Adapting to change

Some evidence from a simple learning model

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Adapting to change: some evidence from a simple learning

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ADAPTING TO CHANGE: SOME EVIDENCE FROM A SIMPLE LEARNING MODEL

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1 INTRODUCTION

In transport research there is an increasing interest in modelling the dynamics of day-to-day decision making, especially in the context of route and departure time choice. This interest has been stimulated by the current discussion about the introduction of various traveller information systems, in particular of route guidance systems. The policy context of this discussion does not need to be rehearsed here, but the interested readers might wish to consult journals, such as *Traffic Engineering and Control*, *Transportation Quarterly* etc.

The modelling of the day-to-day decision making requires assumptions about the way, in which the respondents, as a group or individually, integrate new experiences or external information into their decision making. This learning or updating process is crucial and the assumptions about it have a strong influence on the results obtained. Among the many possible models (see for example Van Berkum and Van der Mede, 1991, Koutsopoulos and Xu, 1993 or Mahmassani and Chang, 1985) the simple exponential smoothing model:

$$\textit{Expectation}_t = \tau\, \textit{Experience}_t + (1 - \tau)\, \textit{Expectation}_{t-1}$$

with the single smoothing parameter τ ($0 \leq \tau \leq 1$) has become popular (see for example Emmerink, Axhausen, Nijkamp and Rietveld, 1993 and 1994, Iida, Akiyama and Uchida, 1992, or Horowitz, 1984). While the model is applied widely, a detailed empirical analysis of the parameter of the model is missing. Iida *et al.* (1992) is one of the exceptions. They report values of τ around 0.5 estimated using a regression-derived procedure based on a set of repeated route choice experiments, in which the respondents had to state their travel time expectations for each of the two routes available. Their results also indicate, that the parameter estimate varies systematically for different subsets of the respondents defined by their willingness to change route.

The popularity of the model is based on its computational and conceptual simplicity and on the clear interpretation of the smoothing parameter τ as a measure of the habit strength. The disadvantages of the model are overlooked for these advantages. Among the disadvantages is that the value of the forecast is bounded by the values of the last experience and the prior expectation, i.e. that the traveller cannot use the experiences of the last day(s) to anticipate a recognized trend.

Figure 1 Visualisation of the route choice, 1993 Experiment

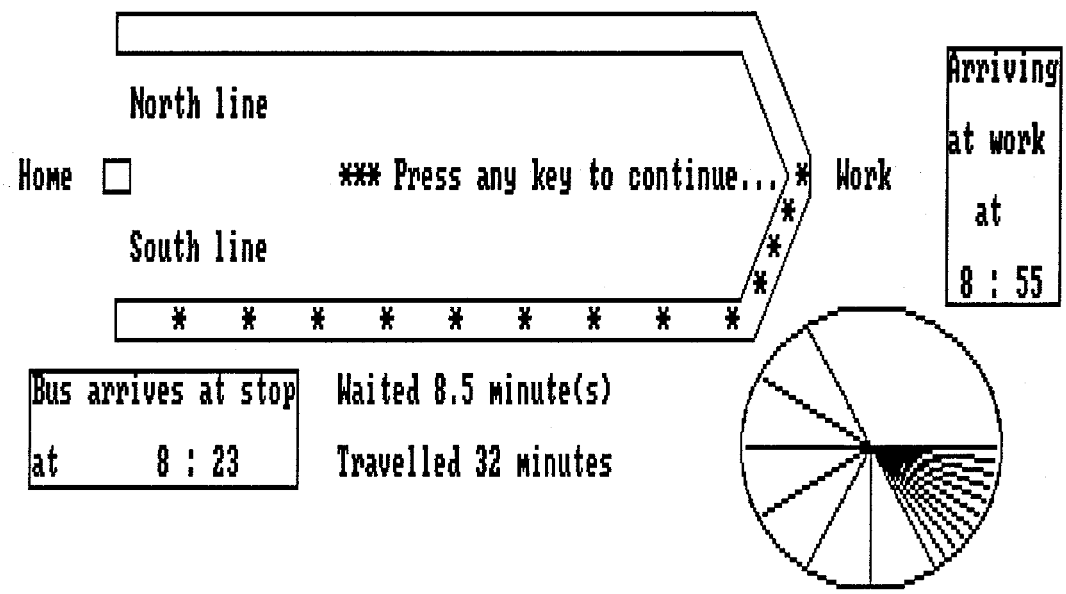
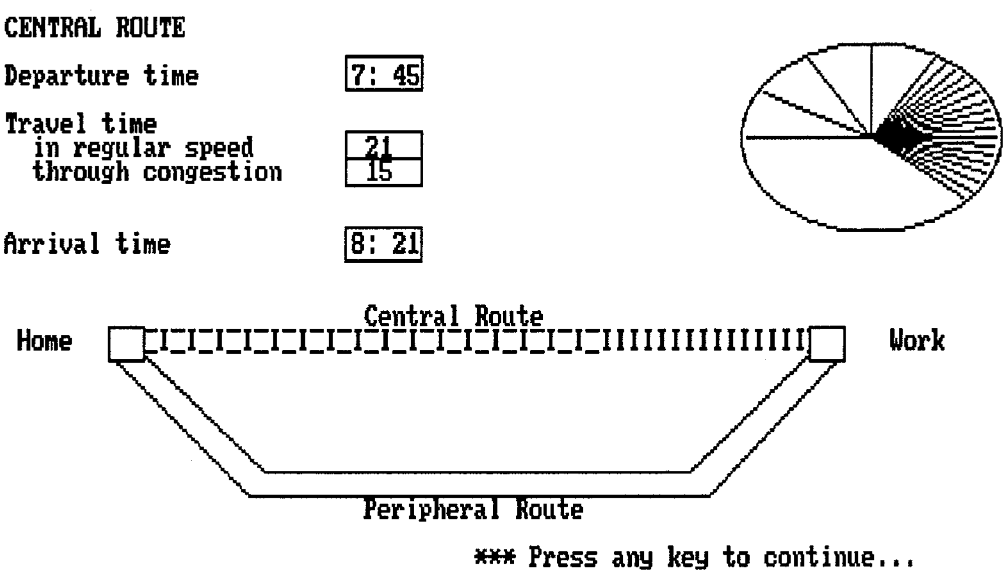


