

A formal model of procrastination

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Abstract

Procrastination is widespread self-undermining behaviour that negatively impacts individual performance and well-being. Psychological research has identified a variety of factors that influence this complex behaviour. However, how these factors interact and influence procrastination is poorly understood; there is no uniform theory that integrates all these factors. This paper presents an initial conceptual model of procrastination built from factors that are found in the psychological literature. In addition, it presents a formalization of the model that will serve as the basis for a computational model. The aim of the project is to develop model-based e-coaching software that can offer personalized support to individuals in their struggle with procrastination.

1 Introduction

Procrastination is voluntarily delaying what one intended to do despite expecting negative consequences. This self-undermining behaviour is widely spread among students [13], but also chronically affects 15% – 20% of the general population [8]. Research shows that procrastination has a negative influence on an individual’s performance [17] and well-being [18]. The majority of the procrastinators (95%) see this behaviour as problematic and want to reduce it [17].

There are many definitions of procrastination but most include the existence of an irrational and unnecessary delay and negative consequences. The definition by Klingsieck combines all these features, stating that procrastination is “*the voluntary delay of an intended and necessary and/or [personally] important activity, despite expecting potential negative consequences that outweigh the positive consequences of the delay*” [9, p. 26]. Notice that not performing an intended action is not necessarily procrastination. Someone may justifiably shift his or her priorities if something more important comes along.

Procrastination is complex behaviour influenced by many factors such as low conscientiousness [17], task aversiveness [4] and self-efficacy [17]. However, how these factors interact and influence procrastination is poorly understood. There is no uniform theory that integrates all these factors. This paper presents an initial conceptual model of procrastination built from factors that were found in the psychological literature. Using this conceptual model, a formalization is made that captures the different factors and defines an agent that can choose to perform activities that are either task-related or not. The goal of the formal model is to gain a better understanding of the factors influencing procrastination and the connections between them. In future work, the formal model will be used to make a computational model to run simulations, train the model on empirical data and test it. It will simulate what decisions an agent will make when it has to choose between different tasks and indicate whether the selected activity classifies as procrastination or not. The aim is that in future work the trained model will serve as the basis for e-coaching software to support individuals in decreasing procrastination.

The paper is organized as follows. Section 2 discusses other approaches to modeling procrastination. Section 3 presents a conceptual model of procrastination that is built from factors prominently featured in psychological literature. A formalization of the model is presented in Section 4. Section 5 outlines an evaluation plan and, lastly, Section 6 discusses conclusions and ideas for future work.

2 Related Work

There are only a few other models on procrastination and the majority of them are economic models. The idea of the economic models on procrastination (e.g. [11], [19]) is that an agent can choose between some tasks. Each task is associated with costs that are incurred when the task is executed, and benefits that are received when the task is completed. Traditional economic models assume time-consistency: an agent's preference for a task remains the same over time. Most people are however time-inconsistent: they prefer well-being at an earlier date over a later date [6]. Economic models on procrastination differ from traditional economic models in that time-inconsistency is taken into account.

In such models agents can have a self-control problem and are either fully aware of this ('sophisticated') or unaware ('naive'). A sophisticated agent will estimate the utility of a task the same for every day, so it will perform the task immediately. A naive agent believes that it is better off to perform the task later instead of now, so it will do the task the next day. However, when this continues, the agent may end up spending too little time on a task. The main determinants of utility are time preference, costs, and benefits.

These economic models give some insight into the dynamics of procrastination. However, it is often not clear how these models relate to relevant psychological concepts. To get a better understanding of procrastination with the use of a model, it is important to specify how the model components are mapped to concepts in psychological literature.

An example of a model that also integrates psychological concepts is the *temporal motivation theory* (TMT). It is based on the economic models, but it also incorporates expectancy and need theory, and aims to integrate different theories on motivation. The model is applied to procrastination, using the following formula [17]:

$$Utility = \frac{E \times V}{\Gamma D}$$

with expectancy E , value V (the costs and benefits received from performing a task), sensitivity to delay Γ (representing to what extent delay influences utility) and the time to the deadline D . Each element consists of different task-related and personality-related factors. This theory integrates a number of psychological notions connected to procrastination. However, it is not specified how the theory should be implemented; only some small, non-formal examples are given. Implementation into a formal model can validate the theory and provide new insights into the underlying mechanisms of procrastination instead of only listing the factors that influence it.

