"10 years on average doesn't mean 10 years in any case" – an Experimental Investigation of People's Understanding of Fixed and Continuous Delays

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Submission to

International System Dynamics Conference 2011, Washington

May 2011

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Abstract

The purpose of the paper is to test whether people make different decisions when a dynamic task requires either a fixed delay or a continuous delay representation. We assume that people have a tendency to cognitively represent continuous delays in real life situations as fixed delays. With the help of a structurally simple dynamic decision making task, we test two conditions in a controlled experiment: hiring when personnel stays in an organisation for <u>exactly</u> ten years (fixed delay condition) or when personnel stays <u>on average</u> for ten years (continuous delay condition). In this preliminary study, 71 participants were tested. Findings so far show no differences in performance between the groups, indicating that they most likely use the same cognitive representation of the task. Since participants' answers are substantially closer to the fixed delay condition, we assume that people have the tendency to represent lags in the form of discrete delays, at least in the context of personnel hiring. Research implications comprise the repetition of the experiment to achieve a higher number of participants and to allow for a more extreme differentiation between the two conditions. Practical implications regard the formulation of decision making tasks within organisations, for instance in human resource management. The value of this paper lies in its rigorous usage of a structurally simple dynamic task to shed light on a fundamental trait of human decision making.

Keywords: discrete delay, continuous delay, experiment, personnel hiring, female professors task

1. Introduction: Discrete and continuous delays

In this paper, we investigate how people make decisions that involve different forms of delays in dynamic systems, and in personnel hiring in particular. Human resource managers are well aware of the fact that hiring personnel involves a delay since not all personnel requirements of organisations can be fulfilled instantaneously. However, what exact form they consider this delay to have seems to be less clear. Earlier studies suggest that people have a tendency to treat personnel hiring as a fixed delay, while in reality this process takes the shape of a continuous delay (Grossler and Zock, 2010, Bleijenbergh et al., 2011). In this paper we test this assumption. Due to the aggregate character of most system dynamics models, continuous delays are more common in this field; however, in particular for technical processes, discrete delays are used as well occasionally. In a stylized fashion, Figure 1 shows two delayed response patterns to a system change, which are based on the two forms of delays used in this paper (for comparison, a immediate response is shown as well, which is an example of non-delay).
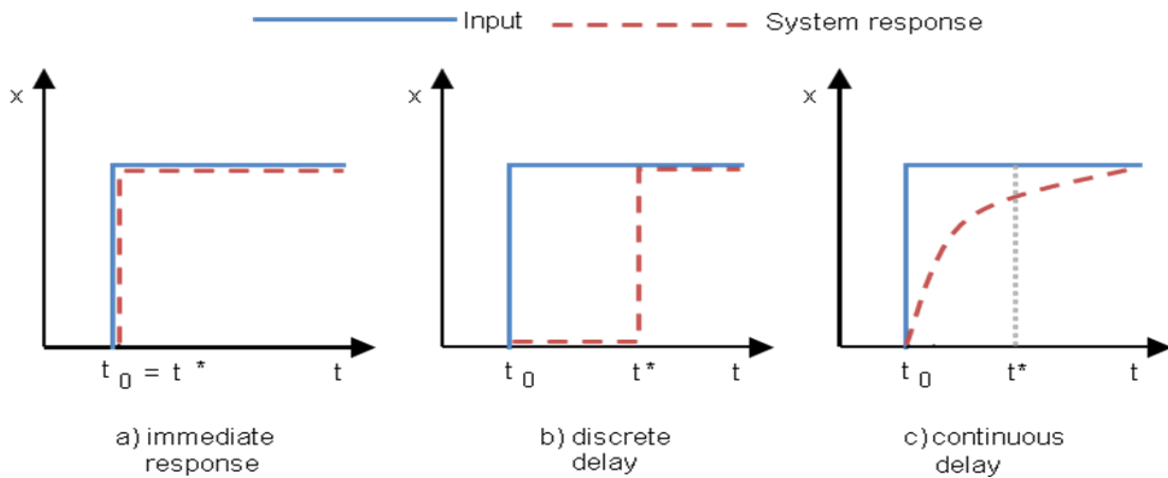

Figure 1: Forms of delays investigated in this paper (part a: non-delay response as comparison)

As can be seen in Figure 1, delays are characterised by two features: delay length and delay order. Delay length (or delay time) signifies the time that elapses from the occurrence of an input until a system response occurs. For reasons of clarification, part a) in Figure 1 shows a non-delayed response of a system to an input, thus delay time is zero. In part b) of Figure 1, delay time is the time from t_0 to t^*; at time t^* the total system response takes place. In the continuous delay in part c), delay time is the time from t_0 until an average response occurs (at time t^*). Delay order signifies the shape of the system response. In a discrete delay, order is

infinite, leading to a full system response exactly when delay time has elapsed (part b) in Figure 1). With continuous delay orders, system response becomes more gradual. This can vary between a pronounced peak and a moderate curve. In the extreme case of a first-order delay, an asymptotic response to an input occurs (part c) in Figure 1).