Figure 2 Visualisation of the route choice, 1994 Experiment



3 CALCULATING T

While the econometric estimation of the error minimizing τ is possible for the sample as a whole, this paper will concentrate on the calculation of the error minimising τ for each individual respondent. (An statistically spoken fuller analysis built on a fuller specification of the error-structures is currently ongoing and will be reported later). The smoothing model looks deceptively simple, but for the calculation of the τ minimising the error from the experiment a number of assumptions have to be made, whose psychological correctness cannot be tested within this study. The assumptions concern:

- the initial value of the expectations
- the possible reinitialisation of the expectations
- the treatment of missing days in multiple choice situations
- the measurement of the error

In the simplest case the initial value of the expectations could either be the information provided about the routes at the start of the experiment or be zero, i.e. assuming that the respondents ignore the advice given. This second assumption seems unrealistic, although there is some evidence to this effect from the development of the schedule delays over the course of the experiments. In the calculations the first assumption was used.

The experiments provide information about the expectations of the respondents at three points during the interview (after the 7th, 11th, 15th day in 1993 and after 5th, 10th and 15th day in 1994). It is therefore possible to use these stated values to reinitialize the expectations at these points or to ignore them. Both possibilities were tested in this paper.

The formulation of the model is unambiguous if the respondent has only one route available, but it becomes ambiguous if multiple routes are available. Assuming that missing days do not affect the updating process and not reinitializing the expectations, it is possible to calculate the new expectations as:

$$e_{ij} = \begin{cases} \tau t_{ij} + (1-\tau) e_{i-1,j} & \textit{if route } j \textit{ was taken on day } i \\ e_{i-1,j} & \textit{if route } j \textit{ was not taken on day } i \end{cases}$$

e_{ij} : *Expectation at end of day i for route j*

t_{ij} : *Traveltime on day i on route j*

τ : *Smoothing parameter*

e_{0j} : *Initial information provided to the respondents for traveltime on route j*

Assuming that the travellers continue to update their expectations for routes even on days on which they were not used, and assuming that the expectations are not reinitialized, it is possible to calculate the new expectations as:

$$e_{ij} = \begin{cases} \tau t_{ij} + (1-\tau) e_{i-1,j} & \textit{if route j was taken on day i} \\ \tau t_{last j} + (1-\tau) e_{i-1,j} & \textit{if route j was not taken on day i} \end{cases}$$

$t_{last j}$: *Traveltime on the last day route j was taken*

If reinitialization takes place, then:

e_{ij} = *Value stated by respondent for route j traveltime at the end of day i*

$$for \begin{cases} 1993 \textit{ if } i-1 = 7, 11 \\ 1994 \textit{ if } i-1 = 5, 10 \end{cases}$$

The error can be measured using the expectations stated by the respondents at the three points during the interview or by using the implied expectations as expressed by the departure time decision on any one day a route was used.