3 Conceptual model

In this section, prominent factors influencing procrastination found in the literature will be discussed. The factors can be divided into different groups: task-related, personality-related and other factors like ego depletion, mood, temptations and coping strategies. All these factors and their influence on procrastination can be found in Figure 1. The + and - of the arrows represent respectively the positive and negative influence from that factor on procrastination or another factor. This conceptual model was reviewed at an early stage by a self-regulation expert.

The nature of the task and how the agent perceives it influence how likely someone is to procrastinate:

Boredom When a person finds a task really boring, it is hard to sustain it as an intentional activity when there are less boring alternatives present [3]. The more boring a task, the more procrastination [4].

Frustration Being frustrated makes it harder to focus on a task. This lack of focus makes someone more likely to procrastinate by engaging in other activities [4].

Personal Meaning The extent to which individuals feel their projects are worthwhile pursuits [10]. This includes factors such as fun, pleasure, passion and other's benefit. The lower this is, the less desirable it is to do a task, which leads to more procrastination [4].

Autonomous Motivation A combination of intrinsic motivation, where there is an inner drive to reach a certain goal, and extrinsic motivation, where people have identified with an activity's value [5]. Autonomous motivation for a task leads to less procrastination [20].

Task Delay Events that are further away in time have less impact on people's decisions. So when the deadline or the consequences are far away, there is more procrastination [14].

Self-efficacy A person's belief in his/her own competence. When someone's self-efficacy for a certain task is high, one is more likely to put effort in the task and set appropriate goals for oneself [1]. Self-efficacy varies across different domains and tasks and is thus grouped with the task-related causes.

When self-efficacy is high and someone believes that a certain goal is attainable, he/she is less likely to procrastinate [17].

Task Structure When a task is less structured and more difficult to coordinate, there is more procrastination. The reason for this is that when the task is less structured, there are many points in time at which a decision has to be made about what to do next, and this gives more opportunities for procrastination [4].

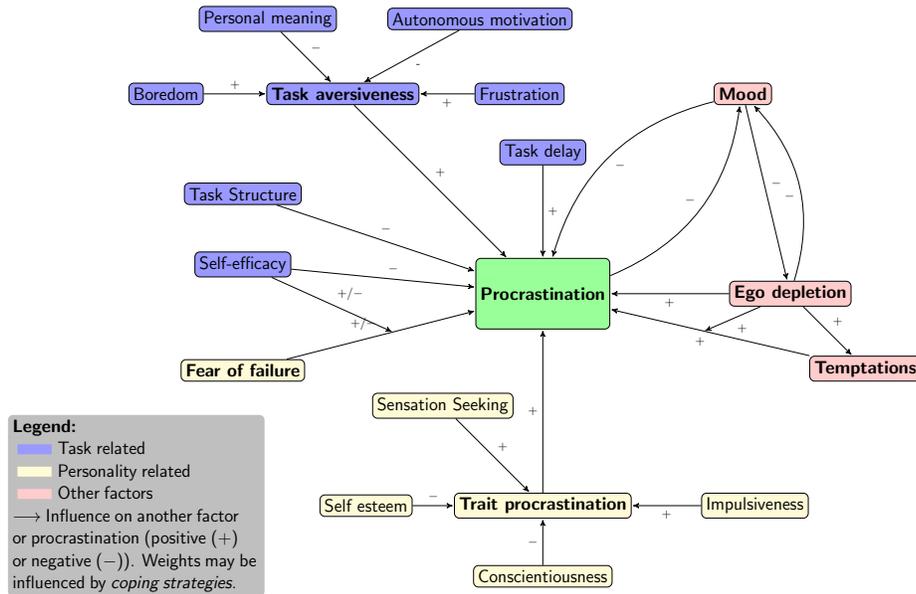


Figure 1: Overview of causes and relations of procrastination

The personality of the agent is also important:

Impulsiveness Impulsive people are more likely to act on the desires of the moment. People that score high on impulsiveness are more likely to procrastinate [17].