Figure 2 depicts the response of continuous delays of different order to a pulse input. The figure shows graphically, how higher order continuous delays more and more resemble a discrete delay (which is an infinite-order continuous delay). For further technical treatments of delays see Forrester (1961, app. H), Rahn (1976) and Roy (2000).
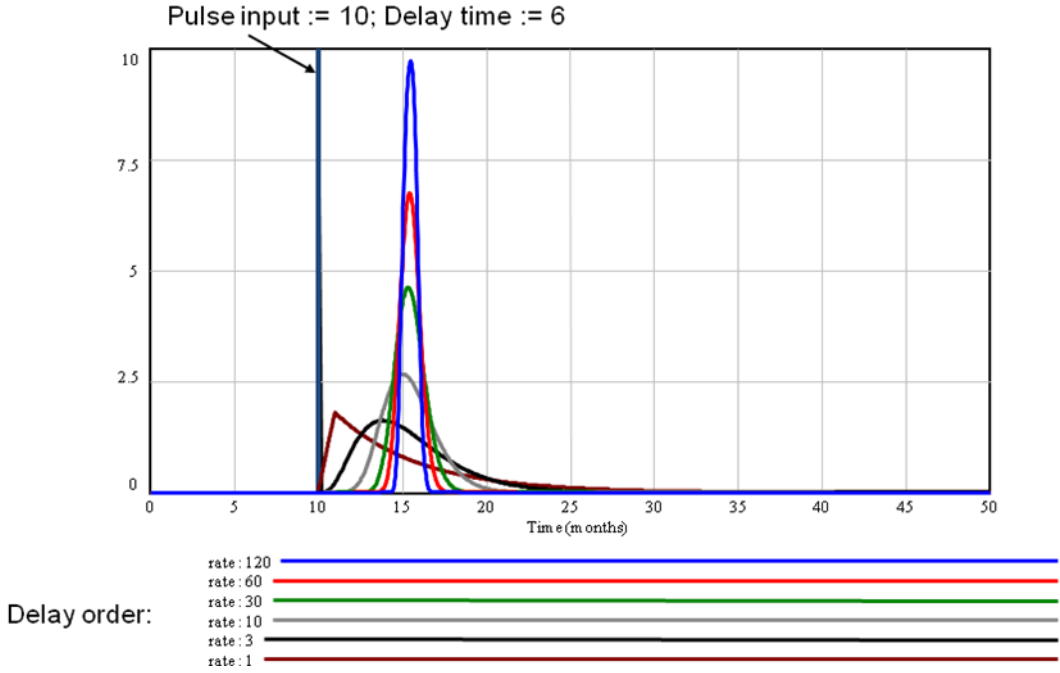

Figure 2: Response of different order delays to pulse input

The purpose of the paper is to examine how people cognitively represent delays when they perform a dynamic task, in order to contribute to improving decision making. By testing whether people make different decisions when a dynamic task requires either a fixed or a continuous delay representation, we examine the role of basic assumptions in this decision making. With the help of a structurally simple dynamic decision making task ('female professors task'), we test the two delay forms as two conditions in a controlled experiment: hiring when personnel stays in an organisation for exactly ten years (fixed delay condition) or when personnel stays on average for ten years (continuous delay condition).

The motivation for this study stems from two observations. First, in an earlier experiment we used the 'female professors task' (including a continuous delay formulation) to investigate participants' ability to understand and control this system (Bleijenbergh et al., 2011). We wanted to know whether people were able to make a realistic estimation of the personnel hiring to reach target figures. One outcome of the analyses of this case was that participants in general underestimate the amount of personnel that need to be hired to reach a target figure. A second outcome was that participants seemed to underestimate the delay involved in reaching target figures. The results suggested that people cognitively represent these delays as discrete, even when the task assumes a continuous delay, which would explain their apparently sub-optimal performance in the task.

Second, in an extensive modelling and simulation project within a service organisation, Größler and Zock (2010) found that human resource management was severely hampered by a mis-conception of the order of the delays involved. For the hiring process of employees, human resource managers knew that it took on average 51 months until a new contracted employee would be fully productive (they even used the words "on average"). However, they interpreted it in a way that after 51 months all new employees would be available. Thus, they understood a process that could be characterised by a continuous delay (with employees needing less or more time than 51 months) as being a discrete delay (with all employees needing exactly the same time of 51 months). Based on these two observations, we want to shed some more light on cognitive representation of delays and their effect on managing dynamic systems, in particular personnel hiring.

