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Decision-Making under Time Pressure when Rescheduling Daily Activities

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Abstract

Generally during the execution of the daily schedule, there is a mismatch between the plan and the reality. Faced with unexpected events, which affect the schedule, individuals need to reschedule their decisions. In such situations, time is an important factor when making a rescheduling decision, as people feel time pressure because of the time threshold. Consequently, the rescheduling decision is made under the individual's own perceived time pressure (PTP). PTP does not only depend on the actual time pressure, but also on the individual's characteristics. The aim of this paper is to establish a model to simulate the individual decision behavior under PTP. Under different levels of PTP, individuals will choose different strategies to make the decision, and there are three decision strategies to consider: optimal, salient and experience.

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Keywords: Perceived Time Pressure, Decision Strategy, Individual Decision Model, Task Complexity, Choice Probability, Activity Rescheduling;

1. Introduction

Growing concerns in many urban areas related to traffic congestion and the behavioral inadequacy of trip-based travel approach, has led to the emergence of the activity-based approach in order to study travel behaviour. In fact, travel decisions are activity based, and generally, individuals have a schedule for daily activities. In the complicated schedule execution environment, there are uncertainties (unexpected events) disturbing the schedule. Under this situation, people may need to reschedule the rest activities in the original schedule. In such cases, time is an important

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factor. People feel time pressure because of the time threshold, and it determines how people react to the unexpected events.

Time pressure is defined as the difference between the amount of available time and the amount of time required to resolve a decision task[17]. When making decisions, the factor that affect the decision is the feeling of time pressure, rather than the actual time pressure. Therefore, under the same time threshold, different people may feel different time pressures, and then, they may have different choices. Batool [2] regards this fact as perceived time pressure (PTP). According to him, PTP is the feeling of individual of not being able to reach the wanted level of utility at a certain time. This time deadline is specified by either third party or individual himself. In fact, PTP arises with a limited time deadline under the situation of unexpected events happening in the execution of a daily schedule.

The factors affecting PTP are an ongoing investigation. Many studies find that the individual characteristics and time threshold have an influence on PTP[17][18][19]. As for the decision making, [4] put forward that PTP and task complexity affect the decision together. And, there is no strategy model to simulate the decision-making progress. This paper investigates factors affecting PTP and the strategies to make rescheduling decision under PTP. More specifically, the goal of this paper is twofold: (i) it presents a short state of the art of decision strategy and factors affecting time pressure, and (ii) based on this brief review, it proposes a model to simulate the individual decision behavior under PTP. The paper focuses on time threshold and individual characteristics as main factors affecting PTP. This paper runs an experiment to show the choice probability change under different PTP and task complexity, and it defines the new meaning of task complexity in rescheduling decisions.

This paper is structured as follows: It firstly introduces the current researches about time pressure (Section 2), and then analyzes the factors affecting PTP (Section 3). It also explains three decision strategies: optimal, salient and experience, and it establishes an individual decision model under PTP (Section 4). Then, it analyzes the time pressure by implementing an experiment (Section 5). Last section concludes the paper with stating the future work.

2. State of the art

According to the number of participants in the activity, we classify the time pressure as individual time pressure, which occurs when making solo decisions, and group time pressure, which occurs when making group decisions.

For individual time pressure, Rastegary and Landy [17] assert the importance of time urgency in studying decisions under stress. It elaborates that time urgency can be related to all facts of decision making under time pressure and in the presence of other stressors. Time-urgent and non-time-urgent individuals differ in their perception of stress, their response to that perceived stress, and the strategies they use to make decisions. Saleem et al. [18] study the effect of time pressure and human judgment on decision making. The study finds that there is a positive correlation between them by designing and analyzing a questionnaire. Chen et al. [4] apply a discrete choice model of activity-travel behavior that accommodates potential effects of task complexity and time pressure on decision making. It found that there is no interaction between task complexity and time pressure. The results also suggest that policy makers are likely to overestimate traveler sensitivity to changes in the attributes of travel option. Stern [19] studies time pressure faced with congestion. By using decision field theory (DFT), it establishes a model to analyze the effect of time pressure on the route decision under congestion. Batool [2] finds out that people usually perceive less time pressure than the actual time pressure for each activity, while the perceived time pressure exceeds actual time pressure for the whole agenda. Among socio-demographic variables, only gender and category of net household income have an influence on perceived time pressure. Besides, the alternative solutions have a significant influence on PTP as well. Higgins et al. [7] study the stress for commuters. Their paper explains two related concepts: individual's feeling of time pressure that results from incidences of congestion, and traits susceptibility to congestion as a stressor. The paper finds out that compared to drivers who experience only infrequent congestion, those who spend more time commuting in congested conditions show drastically different tolerances for travel times.