Sensation Seeking Sensation seeking is the tendency to find exciting activities, take risks and avoid boredom. The higher someone scores on this trait, the more likely he/she is to procrastinate [17].

Conscientiousness Someone who scores high on this factor can be described in terms such as orderly, neat and organized. Highly conscientious people are less likely to procrastinate [15].

Self-esteem How someone evaluates oneself. When someone has low self-esteem, one is more likely to procrastinate [17].

Fear of Failure The fear of the negative consequences of not reaching one's goals. How it affects procrastination is dependent on self-efficacy: individuals with fear of failure and high perceived competence believe they can avoid failure by working very hard, thus reducing procrastination. When the perceived competence is low, individuals feel that the probability of failing is very high and they will avoid this by procrastinating [7].

Other factors that are taken into account are listed below. These are either external or internal variables that change.

Mood The influence of mood on procrastination is not clear. Some research (e.g. [18]) suggests that a bad mood can increase procrastination and that procrastination will have a negative influence on mood in return, which will increase procrastination again. Yet others say there is no relation between mood and procrastination [17]. We include it to be able to investigate the influence.

Ego Depletion The strength needed for self-regulation is a limited resource and when this resource is depleted, it is much harder to control oneself [2]. The lower the ego resources, the more procrastination. There is also a link between mood and ego-depletion. The reason for this is that when mood is low, it makes a person more depleted, and a more depleted person has more difficulties maintaining a positive mood.

Temptations Other activities that can be done instead of the current activity, but don't contribute towards reaching any of agent's goals. The more temptations are present, the more likely that someone will procrastinate [17].

Coping Strategies Strategies that can be applied to reduce procrastination [16]. Good coping strategies help to reduce the effects that certain factors have on procrastination. For example, a coping strategy like ‘gamifying a task’ can decrease procrastination by decreasing task aversiveness, while another strategy may affect the influence of a particular temptation. Coping strategies are not directly included in the figure. Instead, they are considered co-determinants for the weights of the connections.

4 Formalisation of the model

In this section a formalisation of the conceptual model is presented. In this model an individual agent has various goals. These goals are the personal projects [10] of the agent and can be virtually anything. A goal can be implemented by tasks. These tasks can have subtasks or a single activity. The tasks are on a list of intended tasks and the place on this list is determined by the priority of the task. The agent can perform activities belonging to tasks (one at the time) to reach given goals or perform other activities that do not belong to a task. The activities that don’t belong to a task are generated by events. Figure 2 gives an illustration of the model. Note that the events e_1 and e_2 are triggers that add a_5 and a_6 to the agent’s options. When, for example, one of the activities in the block ‘Procrastination’ is performed, the agent is procrastinating. Structured procrastination occurs when an agent is doing something useful that is on the list of intended tasks, but not the most important thing to be done [12]. (A typical example of this is the increase in cleanliness of student housing by the end of the semester because students don’t feel like studying but do want to do something useful.) This is the case when a_2 , a_3 or a_4 are performed.

In the following sections, first all the definitions will be discussed, followed by an explanation of how the model works. All concepts and their formal notations can be found in Table 1.

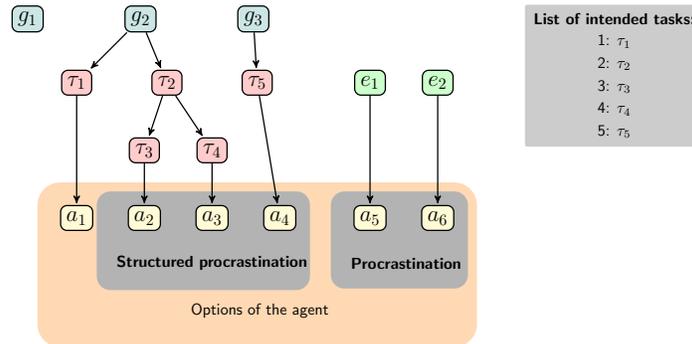


Figure 2: An illustration of the formal model

4.1 Definitions

The agent p , goal g , task τ and activity a are defined as tuples:

$$p = \langle \text{Mood, EgoResource, SensationSeeking, SelfEsteem, Conscientiousness, Impulsiveness, } I, G_p, \text{CurrentActivity, } O \rangle$$

where I is an ordered set containing all intended tasks ordered by their priority, G_p the set of personal goals of the agent, CurrentActivity the activity the agent is performing and O the set of all possible activities an agent can choose from (i.e. the agent’s options): $O = A_E \cup A_T$ (where A_E is the set of all activities that belong to any event and A_T the set of all activities that belong to any task). The other elements are the personality traits found in the literature (see Section 3).

$$g = \langle \text{Description, } T_g, \text{Importance, EstimatedTime, Deadline} \rangle$$

where T_g is the set of tasks belonging to a goal. This set can be empty when the agent hasn’t implemented the goal yet with some tasks. It is assumed that each goal has a known importance value for the agent. EstimatedTime and Deadline can be 0 when the agent doesn’t know these values.

Concept	Formal notation	Definition
Agent	p	An individual agent in the model.
Goals	$g_p \in G_p$	The personal projects of the agent. Given as an input in the model. G_p is the set of goals of an agent p .
Task	$\tau \in T_g$	Implementation of the goal g . A task consists of subtasks or an activity.
Activity	$a \in A_E \cup A_T$	Description of what an agent can do. An activity belongs either to an event (a_e) or a task (a_τ), and is thus either part of the set of all activities belonging to an event (A_E) or to a task (A_T).
Intended tasks	List I	Every task is on this list, but ordered by priority. The priority is a function of the importance of the goal and other task characteristics. I is a list containing all elements in T_G .
Options	$o \in O$	Options are all possible activities an agent can do. $O = A_E \cup A_T$.
Event	$e \in E$	Something that triggers the agent to reconsider his current activity. Adds an activity to O .
Utility	$U(a, p)$	Representation of the desirability of an activity a for a person p .

Table 1: List of definitions

$\tau = \langle \text{Description, Components, Priority, EstimatedTime, Deadline, Preconditions, Structure, Boredom, PersonalMeaning, AutonomousMotivation, Frustration, FearOfFailure, SelfEfficacy} \rangle$

where $\text{Components} = a_\tau | \text{Subtasks}$. Subtasks is a set of tasks (which can have subtasks as well). So a task either has an activity, other tasks or nothing as its component. Preconditions are the tasks that have to be performed before τ can be performed. Initially, we assume there are no preconditions to any tasks. The priority determines the order in the list of intended tasks. It can be calculated with the following formula:

$$\text{Priority}(\tau, p) = \frac{E_{\tau, p} \cdot V_{\tau, p}}{\Gamma \cdot D} \cdot \text{Importance}(g_\tau)$$

where $E_{\tau, p}$ is the expectancy of agent p succeeding in the task, $V_{\tau, p}$ the value, which are the costs and benefits of performing τ , Γ the sensitivity to delay, D the delay and g_τ is the goal associated with task τ . EstimatedTime is a summation over all subtasks or the underlying activity:

$$\text{EstimatedTime}_\tau = \text{EstimatedTime}_{a_\tau} + \sum_{\text{Subtasks} \in \tau} \text{EstimatedTime}_{\text{Subtasks}}$$

τ and a (described next) both include task-related factors found in literature (see Section 3).

$a = \langle \text{Description, EstimatedTime, Preconditions, Boredom, PersonalMeaning, AutonomousMotivation, Frustration, FearOfFailure, SelfEfficacy} \rangle$

In this model, an event is a trigger for the agent to reconsider the current activity. The reason for this is that when an agent is performing an activity, it is most likely that the agent continues with this activity. An agent will consider switching to another activity only when a) the current activity is finished, b) the deadline of the current activity passed or c) an event occurs.