The structure of this paper is as follows. In the next section, we review the literature concerning the effects of delays on decision making in dynamic tasks. We concentrate on studies from the fields of system dynamics and complex problem solving in psychology. The third section starts with a formulation of our research propositions. We continue with describing the 'female professors task' and the actual experiment conducted, including the characteristics of our research participants. In the fourth section, preliminary findings of the experiment are presented. The paper closes with a discussion of findings, some preliminary conclusions, and potential implications for research and practice.

2. Background: Existing research regarding the effects of delays on control performance

Relevant studies regarding the effect of delays in decision making can be found in the system dynamics as well as in the psychological literature on complex problem solving. We review these literatures here, starting with two remarks. First, most studies do not explicitly address the difference between discrete and continuous delays (thus, the order of the delays) and rather focus on the length of the delay. Second, we do not include studies on the understanding of accumulation processes or feedback loops here although they are necessarily related (delays usually work in feedback loops; structurally, delays contain an accumulation process). We refer to some more salient articles in this areas (accumulation: Booth Sweeny and Sterman, 2000; Ossimitz, 2002; Sterman and Booth Sweeny, 2002; Pala and Vennix, 2005; Cronin et al., 2009; Sterman, 2010; feedback loops: Sterman, 1989; Diehl and Sterman, 1995; Langley et al., 1998).

In their review on dynamic decision making experiments in system dynamics, Rouwette et al. (2004) identify "delays" as a characteristic that influences participants' performance when working with a system (e.g. in a dynamic task). They found four studies that systematically investigate the effect of delays on decision making. The study by Sterman (1989) does not vary delay time or order as such but uses it as an explanation for participants' performance. Diehl and Sterman (1995) and Diehl (1989) vary the delay time and found (partially mixed) results that indicate a decrease in performance with growing delay time. Barlas and Özevin (2001; updated and elaborated in Barlas and Özevin, 2004) is to our knowledge the only study that varies delay order (discrete vs. first-order continuous) in the inflow to a production/inventory system. Their main finding is that fixed delays make a system more oscillatory/unstable; continuous delays smooth participants' reactions to external inputs.

Rahmandad (2008) and Rahmandad et al. (2009) use simulations as experiments to analyse the effect of delay time on organisational decision-making. They propose heuristics with different qualities regarding decision-making under the influence of delays. Partially, these two studies build on Repenning and Sterman (2002), in which the authors—based on a case study—identify delays between investment in improvement programmes and the benefits stemming from such programmes as being a major factor for misunderstanding the dynamics of improvement initiatives. Like in most other studies, Repenning and Sterman discuss the length of the delays as being critical. On the bases of simulation models, Yasarcan and Barlas (2005) show that material delays, information delays, and secondary control of a stock can

result in similar behaviour patterns (in particular, oscillations); the authors propose the idea of a "virtual supply line" and a general control heuristic suitable for all three forms of delayed systems. Yasarcan (2011) reports on the effect of measurement delays (again referring to delay length) on stock management performance and bases his investigation on simulation studies.

In the psychological literature on decision-making in complex situations (Sternberg and Frensch, 1991; Brehmer and Dörner, 1993; Frensch and Funke, 1995), quite some studies vary the length of delays in systems as experimental input (we did not identify studies that vary delay order). In many cases, delays are implemented in the experimental tasks in form of information that is reported to participants with a time lag. Notable in this respect are the studies by Brehmer (1989; 1990; 1992; 1995; Brehmer and Allard, 1991), mostly employing his so-called 'fire fighting task'. For instance, Brehmer (1995) reports on four experiments with this task that vary delays on three different levels (reaction time of fire fighting crews, response time of fire on fire fighting, reporting time of fire fighting success to headquarters). One important finding from this study is that participants do not adjust their decisions regarding systems control when delays are present compared to when there are no delays—even when they got explicit information on the existence of these delays. Other psychological studies employing delays as research objects are Mattern (1979), Funke (1985) and Reichert and Dörner (1988). All the psychological studies reviewed here use discrete delays in the experimental tasks.

In summary, delays are acknowledged as a constituting element of dynamic decision making and, thus, are the object of some studies in system dynamics and complex problem solving that test their effect on participants' performance. However, these studies (with one exception) vary either delay time or whether there is a delay or not. Therefore, we identify delay order (and its interpretation by humans) as a research gap to which our paper wants to contribute, in order to improve our understanding of decision-making on dynamic tasks.

3. Experimental method

a. Propositions

Based on the two observations that built the motivation for this study (reported in Section 1) and on the literature reviewed above, the following three research propositions were formulated:

P1. People underestimate the effect of delays on the behaviour of systems.

