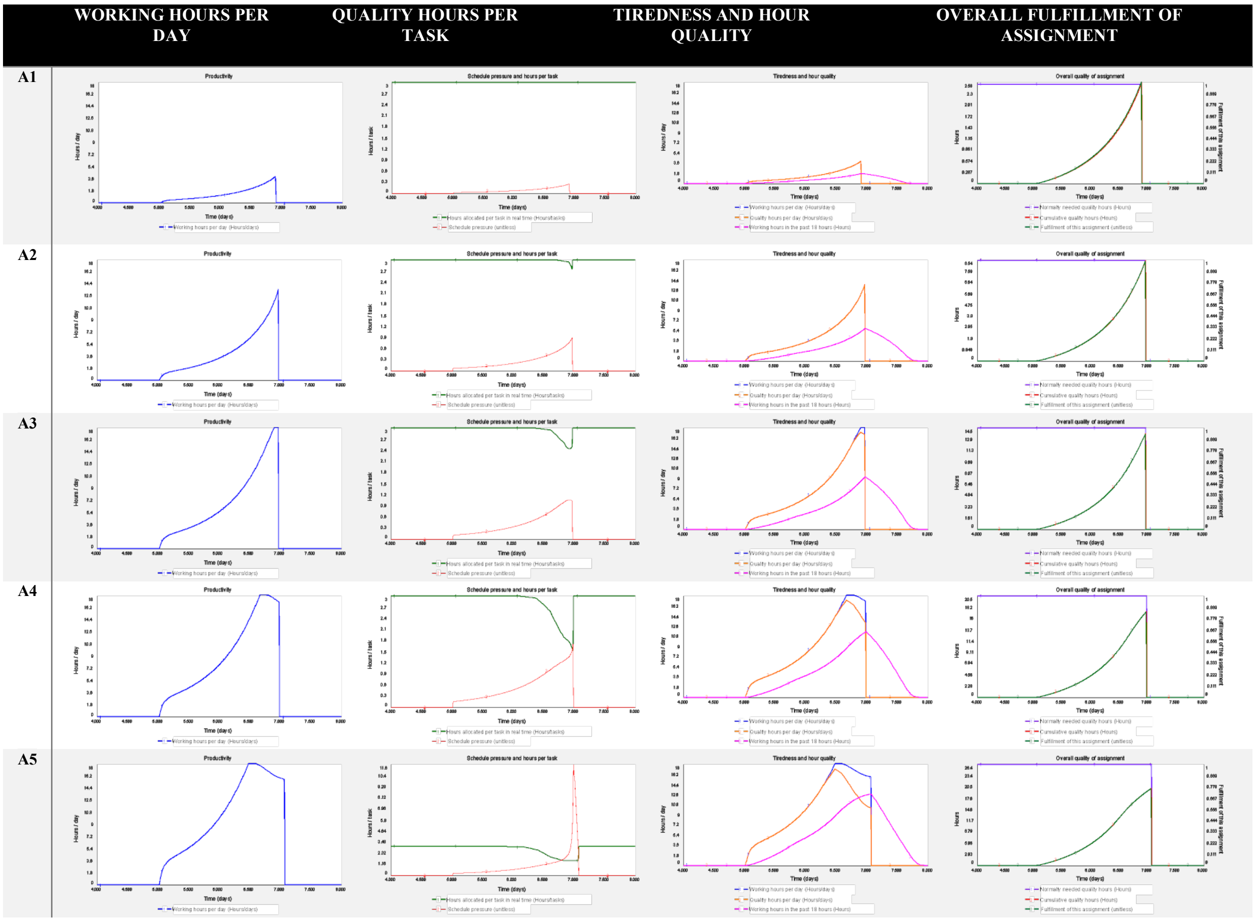


Table 4: Simulation results with constant salience factor and various workloads

The simulation results show that if we take salience factor as a constant, no matter how much workload a procrastinator gets, he would start from the same time point. Explanation could be found in how the person decides to start. The decision rule governing the procrastinator, as shown below, is to compare the utility cost for today and for tomorrow, if there is a decrease in utility cost for tomorrow due to less workload, there should also be a decrease in today's, for they are calculated from the same 'Perceived quality hours still needed', as shown in the equations.

On the contrary, procrastinators develop tactics to dispose of the workload. As shown in the result, the procrastinator simply increased every day's working hours in response to assignment with more workload, which led to obvious burnout in the last 2 runs - a huge gap between 'working hours per day' and 'quality hours per day', indicating a lowered hour quality due to cumulative tiredness. Along with this was the considerable drop in task quality across assignments because of schedule pressure, which in turn caused increasingly unsatisfactory overall task fulfilment, as shown in the last column.