For the τ's calculated across all fifteen days of the experiments the total error was calculated as:

Stated expectations : $SSE = \sum_{i=5,10,15 \text{ or } i=7,11,15} (e_{ij} - se_{ij})^2$

Implied expectations : $SSE = \sum_{i=2}^{15} (e_{i-1j} - (pat - dt_i))^2$, *if route j was chosen*

with

SSE : *Squared sum of errors*

e_{ij} : *Expectation for traveltime after day i for route j*

se_{ij} : *Stated expectations for traveltime of type k after day i on route j*

pat : *Preferred arrival time*

dt_i : *Departure time on day i*

The different permutations of the approaches were tested for the 1994 data set. The combination, which minimized the sum of the errors across the whole sample, was chosen for the further analysis. It combines:

- No reinitialisation
- No interpolation of missing values
- Measurement of the error against the stated expectations

Given the dominance of public transport for the journey to work in London the choice was presented as the choice between two bus routes, which offered a trade-off between average waiting and travel time. The experiment in Athens was formulated as the choice between two routes (Central - Peripheral), which offered a trade-off between congested and uncongested travel times.

The sequence of the travel times experienced by the respondents followed different patterns in the two experiments. In the 1993 London experiment the travel times (waiting and in-vehicle times) were varied around their stable average values, except for one day, when both routes experienced a major delay explicable to Londoners as a bomb-alert, a failed signal etc. The amount of variation was varied defining two groups (small and large variation). In the 1994 Athens experiments the travel times for one route (congested and uncongested) varied around a stable mean, while for the other route they varied around a linearly increasing trend. Two groups were defined by the pattern of increase and stability (Central route stable - Peripheral route increasing and vice versa).

In the 1993 experiment the respondents were asked to state their expected total travel time for both routes, while in the 1994 experiment they were asked to distinguish additionally between congested and uncongested travel times. Dimitrakopoulou (1994) observed, that the respondents had difficulty with this task; in particular that they seemed to generate the congested travel times by subtracting the uncongested travel time from the total travel time. The paper will therefore only analyse total travel times.

The experiments lasted about 25 minutes each. None of the respondents abandoned the interview once it had started. In the visualizations of the choices the time scale used was 1.0/0.8 seconds of screen display for each minute of in-vehicle/uncongested time (1993/1994) and 2.0/1.2 seconds for each minute of waiting /congested time. The different scaling was adopted to convey the nuisance of waiting or driving through congested time. This difference was also visualized through denser line patterns on the clock and route displays (see below).

2.2 Samples

The two samples were contacted at their work places, where also their interviews took place. The 1993 sample is older, has more males and is more senior in professional terms than the 1994 sample, but in turn reflects London conditions by relying more on public transport and by travelling substantially longer to work.

Detailed results about the choice behaviour and the socio-economic characteristics are reported in Dimitropoulos (1993) and Dimitrakopoulou (1994).

The purpose of this paper is to contribute to the knowledge about the empirical value of τ for different groups of respondents, but in particular to present information about the distribution of the values of τ given certain assumptions about the calculation of τ. The paper will also shed light on the set of assumptions needed for the calculation of that τ, which minimizes the measured error.

The remainder of the paper is structured in the following way. Section 2 presents the experimental procedures used to collect the data. Section 3 discusses the available approaches to calculate τ for each respondent. Section 4 presents detailed results for the chosen method. Conclusions are drawn in the last section.

2 EXPERIMENTAL PROCEDURES AND SAMPLES

2.1 Experimental design

The experimental observation of mental updating processes is fraught with problems (see Jackson, 1994 for a full discussion in the contexts of mental maps). These problems have not been fully solved in the spatial domain in spite of substantial methodological research over the last decades. The problems have not even been addressed in the research in the temporal domain, which so far has been dominated by engineers, who as a rule discount such problems. The work reported here falls in the same category and should therefore be seen as a cautious step in the development of valid experimental procedures for the observation of the temporal learning and updating processes.

Inspired by the work of Mahmassani and Chang (1995, 1986), Iida *et al.* (1992), Bonsall (Bonsall, Stathopoulos and Pickup, 1991) and others, computer based experiments were developed in 1993 (Dimitropoulos, 1993) and 1994 (Dimitrakopoulou, 1994), which had the following basic structure:

- A simple choice situation between two routes on the way from home to work
- No late arrival permitted
- Repeated choice of route and departure time by the respondents (15 days)
- Predetermined travel times, common to subsets of the respondents
- No information about the non-chosen route was provided
- Visualisation of the choice by a screen display of a duration proportional to the duration of the trip (See Figure 1 and Figure 2)
- Explicit questions about the expected travel times on both routes at regular intervals during the interview (after days 7, 11 and 15 in 1993 and after days 5, 10 and 15 in 1994)
- A small set of socio-economic questions at the end of the interview

The choice context and the logic of the travel times differed between the two studies reflecting the different interview locations. The interviews in 1993 were conducted with staff members at Imperial College, London and University College London, whereas the interviews in 1994 were conducted with employees working in a number of firms in the centre of Athens.