For group time pressure, Kelly and Karau [9] find that initial preferences dramatically influence both group interaction processes and final group decisions, and that decisions are biased in favor of initial preferences. Time pressure leads to a faster work rate and also leads group members to report that their attention was more focused on task completion. Time pressure also tends to enhance the impact of initial preferences on final group decisions but only in the correct and weak incorrect preference conditions. De Dreu [5] explains that during the negotiation process, in high time pressure conditions, participants were led to believe that this amount of time was relatively tight, while those in low time pressure conditions believed that this same amount of time was more than enough to reach agreement. Noh and Gmytrasiewicz [14] use a recursive model structure [21, 20] to represent the agent's information of other agent. Their work defines the value of time, and its goal is to enable the agent to be optimal as it trades off the value of time for increasing in quality of more informed decision making. The decision of whether to execute the best current action or to keep computing with extra information, it depends on the utility comparison of time and further information benefit [13]. Rai and Mahanty [15] put forward that during the software project process, the emerge certain parameters or variables, pertaining to behavioral and organizational issues will dynamically affect the project. Additionally, the involved agents need to interact with each other to solve the issue under schedule pressure. Schedule pressure comes from the limited time and the consideration of finishing the project with high quality. The paper regards time ratio as schedule pressure, and classifies it as low, medium, and high. In addition, it finds that if the schedule pressure is increased, the project progresses faster.

Time pressure generally has a negative affect on the solo-decision making, and the decision is determined by the individual herself, the activity (or schedule) complexity, and also the time threshold. Under time pressure, participants in the group will increase the speed of negotiation [11, 12]. While, the quality of exchanging information is based on the characteristics of the individual and his knowledge about other participants. The main focus of this paper is the individual rescheduling decision behavior under PTP.

3. Time Pressure Classification and Factors

This section classifies the time pressure according to time horizon, and analyzes the factors affecting time pressure.

3.1. Time pressure classification

The time pressure classification, briefly explained in Section 2 is based on the number of decision makers. And from the time period to make the decision in the schedule, we propose to classify and define the time pressure as execution time pressure and decision time pressure. They can be involved in the individual or group time pressure. The classification is to distinguish the time deadline to make the rescheduling decision. The definitions of them are follows:

- **Execution time pressure:** If the unexpected event happens during the execution of the activity, then the individual needs to make the rescheduling decision before end time of the affected activity, and only the end time of affected activity can be changed. Time pressure under this situation is considered as *execution time pressure*. It comes from the time threshold of the end of the affected activity.

- **Decision time pressure:** If the unexpected event happens before the start time of the affected episode (trip/activity pair), and also, the time left to make a decision is smaller than the limited rescheduling time, then the individual is faced with a decision time pressure. The attributes of the affected activity can be changed. Time pressure under this situation is considered as *decision time pressure*. It comes from the time threshold of the limited rescheduling time and the start time the affected activity.

3.2. Factors affecting PTP and PTP's effect on individual decision-making

Time threshold and individual characteristics are the two factors affecting PTP. Time threshold means the deadline to make a decision or to execute the affected activity. It is the actual time pressure according to the literature. Every activity has a certain threshold of time to perform it. Additionally, individual characteristics have an essential influence on time pressure, like gender, income, and job state. They determine the level of perceived time pressure an individual can feel.

To study the effect of PTP on individual decision-making, probabilistic theories are used. In dynamic situations, time pressure is connected to the development of the situation itself. Busemeyer and Townsend [3] elaborate that the aim of DFT is to understand the motivational cognitive mechanisms that guide a deliberation process involved in making decisions under uncertainties. They integrate both information from the external environment and information from the individual's associative memory as determinants of possible actions to be evaluated in a deliberation process.