Scenario 2: same workload with various salience factor

Scenario 2 is designed to test if the model can reproduce behavior patterns of people with different procrastination levels, i.e. the model's sensitivity to the salience factor which is the critical feature that distinguishes procrastinators from the others. Akerlof (1991) used a salience factor of 2 in his discussion, and referred to it as 'a small salience cost of beginning a project'. In this scenario, we first assumed salience factor to be constant and test how change in workload would influence the behaviour; then we tested how, given a certain assignment, would different salience factor influence the behaviour. In both tests, we assumed the person knew the difficulty of assignment from the very beginning, to eliminate the influence of misperception of difficulty.

Taking assignment 4 from scenario 1.1 as the base run (difficulty = 3hrs/tsk, tasks = 7) and salience factor from 0 to 4, we got the following runs:

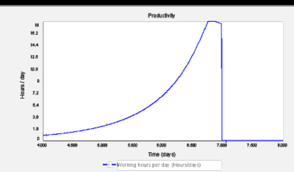
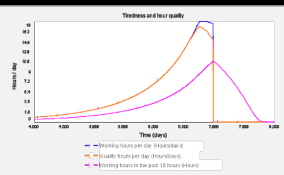
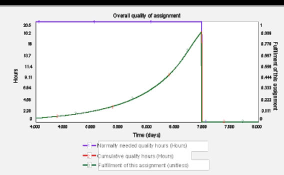
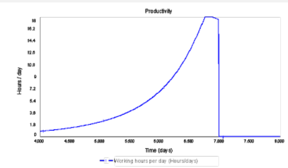
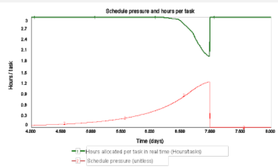
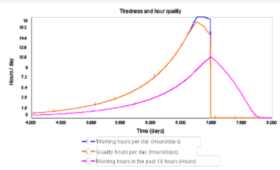
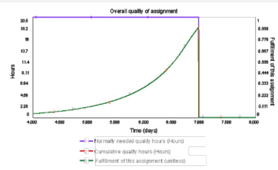
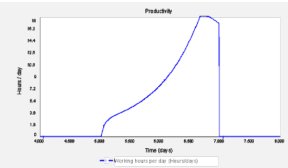
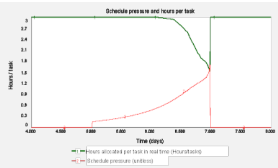
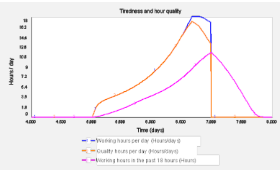
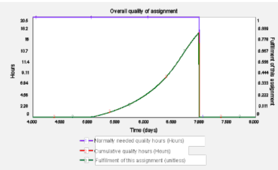
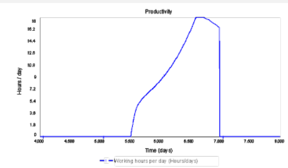
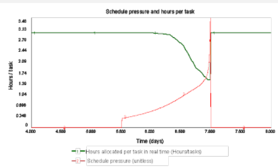
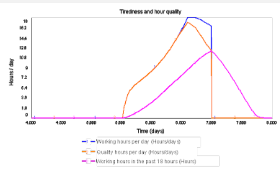
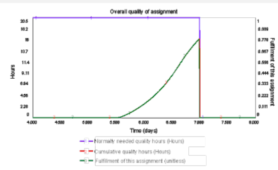
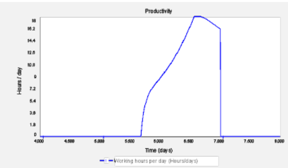
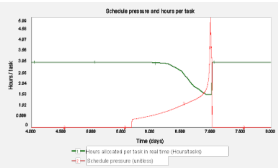
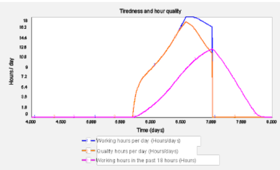
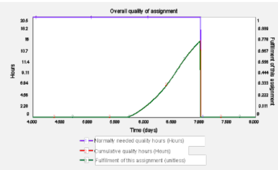
	Working hours per day	Quality hours per task	Tiredness and hour quality	Overall fulfilment of assignment
Salience factor = 0				
Salience factor = 1				
Salience factor = 2				
Salience factor = 3				
Salience factor = 4				