Figure 5 Distribution of optimal τ's for Central route and Group 1 (All days, 1994 data)

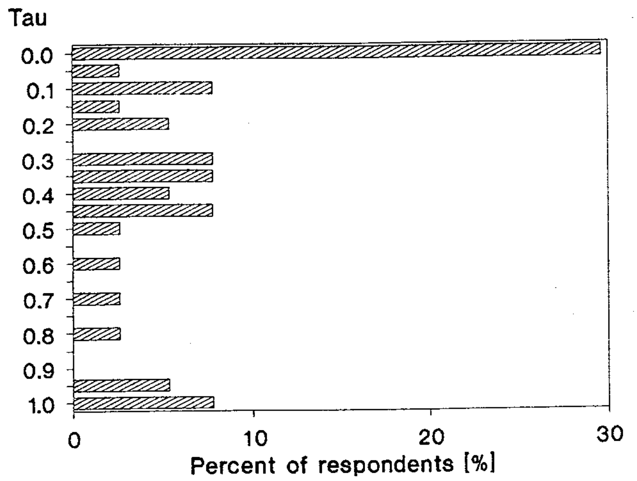


Figure 6 Distribution of optimal τ's for Peripheral route and Group 1 (All days, 1994 data)

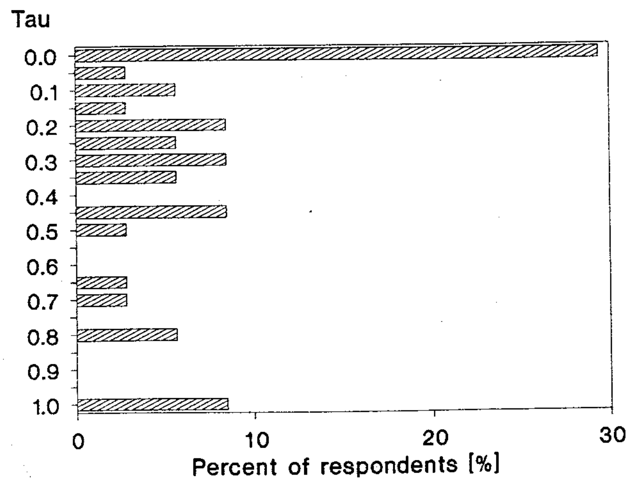


Figure 7 Distribution of optimal τ's for the Central route and Group 2 (All days, 1994 data)

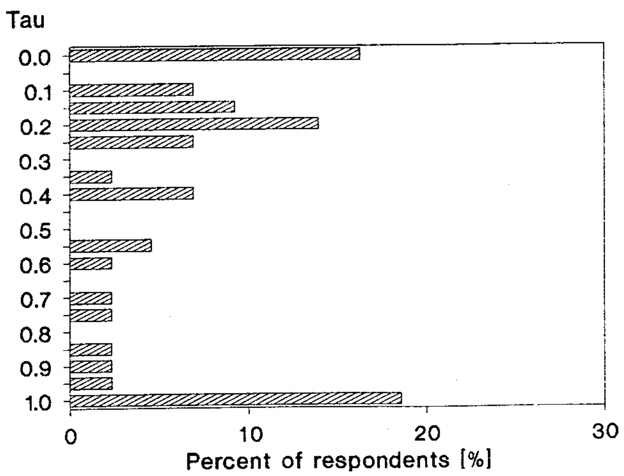
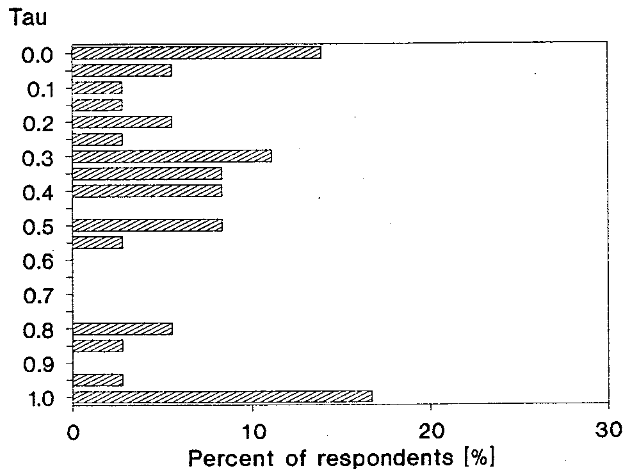


Figure 8 Distribution of optimal τ's for Peripheral route and Group 2 (All days, 1994 data)



4 RESULTS FOR PREFERRED CALCULATION METHOD

The preferred calculation method was applied to all days, i.e. calculating one optimal τ, and by week, i.e. calculating the sequence of three τ's - one for each week -, which in that sequence minimized the overall error. This second method is of particular interest as it indicates the reactions of the respondents to the changes in travel times. Due to the combinatorial increase in the number of sequences the sequences were only calculated for a step size of 0.1, while the single τ's were calculated using a step size of 0.05.