Deliberation is a time-consuming cognitive process that seeks the consequences of recognizable actions, weighting of the payoffs of events, and comparing the weighted consequences to establish a preference state. The deliberation process ends when a choice is made and an action is taken. There are two types of theories in DFT: deterministic theories and probabilistic theories. For two choices A and B, the deterministic theories use a binary preference relation to choose the best one, while the probabilistic theories regard the probability as a primary measure, and the binary preference as a secondary measure. The measurement of each choice of probability is described in S_2 in Section 3.3.

3.3. Decision strategies

Faced with unexpected events, a set of alternative choices is obtained according to the decision tree that was proposed by Zhao et al. [23]. Let's assume that $\mathbb{S}$ is the set of alternative choices; $s_{i,\,i=1,\ldots,K} \in \mathbb{S}$ is a given choice with a utility $u_{i,\,i=1,\ldots,K}$; and K is the number of alternative choices. This paper proposes three main strategies to make decision under PTP.

S_1. *Optimal Strategy.* By using the S-shaped utility function [22], the final choice is the one with the highest utility score, and PTP is not considered. It means that some people can make the best decision even under time pressure. Generally, it happens under the situation of a very low PTP. The decision in optimal strategy is $s_i : u(s_i) = max(u(s_{j,j=1,\ldots,K}))$.

S_2. *Salient Strategy.* The use of information is affected by PTP. Under a higher level of PTP, individuals would like to consider the salient choice. It is more selective, but it does not mean not to consider other alternatives. It is to offer higher weight to salient choices under PTP as compared to situations with less time restrictions [16]. For each alternative choice, a probability is provided, and people would like to choose the choice with the highest probability. The probability function is related to utility, PTP and task complexity. For all the alternative choices, each choice is associated with a task complexity. In [4], task complexity is related to the number of activities and travel alternatives. Considering that individual has the resistance to change the planned schedule and there is an original schedule, the goal is to minimize the dissimilarity between the original and schedules. This paper propose the task complexity as the number of changed activities between the original schedule and the new schedule. The more changed activities in the alternative choice, the bigger the task complexity. The probability function is the classical logit function [2]. For a choice $s_i \in \mathbb{S}$, the probability before primary decision is p_i^0. The scale parameter (choice preference) μ is parameterized as a function of task complexity and time pressure [4]. In this paper, PTP is used rather than time pressure.

$$p_i^0 = \frac{e^{\mu_i u_i}}{\sum_{k=1}^{K} e^{\mu_k u_k}} \tag{1}$$

$$\mu = e^{\lambda\ TC + \delta\ PTP + \theta\ PTP^2 + \omega\ TC \times PTP} \tag{2}$$

In Equation 2, *TC* is an indicator of task complexity, λ denotes the parameter for activity complexity, which has a negative sign. The higher the task complexity, the lower the choice probability. *PTP* is the parameter of time pressure in choice situation, δ denotes the parameter for the linear component of the time pressure index, θ denotes the parameter for the quadratic component of the time pressure index. ω gives the strength of the interaction effect of activity complexity and time pressure. The measurement of *PTP* is explained in Section 4.2. The original probability of each alternative p_i^0 is measured as in Equation 1. After the first choice is made, the choice probability will be updated according to the Bayesian method [1].

$$p_i^{t+1} = \begin{cases} \frac{p_i^t M^t + 1}{M^t + 1} & if\ I_i^t = 1 \\ \frac{p_i^t M^t}{M^t + 1} & otherwise \end{cases} \tag{3}$$

$$M^{t+1} = \alpha M^t + 1 \tag{4}$$

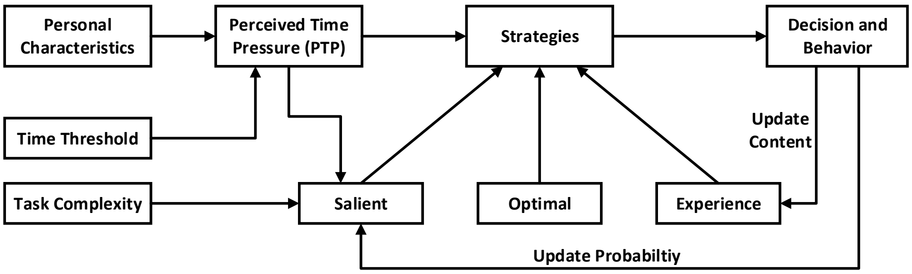

Fig. 1. Decision strategy under time pressure

For the time $t > 0$, set p_t^i as the probability of choosing a choice i at time t. In Equation 3, M is a weighted count of the number of times the choice is made in the past. I_i^t indicates whether or not a choice i is chosen at time t. $0 \leq \alpha \leq 1$ is a retention rate of past cases. As implied by Equation 3, more recent cases have higher weights in the update (if $\alpha < 1$), to account for possible non-stationarity in the agent's decision behavior.