Table 5: Simulation results with various salience factor and constant workload

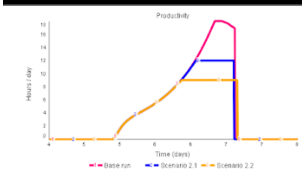
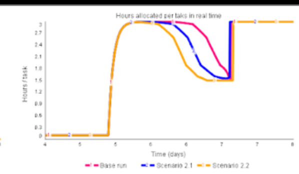
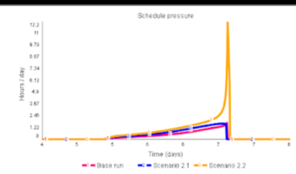
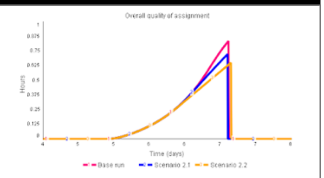
The simulation results show that it is the salience factor that is a determinant of when to start. With salience factor equal to 0 or 1, the person showed no implication in procrastination, he starts working from the very beginning. This is because with a too small salience factor, utility cost for starting today is always smaller than the increase in total utility cost for starting one day later, so the procrastination option will not seem attractive. Via iteration, the critical value for salience factor is around 1.5, regardless of the deadline and the workload, if we accept the assumption that the daily disutility is proportional to the square of working hours in that day. This observation also implies a possible leverage point for policy: can salience factor be reduced intentionally? Policy 2 in the next chapter will discuss more on this.

Scenario 2 compensates flaws in robustness that scenario 1 alone could implies: as our experience, we don’t procrastinate on everything, as shown in scenario 1’s result. A new question is, are the two variables studied above respectively, namely assignment and salience factor, independent? Commonly, we accept inclination to procrastinate as an aspect of one’s personality configuration, but this doesn’t explain procrastinator’s ‘selective procrastination’. In fact, procrastinators often procrastinate by doing something else (‘side-tasks’), and these ‘side-tasks’ used by them to escape from the ‘main-task’ must indicate a smaller salience factor - otherwise it would not have been prioritized over the ‘main-task’. It creates room for further quantitative research on the such links, especially when it comes to a certain industry or a certain group of people, where quantification of difficulty and task amount could be more viable.

Scenario 3: limiting maximum working hours

Setting a run (difficulty = 3hrs/tsk, tasks = 7, salience factor = 2, maximum working hours per day = 18hrs/day) as base run, and reducing the maximum working hours from 18 hours/ day to 12 (run 2.1), and finally to 9 working hours/ day (run 2.2), we got the following results:

Table 6: Simulation results, Base run vs. Run 2.1 vs. Run 2.2

working hours per day	quality hours per task	schedule pressure	overall fulfillment of assignment
			

In all scenarios, the procrastinator started at the same time, since the parameters governing his decision rule were not affected by how many hours he can work/ day, rather by the time left, utility cost, and tasks remaining.

The maximum working hours’ limit did affect the quality of the output, however, since loop B3: "Haste makes waste, but gets things done" activated to kill tasks, faster than the original loop B2 due to the time constraint placed on the procrastinator. Yet the effects of this loop in run 2.2 were more prominent than in the base run. Run 2.2 delivered the worst quality of work.

The results above confirm the aforementioned hypothesis, that work began at the same time, with the working hours being capped, loop B2 played caused a reduction in quality hours per task, reflected in the graph of run 2.2 falling short of both the base run and run 2.1. The key driver behind loop B2 is schedule pressure, confirmed by the graph above. Run 2.2 experienced the highest peak due to the large disparity between desired working hours per day, and maximum working hours per day.

Considering the implications of runs 2.1 and 2.2, it does not come as a surprise that overall fulfillment of the assignment was the lowest for run 2.2. This measure compares cumulative quality hours actually spent on the assignment to the normally required working hours (calculated from actual difficulty of the assignment and number of tasks required).

The base run procrastinator completed the assignment with an 84% quality, meaning that based on average standards he would not get the maximum grade he would have fulfilled had he started earlier. This is debatable of course if the procrastinator was especially talented, or well informed in the topic of the assignment; and thus this quality measure assumes that the procrastinator’s abilities, and the difficulty measure (number of quality hours required per task) are both reflective of each other.

Run 2.1 achieved a 73% quality, and finally run 2.2 achieved a plummeting 65%. In real life a 'successful' procrastinator balances several factors, namely his abilities, the maximum number of hours he is willing to invest once he starts, and the grade he desires for the assignment. Yet the 'not so successful' procrastinator would be aptly represented by run 2.1 and 2.2.

The results make intuitive sense because if you start late, but not willing to go the extra mile sacrificing some sleep time or other activities, the quality of your output will suffer, and so would your grades.

V. POLICY DESIGN

Analysis of unfavorable implications from procrastination gives us sufficient ground to talk about what we can do about it. Even in cases where procrastinators eventually give out acceptable output as long as getting some ‘side-task’ done as a favorable by-product of procrastination, they still experience both mental strain and physical exhaustion. Observing the reference mode of behavior (as shown in Figure 16), if we assume a person can work for 8 hours with full quality each day, the area of A+B+D would be the workload that he could have normally done within the deadline, while B+D reflects the required quality hours for the assignment. Procrastination, from a perspective of mere behavior, is to transfer a part of work from D to C, while using D for something else. Our wishful thinking of the ideal case is to use only B and D for the work, without occupying C.