Figure 3 and Figure 4 show the distribution of optimal τ's for the 1993 experiments. Both distributions are left-skewed with a mode of zero; implying that the majority of the respondents did not update their expected travel times. For a sequence of random travel times varying around a stable mean this is actually the optimal strategy, if the respondent can assume that he has been given the correct information for that mean. For the South-route this tendency is even more pronounced.

In the 1994 experiments it is necessary to distinguish not only between routes, but also between groups, as they are defined by the patterns of travel times experienced. Figure 5 to Figure 8 show the distribution of optimal τ's for these four respondent subgroups. The pattern of the distribution depends on group membership and not on route, although one would have a priori expected that the route has a stronger impact. The respondents of Group 1 (Stable central route - growing travel times on the peripheral route) show a pattern similar to the 1993 data, i.e. left skewed with a relative majority of no updating, although there is a second mode around a τ of 0.30. This reflects the preference of the respondents for the stable Central route, which in this case gives no reason to updating. The respondents in Group 2, in contrast face a condition, in which the preferred Central route deteriorates, giving an incentive to incorporate recent information into the expectations. These distributions have a mode at 1.0, i.e. complete reliance on the last experience, while they have pronounced further modes around $\tau = 0.25$ and at $\tau = 0.0$. Clearly a complex learning process is involved, in which the respondents combine their travel times experiences on the different routes to choose an optimal updating strategy.

Figure 3 Distribution of optimal τ's for North route (All days, 1993 data)