Finally, an event e is defined as:

$e = \langle \text{Kind, Activity, Saliency} \rangle$

where Kind can be internal or external, Activity is an activity that will be added to the options of the agent (and, when applicable, connected with a task) and Saliency is how difficult it is to resist the activity associated with the event. Temptations can be modeled with events. An example of this is a friend who calls to have a drink. This is an external event, with the activity ‘Go out for a drink’ and the strength depends on how difficult it is to resist this temptation. Internal events are governed by rules like ‘when a value (e.g., EgoResource) gets below a certain threshold, a specific event will happen’. External events can also be governed by rules, but will initially be added manually to model a given situation.

The definitions of procrastination and structured procrastination are as follows:

An agent p is procrastinating when $(\text{CurrentActivity}_p \in A_E \text{ or } \text{CurrentActivity}_p = \emptyset)$ and $I \neq \emptyset$.

An agent p is performing structured procrastination when $\text{CurrentActivity}_p \in A_\tau$ and $I \neq \langle \tau, \dots, n \rangle$.

4.2 Process overview

This section contains an overview of the process of the model. It explains how an agent chooses activities and what happens when events occur. Algorithm 1 gives a more formal specification.

Algorithm 1 Process overview

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1: for All tasks  $\tau$  in  $I$  do
2:   Calculate priority
3: end for
4: Sort  $I$ 
5: for each activity  $a$  do
6:   Calculate  $U(a, p)$ 
7: end for
8: for Each timestep  $t$  do
9:   EgoResource = EgoResource · updatespeed
10:  for Each activity  $a$  do
11:    if  $a_\tau$  is finished then # Remove finished activities and their tasks
12:       $O = O \setminus a_\tau$ 
13:       $T_G = T_G \setminus \tau$ 
14:      Go back to line 5
15:    end if
16:  end for
17:  for Each task  $\tau$  do
18:    if  $t \geq \text{Deadline}_\tau$  then # Remove tasks with passed deadlines and their activities
19:       $O = O \setminus a_\tau$ 
20:       $T_G = T_G \setminus \tau$ 
21:      Go back to line 5
22:    end if
23:    if an event  $e$  occurs then
24:      if activity  $a$  is associated with a task  $\tau_g$  then
25:        #Connect activity with associated task and add to set of task-related activities
26:         $\tau_g = \tau_g \cup \tau$ 
27:         $A_T = A_T \cup a$ 
28:      else #Add to set of event-related activities
29:         $A_E = A_E \cup a$ 
30:      end if
31:      EgoResource = EgoResource - Saliency $_e$ 
32:      Go to line 1
33:    end if
34:    CurrentActivity $_p$  = MaxUtility( $a$ )
35:  end for
36: end for

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First, the priority of all the tasks in the model is calculated to determine the order in the list of intended tasks. Next, for each activity the utility is calculated with one of the following formulas (depending on whether it's a task-related activity or event-related activity):

$$Utility(a_\tau, p) = \frac{E_{a_\tau, p} \cdot V_{a_\tau, p}}{\Gamma_p \cdot D_{a_\tau}} \cdot B_\tau \qquad Utility(a_e, p) = \frac{E_{a_e, p} \cdot V_{a_e, p}}{t - \text{EstimatedTime}_{a_e}}$$

where $E_{a_\tau, p}$ is the expectancy, $V_{a_\tau, p}$ the value, Γ_p the sensitivity to delay, D_τ the delay, B_τ a small bonus when an activity is associated with a task in the list of intended tasks and t the current time step. The formulas to calculate these variables are given below. The weights w determine how strong a factor influences procrastination. The formulas include all factors discussed in the conceptual model. Some factors have a positive effect, others a negative, and this is dependent on the influence of this factor on procrastination.