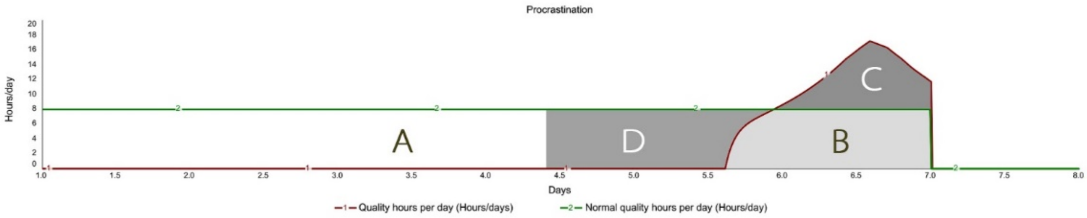


Figure 16: Procrastination as a type of time arrangement with high concentration in the end

However, such ‘optimal arrangement of time’ couldn’t simply be achieved by ‘ordering the procrastinator to do so’. All discussions above have shown that such a behavior of pattern has an origin rooted deeply in procrastinator’s underlying system of making decisions. As long as a procrastinator is asked to do some task and has a period of ‘free time’ to work on it, he or she will automatically produce such pattern. It may be argued that an environment of strict discipline could overcome the tendencies to procrastinate, but such external intervention is not always available, and living under long-lasting surveillance may bring considerable unfavorable side-effects.

Policy 1: Splitting up the task

A reasonable policy suggestion could be ‘to break down the task into smaller ones. Since procrastinators show a better performance (both in overall fulfillment and in tiredness) when they are faced by a smaller assignment (as shown in Table 2 in Chapter IV - Analysis, the smaller a task is, the less likely its quality will be lowered in the end), if we can divide a larger assignment into 2 or more smaller ones, it is reasonable to predict procrastinators will do better in each and thus show a more favorable overall fulfillment. A policy scenario is thus designed to test whether “chopping large assignment up” will make a difference to the overall fulfillment.

Taking assignment 4 from scenario 1.1 as the base run (difficulty = 3hrs/tsk, tasks = 7), a constant salience factor of 2, and splitting up the task into 2 smaller equal tasks (scenario 3.1), and another time unequally (scenario 3.2), yielding the following results:

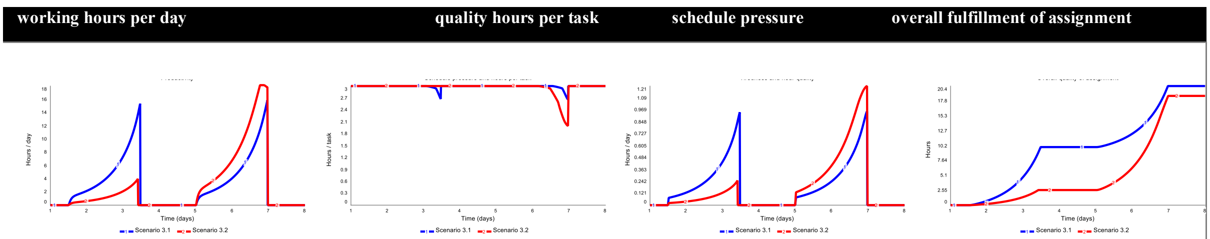


Figure 17: Scenario 3 results

These scenarios explores what would happen if a procrastinator did not fundamentally change his perception of utility, yet took action by placing an interim deadline on himself, once fairly, and a second time with a more spaced-out attitude towards the deadline, meaning that the first deadline was a smaller bit of the total workload. This notion has been explored thoroughly by Ariely and Wertenbroch (2002) where they conducted field studies to determine if interim deadlines helped improve performance. One of their findings was that suboptimal splitting of tasks yielded lower performance than evenly spaced deadlines; it is thus assumed that scenario 3.1 is an external deadline, while scenario 3.2 is one internally set by the procrastinator, suboptimally.

This model agrees with their results, as breaking up the task reduces the maximum schedule pressure incurred throughout the assignment. When the task is split equally the overall performance is better than when adopting a more lax approach to the interim deadline. Leaving more work to be completed before the 2nd deadline, as opposed to fair splitting, leads to B3 activating to finish the task before the 2nd deadline, lowering quality of output. This is shown in figure above comparing the 2 scenarios. The person had to work for longer hours during the last 2 days, leading to less hours spent on each task due to higher schedule pressure. This resulted in an overall lower quality of the assignment.

Policy 2: Incentive factor and discounting rate adjustment

It has been outlined that the salience factor is the main reason a procrastinator delays the start of work, yet what would happen if a counterweight was placed? An incentive factor which depicts the rewards of starting today?