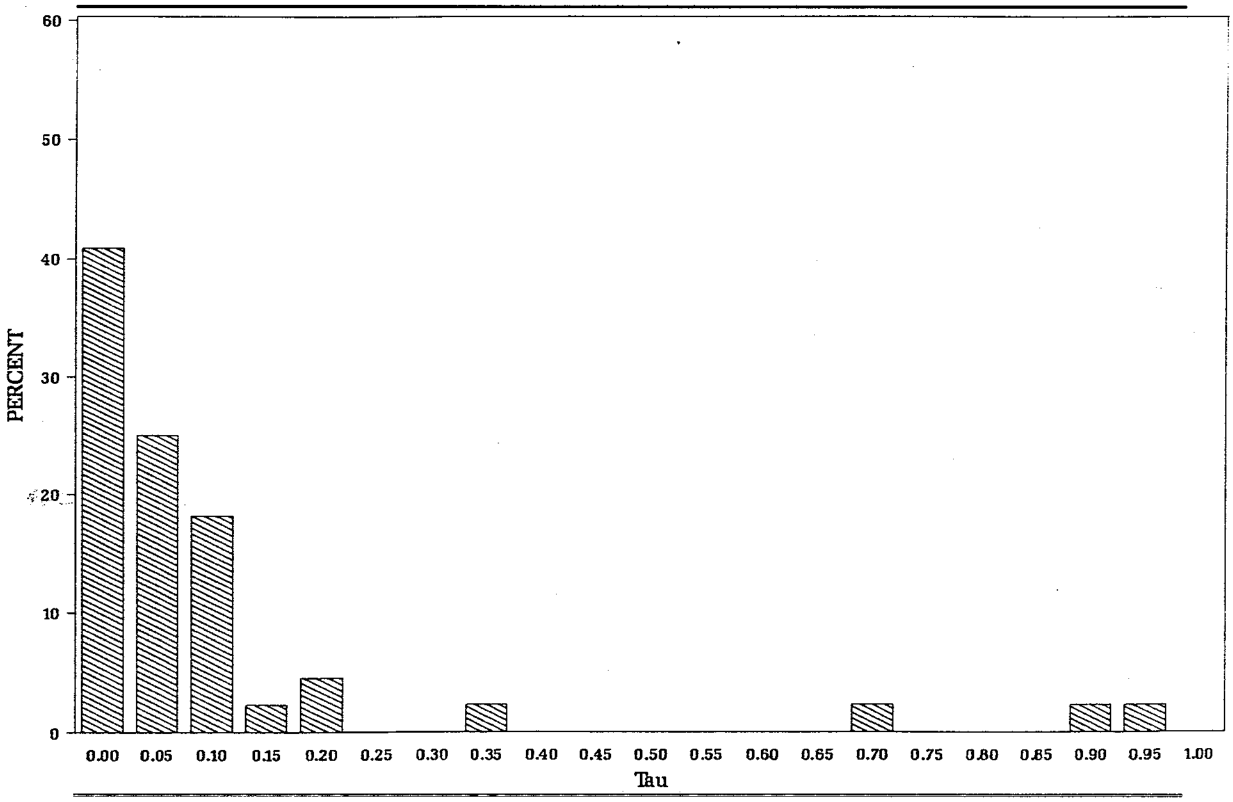
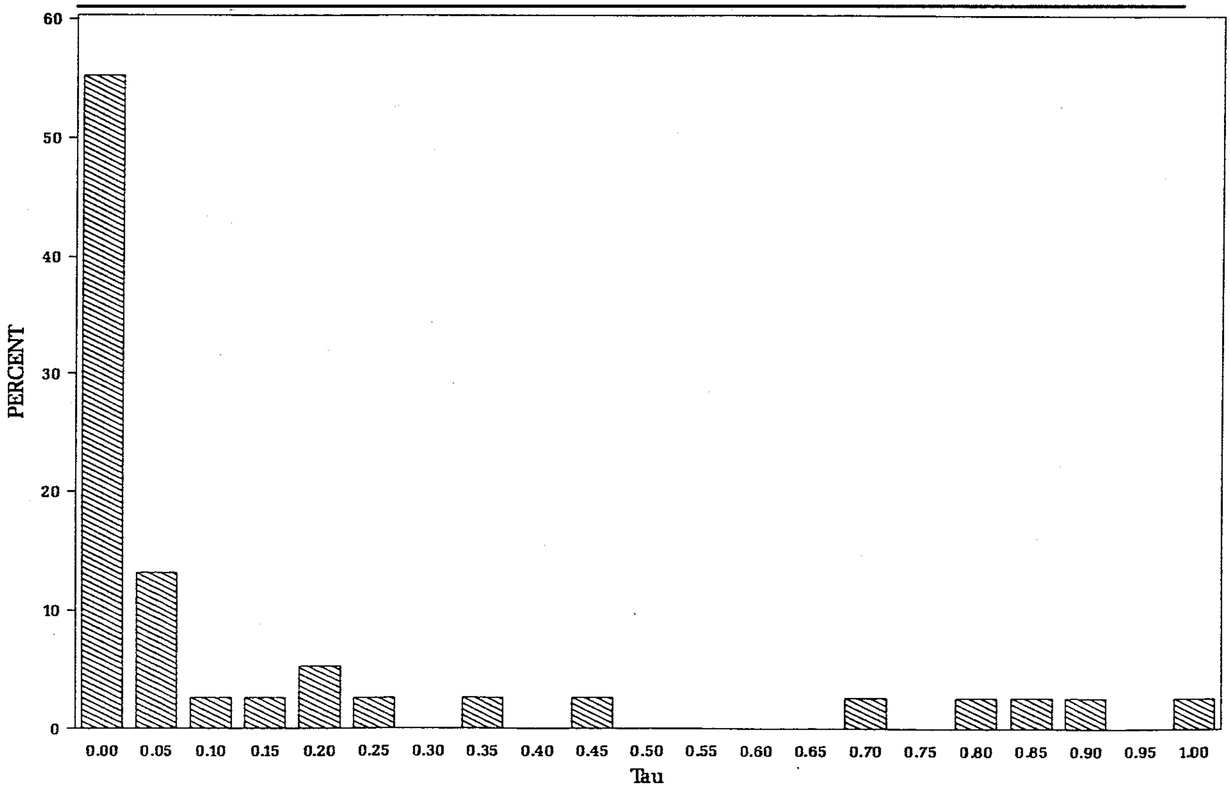


Figure 4 Distribution of optimal τ's for South route (All days, 1993 data)



This learning process can be traced even better in the τ-sequences described above. For the 1993 experiments and the South route Figure 9 shows the distribution of the τ's for weeks one to three, belonging to the optimal sequences. It is clearly visible, that in weeks one and three, where the travel times vary around a stable mean, the distribution is left-skewed with a mode of zero, while in the second week with its "disaster" a substantial number of respondents switch to a strategy of incorporating that experience in their assessment. The value of τ = . indicates no travel experiences of that route in that week, which makes the calculation of the τ impossible in that week. The share of this missing value in week three indicates, that nearly half of respondents shifted completely away from that route because of the disaster. The experiment was not long enough to see how long this effect would have lasted.