S_3. *Experience Strategy.* Gärling et al. [6] put forward that during time pressure, people tend to act and think in ways that have previously met with satisfaction. In this paper, experience strategy is to choose the most satisfied choice $s_e \in \mathbb{S}$ according to the memory in the previous experiences. For the round of $t+1$ time to make a decision, the new choice s^{t+1} is made. And it needs to be compared with the previous experience choice s_e^t, if $u(s^{t+1}) > u(s_e^t)$, then $s_e^{t+1} = s^{t+1}$. Otherwise, $s_e^{t+1} = s_e^t$.

4. Individual Decision-making Models under Time Pressure

Three decision strategies are introduced in Section 3.2, and a decision model is established based on these strategies and factors, which affects PTP.

4.1. Individual decision model

The decision model is shown in Figure 1. Under PTP, an individual has three strategies: salient, optimal and experience. Time threshold and individual characteristics can affect PTP, then PTP and task complexity affect individual's choice in salient choice.

4.2. Measure PTP

To measure PTP, time threshold and characteristics should be considered. The basic measurement of time pressure [2] is shown in Equation 5. In the equation, TP is time pressure, DT is the time needed to make a decision, and DTB is the time budget to make the decision.

$$TP = \frac{DT}{DTB} \tag{5}$$

Lau et al. [10] combine individual characteristics into time pressure in negotiation. Their work puts forward the term of *eagerness* that means an individual may be eager to reach a deal in negotiation. If he/she wants to get the final decision quickly, he/she will concede more quickly. The measurement of time pressure is shown in Equation 6. In the equation, t is the absolute time left to make the decision, t^d is the allowed maximum time budget to make the decision, e is the eagerness factor.

$$TP(t) = 1 - \left(\frac{t}{t^d}\right)^{\frac{1}{e}} \tag{6}$$

Based on the measurement above, and also considering the classification of execution time pressure and decision time pressure, the equation of PTP is proposed as follows:

$$PTP = \begin{cases} 1 - \left(1 - \frac{ET}{DTB}\right)^{\frac{1}{f}} & \text{if Execution Time Pressure} \\ 1 - \left(\frac{ET}{RST}\right)^{\frac{1}{f}} & \text{if } ET < RST\text{, Decision Time Pressure} \\ 0 & \text{Otherwise} \end{cases} \tag{7}$$

In Equation 7, ET is the distance from the start of the activity and the event happen time, DTB is the planned duration time to finish the episodeRST is limited time to make a rescheduling decision, and f is the factor related to individual's characteristic, which reflects individual's ability to obtain PTP.

4.3. Choose strategy

We assume that under a level of PTP, individuals would like to choose a certain decision strategy. Under a high level PTP, people do not have too much time to make a decision, and they just choose the past best choice in experience. Under a low level PTP, people have time or ability to make the optimal choice. In other situations, people would like to choose the salient choice. Set a level value a, b, the probability of choosing a strategy is shown in Table 1:

Table 1. Decision-making strategies under PTP.

PTP	PTP $\leq a$	$a <$ PTP $< b$	$b \leq$ PTP
Strategy	optimal	salient	experiment

5. Analyses of Decision-Making Choice and PTP

This section analyzes the factors' influence on PTP, and the probability of each alternative choice under PTP.

5.1. Parameters related to PTP

According to PTP Equation 7, the effect of time threshold and individual's eagerness on PTP can be analyzed. For time threshold's effect, we assume event time is the event happen time. It may be before the start of the affected activity (negative) or during execution process of the affected activity (positive). Set the eagerness $e = 10$, the time duration $DT = 40$ minutes, and the limited rescheduling time $RST = 20$ minutes. The relationship between event happen time and PTP is shown in Figure 2. For the eagerness's effect on PTP, set the time duration $DT = 40$ minutes, and event happens during the activity execution process, $ET = 20$ minutes. The relationship between eagerness and PTP is shown in Figure 3. From Figure 2 and Figure 3, it can be seen that if the event happens before the start of the affected activity, and there is no PTP. The PTP increases as the event happen time being closer to the start time of the affected activity. During this period, the PTP comes from decision time pressure. If the event happens during the execution of the affected activity, it is the execution time pressure. Under different kind of time pressure, the alternative choices in mind are different. Under decision time pressure, the value of PTP is rising from the beginning. And then it is calculated from zero when it transfers execution time pressure, it increases as the time being closer to the end of the affected activity. As for the individual characteristic f, the bigger the f, the lower the PTP can be obtained.