A new factor was added to the equation of utility cost of starting tomorrow as follows:

$$\textbf{Overall utility cost of starting tomorrow} = 1 + \frac{\textit{Perceived quality hours still needed}}{\textit{Days left}}\; x\; (\textit{Days left} - 1 + \textit{Incentive factor})$$

Results showed that it is not enough, because of the discounting in determining the perceived quality hours needed. This means that to overcome procrastination one not only needs to incentivize, but also to thoroughly assess the task requirements beforehand in order to start strong and this has prominent policy implications as will be discussed in the following section.

The graph below shows the results of adding an incentive factor of 3, as well as reducing the discount rate to 0.1. This means that the *Perceived quality hours still needed* will be more in line with the actual *Quality hours still needed*.

Less hours are worked towards the deadline, quality is maintained throughout, there is minimal schedule pressure, and finally the outcome is of higher quality than the base run.

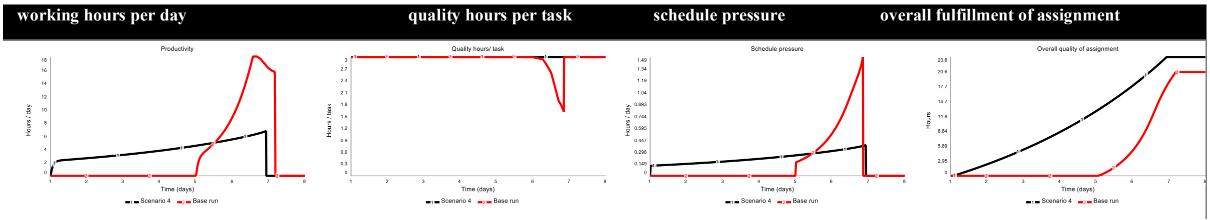


Figure 18: Scenario 4 results vs. Base Run

VI. IMPLEMENTATION AND CONCLUSIONS

As discussed before, 'chopping assignment up' would be a useful policy, but a policy can be effective only with proper enforcement, which is hardly what we can expect from a procrastinator. We couldn't expect a procrastinator to be 'selectively procrastinative' when assigning them equally burdensome tasks. The main force that drives a procrastinator to work is a nearer-drawing deadline, and a deadline can only be a deadline if there is some penalty upon missing it. In other words, what a procrastinator fears is not the deadline itself, but the consequence of failing to meet it. Such consequence often comes from those who supervise the procrastinator. Supervisors' active action in the process of procrastination will make both parties better off.

This “Shifting burden to intervention” (Braun, 2002) means to rely on external help to solve the problem rather than making change inside the system. It is usually referred to as a bad policy, with negative long-term implications. However, before judging a policy to be bad, one needs to define the boundary of the system in question, in order to tell ‘external’ from ‘internal’. Procrastination, in the first glance, happens only to the procrastinators, having nothing to do with others, so procrastinators are often suggested to ‘change themselves’. But since low-quality works would not do any good to their ultimate users, stakeholders of this issue should include the supervisors of the work, or other students involved in the same task. Policy based on interpersonal dynamics therefore can take place.

Promising to a group of people a certain progress before a specified time can create a positive pressure, which can be used to counter the extra utility cost of starting to work right now. Thus the self-esteem of the procrastinator would be improved upon better productivity, which would drive a procrastinator to start early. This is also effective when it comes to tasks without deadlines (like term projects), in such conditions to get enrolled in a group and discipline oneself with the group's schedule is considerably useful. Supervisors could also set micro-deadlines, halfway through the assignment, to slice a 'huge' procrastination into two smaller ones to guarantee an acceptable progress, as discussed in one of the policies.

Moreover, to make a 'one-time' decision is always easier than to regulate oneself for a long time. For procrastinators, if they can choose to do a task in a way other than doing alone, it's highly suggested to choose so. Similar tactics include to set fixed 'time point' in one's daily life. For instance, if you choose to attend a lecture next morning, it's less likely you will stay up until very late tonight.

This paper aimed to explore the drivers underlying procrastinating behavior, and pointed out to the key leverage areas to improve performance. It utilized System Dynamics as a tool for analysis and policy design. What the authors conclude is that procrastination is a systemic problem affecting a multiple people, rather than a flaw of one's moral character; misperceived extra importance attached to salient matters is also an important factor constituting the stability of our world. Generally speaking, it is the connection with people that gives us a better-founded reflection of the world and eliminates all possible misperceptions. Procrastinators are encouraged to reach out to people surrounding them, to solve the problem systemically, and to lead a systematically better life.