The following two figures show the transitions between the τ's in the sequence. In Figure 10 it is obvious that independent of their original updating strategy many respondents switch to a strong updating strategy ($\tau = 0.8$) in response to the disaster. That these respondents overwhelmingly abandon this route in the following week can be seen in Figure 11, i.e. a transition from $\tau = 0.8$ to a missing value, whereas those respondents which discounted the experience stay with it during week three. It should be pointed out that the figure does not distinguish between those who experienced the disaster on this route or the other route (The areas of the circles are proportional to the number of respondents).

This effect is naturally missing in the 1994 experiments, but the analysis showed for Group 2 that in week 3 a substantial number of respondents have adopted an updating strategy, which included both past and current experiences. There is a noteworthy amount of movement between the optimal τ's in the different weeks indicating that the learning process is not stable, but subject to various outside influences.

No attempt to identify these influences was be undertaken in this paper, but any attempt will have to look at the interaction between choices and experiences and the information inferred from the respondent from this.

5 CONCLUSIONS

This paper has investigated the properties of a simple learning model, which has been proposed by a number of authors as appropriate to the modelling of temporal mental maps. It has become clear, that the model has to be described in a number of dimensions for an unambiguous definition. The dimensions are:

- the initial value of the expectations
- the possible reinitialisation of the expectations
- the treatment of missing days in multiple choice situations
- the measurement of the error

Testing the alternative model formulations has shown that the results can be substantially different from each other, but that all results show a multimodal distribution of optimal updating parameters. This fact makes the use of the mean of the distribution and therefore samplewide estimation of the parameter problematic. Especially in a dynamic context, populations with different distributions of optimal τ's could behave very differently. Tests of the dynamic stability of the simulation systems are required.

Using a preferred set of modelling assumptions the more detailed analysis of the two available samples showed, that the respondents incorporate their experiences into their optimal τ indicating the existence of different learning strategies, which the respondents employ under different circumstances. The effect of the disaster in the 1993 experiments and of the different strategies for the different travel time trends in the 1994 experiments underline this.

There is a clear need to understand these switching processes, if this simple learning model is to be used in dynamic simulation of day-to-day behaviour. Future work by the authors will attempt this.

There is also a clear need to test alternative learning models, as it is clear that the model tested here has limitations, which are unlikely to apply to the travellers. The most important limitation is that it is unable to anticipate trends, which travellers are bound to detect and to employ in their naive forecasting. It will therefore be necessary to test the performance of limited moving average and simple forecasting models as an alternative. The authors hope to undertake such work in the future. Such future work will also have to clarify the role of the possible conflicts between the background expectations, which the respondents have about travel times across the week and day, and the travel times they experience in the experiment.

Figure 9 Distribution of τ's for week 1 for South route (By week, 1993 experiments)

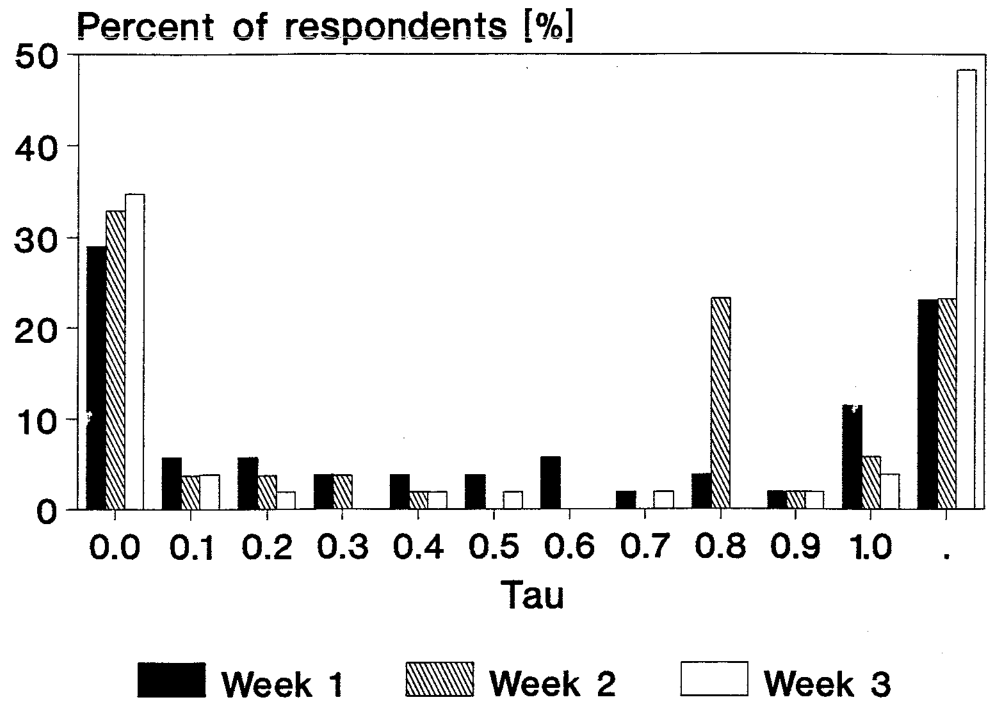


Figure 10 Transition in τ between week 1 and week 2 (South route, 1993 experiments)