5.2. PTP's influence on choice probability

The parameters' values in Equation 2 are determined in this section. λ, δ and θ represent the degree of task complexity and PTP's influence on choice probability. According to Chen et al. [4], $\omega = 0$: it means the task complexity

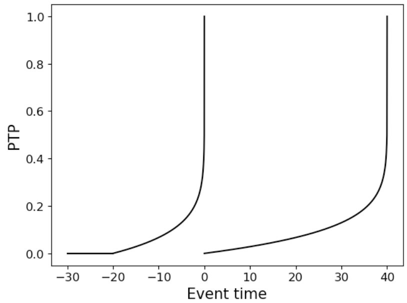

Fig. 2. Event happen time's effect on PTP

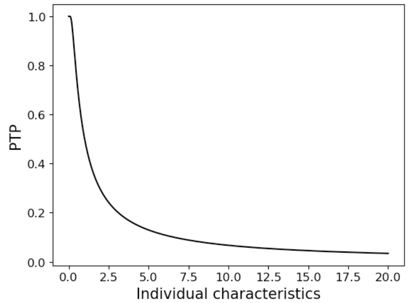

Fig. 3. Individual characteristic's effect on PTP

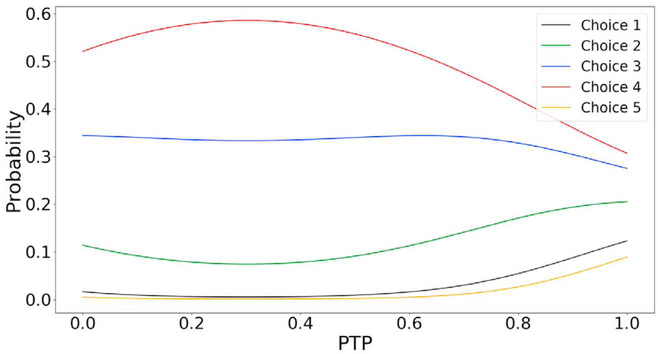

Fig. 4. Probability of each choice under PTP

and PTP have no correlation. Set $\lambda = -0.0101$, $\delta = 2.03$, $\theta = -3.36$. And, the value of task complexity is the number of changed activities in the new schedule. Joh et al. [8] study the utility for different types of activities, the value of activity utility is different for different people. This paper assumes five alternative choices. The values of utility and task complexity are shown in Table 2, and we assume the utility of each choice stay same as time passing by.

Table 2. Values offered for each choice's utility and task complexity

Choice	1	2	3	4	5
Utility	39	41	43	43	37
Task complexity	3	3	5	4	1

Figure 4 shows that as PTP increasing, the probability of each choice has the trend to reach an average level. While, utility plays the most important role in choice probability, the choice with high utility still has a higher probability than lower utility choices. Although choice 3 and choice 4 both have the highest utility, only the choice 4 has a peak point with PTP increasing, and then it goes down. Choice 3 has a lower task complexity than choice 4, and it has a most stable trend as PTP increasing, just a little decreasing fluctuation when PTP is higher. Choice 1 and choice 5 has a smaller utility and task complexity, their probabilities are going up with time. When PTP is bigger than 0.8, they increase sharply. Choice 2 has a higher utility and the same task complexity than choice 1, it almost has a same trend with choice choice 1, while with a higher probability value.

6. Conclusion

This paper mainly analyzes how individual characteristics and time threshold's impact on PTP. It also explores the PTP and task complexity's influence on each alternative choice's probability. The values of parameters which denote task complexity and PTP come from a survey, they cannot represent all the situations. According to the experiments, it found the main factor that determines the choice probability is choice utility. As PTP increasing, probabilities of all choices have the trend to be equal. What is more, this paper puts forward a decision-strategy model under PTP, and explain each strategy in detail. While, how individual chooses the strategy under PTP will be studied in the near future. Additionally, the future work will also need to validate the model to real human behavior.

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