REFERENCES

1. Akerlof, G. A. (1991). Procrastination and obedience. The American Economic Review, 81(2), 1-19.
2. Ariely, D., & Wertenbroch, K. (2002). Procrastination, deadlines, and performance: Self-control by precommitment. Psychological science, 13(3), 219-224.
3. Beall, A., Fiedler, F., Boll, J., & Cosens, B. (2011). Sustainable water resource management and participatory system dynamics. Case study: Developing the Palouse basin participatory model. Sustainability, 3(5), 720-742.
4. Braun, W. (2002). The system archetypes. System, 2002, 27.
5. Brocas, I., & Carrillo, J. D. (2001). Rush and procrastination under hyperbolic discounting and interdependent activities. Journal of Risk and Uncertainty, 22(2), 141-164.
6. Ford, A., & Ford, F. A. (1999). Modeling the environment: an introduction to system dynamics models of environmental systems. Island press.
7. Forrester, J. W. (1997). Industrial Dynamics. Journal of the Operational Research Society, 48(10), 1037-1041.
8. McIntyre, S. H., & Munson, J. M. (2008). Exploring cramming: Student behaviors, beliefs, and learning retention in the principles of marketing course. Journal of Marketing Education, 30(3), 226-243.
9. Meadows, Donella H; Meadows, Dennis L; Randers, Jørgen; Behrens III, William W (1972). The Limits to Growth; A Report for the Club of Rome's Project on the Predicament of Mankind. New York: Universe Books.
10. Onwuegbuzie, A. J. (2004). Academic procrastination and statistics anxiety. Assessment & Evaluation in Higher Education, 29(1), 3-19.
11. Parkinson, C. N., & Osborn, R. (1957). Parkinson's Law, and Other Studies in Administration: And Other Studies in Administration. Houghton Mifflin.
12. Seo, E. H. (2008). Self-efficacy as a mediator in the relationship between self-oriented perfectionism and academic procrastination. Social Behavior and Personality: an international journal, 36(6), 753-764.
13. Sterman, J. D. (2000). Business dynamics: systems thinking and modeling for a complex world
14. Tucker-Ladd, C. (2006). Psychological self-help,(Chapter 4: Behaviour motivation and self-control) viewed 2 March 2009.

APPENDIX 1: List of tables

APPENDIX 2: List of figures

APPENDIX 3: Model documentation

Formulation and comments	Units
Tasks and Assignment	
*Remaining tasks(t) = Remaining tasks(t - dt) + (Assignment input - Task killing rate) * dt = 0.001*	Tasks
The stock of tasks to do, declines as there is a Task killing rate, and arises from Assignment input. Initially there is no task, but initial = 0.001 is introduced to avoid zero division.	
Assignment input = PULSE(7,1,200)	Tasks/Day
Inflow of the stock, an exogenous parameter, reflecting the income of assignment, which comprises several tasks. The step function ensures the inflow only lasts for 1 day.	
Task killing rate = Quality hours per day/Hours allocated per task in real time	Tasks/Day
Outflow of the stock, decided by daily working hours and how many hours the person would allocate into a task, which is modified by the influence of anxiety from the reference hours allocated per task.	
"Difficulty, quality hours per task" = 3	Hours/Task
An exogenous parameter, calibrating the difficulty of the assignment by how many quality hours a single task needs (e.g. how many hours the professor wants the student to allocate to a task). It is presumed that all tasks in one assignment are of the same difficulty. Quality hours is a working hour with full outcome.	
Reference hours allocated per task = "Difficulty, quality hours per task"	Hours/Task
It is assumed that people are doing tasks in full quality if they will spend as many hours on one task as they are required to spend (e.g. by the professor). Therefore, reference hours allocated per task equals to difficulty.	
*Hours allocated per task in real time = Reference hours allocated per task*Effect of schedule pressure on hours allocated per task*	Hours/Task
When schedule pressure level is high, people tend to lower the quality of their tasks in hand to meet the deadline on time. At this time, the real quality hours they put into one task will be subject to a modification by schedule pressure, represented by a normalized multiplier.	
*Normally needed quality hours(t) = Normally needed quality hours(t - dt) + (Normally needed quality hours input - Clearance of normally needed quality hours for next assignment) * dt = 0.001*	Hours
The stock of quality hours normally needed by the remaining tasks. It arises as assignment being placed, and will not decline until the entire assignment is finished. Quality hours actually spent in the assignment are counted elsewhere. The stock is initially 0 but 0.001 is introduced to avoid zero division.	
Normally needed quality hours input = Assignment input"Difficulty, quality hours per task"*	Hours/day
A co-flow of Assignment input, indicating that incoming assignment (tasks) will lead to the increase of needed quality hours. Difficulty is the converting rate.	
Clearance of normally needed quality hours for next assignment = IF(If finished=0)THEN 0 ELSE (10000)	Hours/day
When one assignment is done (If finished = 1), this stock will be evacuated quickly (10000 hours/day) to get ready for next assignment. This mechanism is designed to simulate consecutive assignments in one single run.	
Difficulty Perception	
Historically perceived difficulty = 3	Hours/task
Reflecting the overall difficulty the person perceived from previous assignments, used to initialize the stock Perceived difficulty.	
*Perceived difficulty(t) = Perceived difficulty(t - dt) + (Adj in perceived difficulty) * dt = Historically perceived difficulty*	Hours/task
It takes time for people to perceive how difficult this current assignment is. A first order information delay is therefore introduced to represent this process and the delay therein. Only when the person has started with the assignment can he or she really know how difficult it is, otherwise the person will rely on his previous experience to form expectation.	
*Adj in perceived difficulty = ("Difficulty, quality hours per task"-Perceived difficulty)/Adj time for perceived difficulty*If started*	Hours/tasks/Days
The adjustment part for the above-mentioned perceiving process. Only when the person has started with the assignment can he or she really know how difficult it is. A global indicator If started is therefore introduced to control the beginning time.	
Adj time for perceived difficulty = (1/12)	Days