$$E_{a_\tau, p} = \text{Selfefficacy}_{a_\tau} \cdot w_{\text{selfefficacy}} + \text{SelfEsteem}_p \cdot w_{\text{selfesteem}} + \text{AdjustedFearOfFailure}_p \cdot w_{\text{fearOfFailure}}$$

$$\text{AdjustedFearOfFailure}_p = \begin{cases} \text{FearOfFailure}_p & \text{when } \text{SelfEfficacy}_{a_\tau} > 0,5 \\ -\text{FearOfFailure}_p & \text{else} \end{cases}$$

$$V_{a_\tau, p} = -\text{Boredom}_{a_\tau} \cdot w_{\text{boredom}} - \text{Frustration}_{a_\tau} \cdot w_{\text{frustration}} - \text{AutonomousMotivation}_{a_\tau} \cdot w_{\text{AutonomousMotivation}} \\ - \text{SensationSeeking}_p \cdot w_{\text{SensationSeeking}} + \text{Conscientiousness}_p \cdot w_{\text{conscientiousness}} + \text{EgoResource}_p \cdot w_{\text{EgoResource}} \\ + \text{PersonalMeaning}_p \cdot w_{\text{Personalmeaning}} + \text{Mood}_p \cdot w_{\text{Mood}}$$

$$\Gamma_p = \text{Impulsiveness}_p \cdot w_{\text{Impulsiveness}} \qquad \& \qquad D_{a_\tau} = \text{Deadline}_\tau - t - \text{EstimatedTime}_{a_\tau}$$

$$B_t = 1 - \frac{\text{position of } \tau \text{ in } I}{\text{number of items in } I}$$

In each time step, EgoResource is updated. Next, it is checked whether activities are finished, and if so, they are removed from the options. Tasks with deadlines that are passed are also removed. After this, the utility of all activities is calculated again. When an event occurs, it is checked whether they belong to a task that doesn't have an activity yet. If this is the case, the activity is connected to this task and added to the task-related activities A_τ . Otherwise, the activity is added to the set of event-related activities A_e . Because it requires ego resources to resist the event, this value is also updated (depending on the saliency of the event).

After this, the utility of all activities is calculated again. If none of the previously described conditions are the case, the activity with the highest utility is performed. When this activity is in A_e , the agent is procrastinating because the agent is performing an activity that does not belong to a task therefore is not part of the agent's goals. When an agent is performing an activity that does not belong to the task on top of the list of intended tasks, it is structured procrastination.

5 Evaluation plan

The proposed model described in the previous sections should provide insights into the mechanisms of procrastination. We will evaluate the model in three stages. First, we will implement the model in Matlab and run some initial simulations. The weights will be determined in consultation with a procrastination expert and will be the same for all scenarios. A few different scenarios with different kinds of agents (e.g., with high or low conscientiousness scores) will be tested to see if the expected behaviour will follow from the model. Second, we will use an existing data set from a previous psychological experiment on procrastination as training data to determine the appropriate weights for the model. Supervised learning can be used to train the model. The trained model will be evaluated by using another data set as a test set. Third, the trained model will be used to make predictions about behaviour under certain conditions. These predictions will be tested empirically in collaboration with psychologists.

6 Conclusions & Future Work

In this paper, a conceptual model of procrastination is presented that includes prominent factors from psychological literature that influence procrastination. In addition, it presents a formal specification of this model that will serve as the basis of a computational model, which in turn will be used to validate the conceptual model. In future work, the stages presented in the evaluation plan (Section 5) will be executed to validate the model. The complexity of the proposed model mirrors the complexity of the phenomenon. Depending on the outcome of the evaluation the model may be pruned, but we did not want to dismiss any empirically identified factors out of hand.

Procrastination is problematic for many people because it negatively influences people's performance and well-being. There are a number of existing coping strategies (e.g., self-forgiveness [22] and making very concrete plans [21]), but because procrastination is complex behaviour, some strategies may have been unexplored. The validated model can be used to explore whether there are points of influence that the model predicts will decrease procrastination, that as of yet are unused in interventions. This will lead to hypotheses for further empirical studies. Another application of the model is to develop e-coaching software that can support people on an individual basis (by identifying the factors that have the most influence for this individual) in their struggle against procrastination.

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