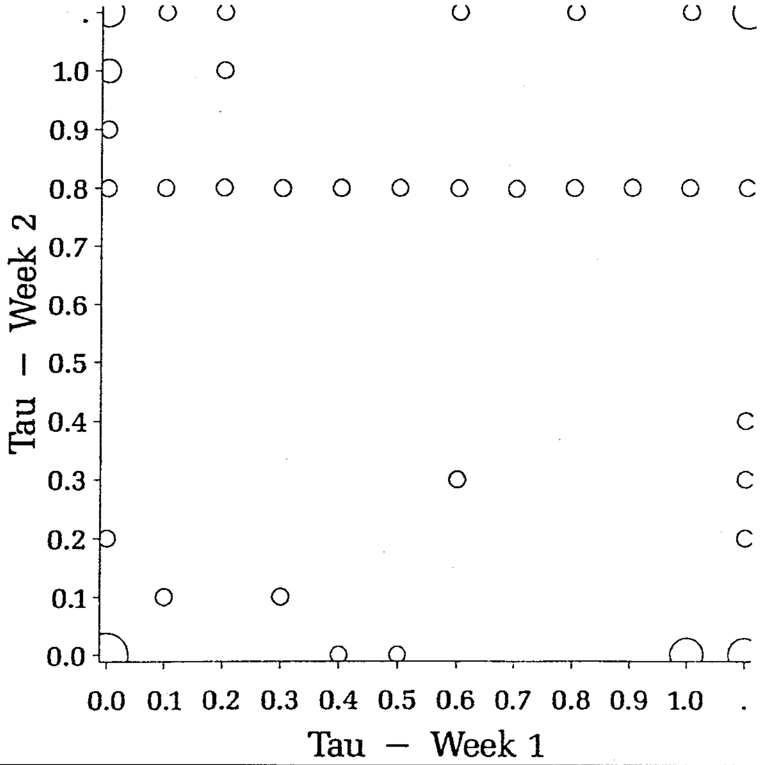
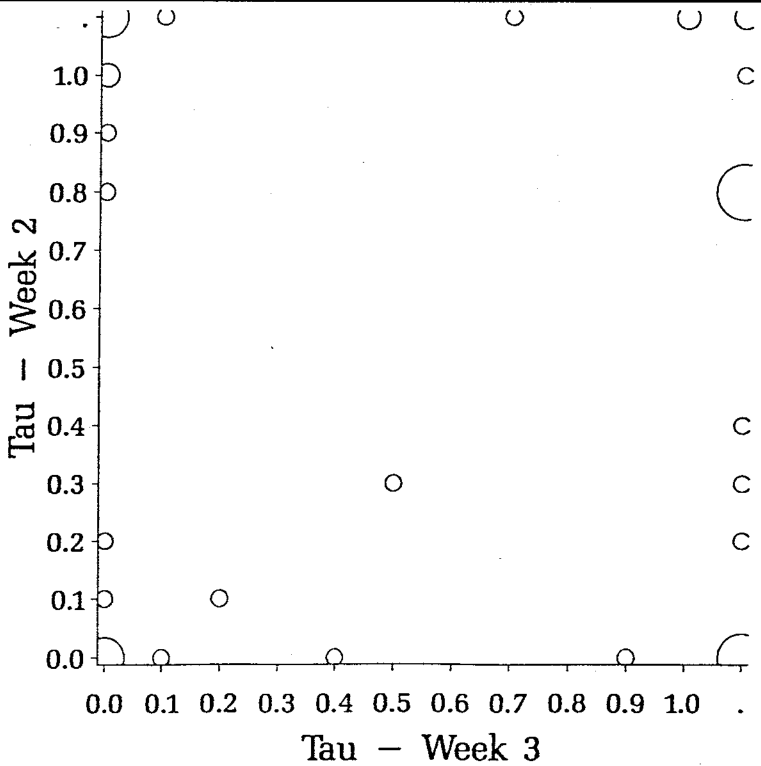


Figure 11 Transition in τ between week 2 and week 3 (South route, 1993 experiments)



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