Formulation and comments	Units
Time for people to perceive the assignment's difficulty. It usually doesn't take a long time, so a relatively small number (1/24 day, or 1 hour) is assigned.	
Global Indicators	
If finished = IF(Remaining tasks>0.15)THEN 0 ELSE 1	Unitless
A global indicator, elicited from Remaining task, indicating where the current assignment has been finished. 0.15 is introduced instead of 0 to avoid the numerical long-tail effect.	
If started = IF(If to trigger>0)THEN(1)ELSE(0)	Unitless
A global indicator, elicited from the block representing mechanism to start working, indicating whether the person has started with the assignment. The block is explained blow.	
Mechanism to start working	
Deadline = 0+STEP(7, 1)	Days
A specific date (counting from the beginning of simulation) on which the assignment should be turned in.	
Days left = MAX(0.01, (Deadline-TIME))	Days
Difference between current date and deadline. The max function ensures that Days left remains non-negative regardless of the current date.	
Quality hours still needed = Remaining tasks*Perceived difficulty	Hours
Calculates how many hours will be used to finish the remaining tasks. This variable calibrates 'how much work the person should have been able to perceive/ take in to consideration', without misperception.	
Perceived quality hours still needed = MIN(Quality hours still needed*(Discount rate/((1+Discount rate)^Days left-1)), Quality hours still needed)	Hours
Calibrates the person's perception of the above-mentioned 'Quality hours needed'. Human being tend to attach more weight to salient event. An assignment with a deadline of 7 days will be perceived as a much smaller one in the very beginning, and the perceived weight will rise as time passes by. A formula used in accounting to calculate present value from a future value is used here to figure out how much work the procrastinator feels he or she has as total.	
Discount rate = 1	Unitless
A concept borrowed from accounting, representing the extent of misperception a person has when perceiving a future event.	
Salience factor = 2	Unitless
A factor calibrating how much more importance a person will attach to a salient event. From Akerlof (1991). In the model, Salience factor is linked to task amount by a linear function, as an alternative assumption that a person has stronger inclination to procrastinate when faced by more tasks.	
Overall utility cost of starting today = (Perceived quality hours still needed/Days left)^2*Salience factor*1+(Perceived quality hours still needed/Days left)^2*Days left	Unitless
From Akerlof(1991), procrastinators attach more importance to salient events. When comparing utility costs of starting work today or tomorrow, while non-procrastinators choose to start early, procrastinators, because of an additional utility cost attached to today, tend to start later.	
Incentive factor = 3	
This is the factor that increases the cost of starting tomorrow, such that it acts as an incentive against procrastination.	
Overall utility cost of starting tomorrow = (Perceived quality hours still needed/(MAX(Days left, 1.01)-1))^2*(MAX(Days left, 1.01)-1+ Incentive factor)	Unitless
Ibid.	
Utility cost difference = Overall utility cost of starting today-Overall utility cost of starting tomorrow	Unitless
Calculate the difference between the above 2 utility costs.	
If to trigger = IF(Utility cost difference<0)THEN(1)ELSE(0)	Unitless
If the utility cost of starting tomorrow finally exceeds the utility cost of starting today, it will trigger the procrastinator to start working.	
If ever triggered = If ever triggered(t) = If ever triggered(t - dt) + (If to trigger) * dt = 0	Unitless
Once triggered to start working, the procrastinator will keep working along. This stocked maintains the triggered status.	
Productivity Adjustment	
Desired working hours per day = Perceived quality hours still needed/(Days left)*If started	Hours/days
Having started to work, the person wants to solve all the tasks in the remaining days. We use even distribution here because in a relatively short period, it's acceptable to assume such. If the period is longer, algorithm for calculating annuity in accounting could be adapted here.	

Formulation and comments	**Units**
Adj time for working hours per day = 0.1	Days
Once starting to work, i.e. getting his or her hands around the work, the person will adjust his productivity very fast, because of no more influence form salience factor.	
Max working hours per day = 18	Hours/days
Maximum working hours a person can have in one single day.	
Adjustment in working hours per day = IF(Working hours per day base<Max working hours per day)THEN((Desired working hours per day-Working hours per day base)/Adj time for working hours per day)ELSE(0)	Hours/days/days
As long as working hours per day (base) hasn't reached maximum of 18 hours per day, it will be adjusted toward the desired working hours per day.	
*Working hours per day base(t) = Working hours per day base(t - dt) + (Adjustment in working hours per day) * dt*	Hours/days
Working hours per day is represented by a stock, since it takes time to change. It is 'base' because a stock cannot turn to 0 immediately after all tasks are finished, therefore needs further modification.	
Schedule pressure = Desired working hours per day/Max working hours per day(1-If finished)*	Unitless
Pressure coming from not being able to finish all the tasks. If a person feels he or she cannot finish everything even if working at maximum working hours in all the rest days, schedule pressure will be over one.	
Effect of schedule pressure on hours allocated per task = GRAPH(Schedule pressure)	Unitless
When schedule pressure reaches a certain level, the person will try to reduce quality of the tasks to get things done faster. This is done by reducing quality hours per task.	
Working Hours per Day	
*Cumulative working hours(t) = Cumulative working hours(t - dt) + (Working hours per day - Clearance of cumulative working hours for next assignment) * dt = 0.001*	Hours
Stock of accumulated working hours up until now, arises from working hours per day (which is the action of production) and gets quickly evacuated only after the assignment is finished. Initial value set to 0.001 to avoid zero division.	
Clearance of cumulative working hours for next assignment = IF(If finished=0) THEN 0 ELSE (10000)	Hours/days
When one assignment is done (If finished = 1), the stock of cumulative working hours will be evacuated quickly (10000 hours/day) to get ready for next assignment. This mechanism is designed to simulate consecutive assignments in one single run.	
Working hours per day = Working hours per day base(1-If finished)*Effect of tiredness on working hours per day*	Hours/days
Working hours per day observed from external, taking the effect of tiredness into account. Introduction of If finished guaranteed it will drop to zero right after all tasks are finished.	
Tiredness / Labor Burnout	
*Working hours in the past 18 hours(t) = Working hours in the past 18 hours(t - dt) + (Tiredness accumulation - Tiredness elimination) * dt = 0*	Hours
The stock of working hours in the past 18 hours. It is assumed that people's level of tiredness is based on how many hours they have worked in the past 18 hours. Too many working hours will affect working hours per day (forced rest from physical condition) and hour quality (outcome from one hour's working).	
Tiredness accumulation = Working hours per day	Hours/days
Working itself builds up tiredness.	
Tiredness elimination = DELAYN(Tiredness accumulation, 0.75, 60, 0)	Horus/days
Working hours happening more than 18 hours ago will be subtracted from the stock of tiredness. This is done by an outflow which is 18 hours (0.75 day) high order delay of the inflow. High order makes it an exact delayed reproduction of the inflow (a translation delay).	
Effect of Tiredness on hour quality = GRAPH(Working hours in the past 18 hours)	Unitless
Tiredness influences working hour's outcome. If there are more than 7 working hours in the past 18 hours, hour quality starts to drop. And hour quality will be dramatically lower if there are more than 13.	
Effect of tiredness on working hours per day = GRAPH(Working hours in the past 18 hours/18)	Unitless
Tiredness influences decision on working hours per day. If there are more than 7 working hours in the past 18 hours, physical condition will stop the person from putting as many hours into tasks as before, i.e., a forced rest.	
Quality Hours	
*Cumulative quality hours(t) = Cumulative quality hours(t - dt) + (Quality hours per day - Clearance of cumulative quality hours for next assignment) * dt = 0*	Hours

Formulation and comments	**Units**
The stock of accumulated quality hours spent on tasks up until now. It raises from quality hours spent per day, and only gets quickly evacuated after the assignment is finished. Initially it is 0.	
*Quality hours per day = Normal hour quality*Effect of Tiredness on hour quality*Working hours per day*	Hours /day
Inflow of the stock accumulated quality hours. When there is not much accumulated tiredness, a working hour is a quality hour. However, when tiredness is built up to a high level, quality hour is subject to a modification, therefore lower than a working hour.	
Normal hour quality = 1	Unitless
When there is not much accumulated tiredness, a working hour is a quality hour.	
Clearance of cumulative quality hours for next assignment = IF(If finished=0) THEN 0 ELSE (10000)	Hours/day
When one assignment is done (If finished = 1), the stock of cumulative quality hours will be evacuated quickly (10000 hours/day) to get ready for next assignment. This mechanism is designed to simulate consecutive assignments in one single run.	
Fulfillment of this assignment in real time = MAX(Cumulative quality hours, 0.0001)/MAX(Normally needed quality hours, 0.001)	Unitless
Fulfillment, or overall quality of this assignment is calculated by the ratio between Normally needed quality hours (required by the assignment) and Cumulative quality hours (spent by the person). The ratio will be lower than 1 only when the person decided to lower his or her quality when faced by high anxiety.	