P2. People's decisions in a task that requires a discrete conceptualisation of delays cannot be distinguished from people's decisions in a task that requires a continuous conceptualisation of delays.

P3. People cognitively represent delays in complex dynamic systems rather as discrete delays than as continuous delays.

These propositions are investigated using a dynamic task ('female professors task') in a controlled experimental setting.

b. Female professors task

The 'female professors task' that we use for our experiment focuses on a social issue in human resource management, i.e. the gender (in)equality in higher management, more specifically the issue of target figures to increase the number of women in top positions, and in leading positions at universities in particular (Bleijenbergh et al., 2011; Bleijenbergh et al., 2008). In a preceding experiment, this task was used in an attempt to find out to what extent people understand the dynamic structure underlying changes in personnel composition and the consequences for decision making on gender quota. Participants were told that the executive board of a university has decided to close the gender gap of their university and to set a gender balance (50/50 male and female full professors) as a target. Participants read a one page description that: in the current situation there were 300 positions available of which 33 were filled by women and 267 by men; the number of positions was to remain unchanged for the years ahead; the board had recently decided to start working with hiring quota to ascertain that a gender balance, would be accomplished in the future. Participants were put in the position of an advisor to this board and were given two questions:

i. What annual percentage of female professors would you recommend to hire as of 2010, given the target of gender balance?

ii. How much time does it take to realize the target of gender balance, given your recommendation of an annual percentage?[1]

Next, they were asked to explain why they had chosen this percentage and target year (see Appendix for original tasks handed out to participants). The task took around twenty minutes for participants to accomplish.

The stock-and-flow structure of the task can be modelled as in Figure 3. Of course, this simple structure embodies some assumptions. For instance, it is assumed that one person fills one position (i.e. no part-time work), that all leaving professors are immediately replaced, and

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[1] Please note that it was neither an explicit nor an implicit task to achieve the goal as fast as possible.

that all hirings, which are not in the recommended percentage of female professors, are male professors. However, all these assumptions are consistent with the task.
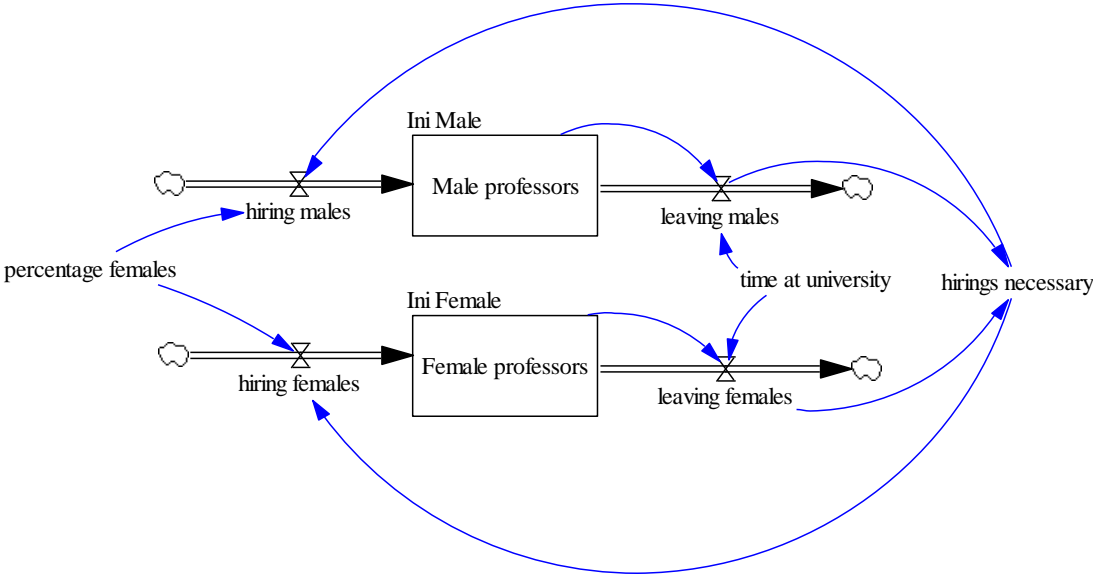

Figure 3: Stock and flow structure of 'female professors task'

Rather than focusing on the relationship between the behaviour of a stock and a flow, or controlling a manufacturing system, the 'female professors task' asks participants how to balance two different stocks, given an initially unbalanced personnel situation. The first part of the task (recommending the percentage) appears to be easy in the sense that, in order to reach the target, the lower boundary is 50% and each recommendation equal or greater than 50% leads to goal achievement. Figure 4 shows simulation results for four different recommendations: 25%, 50%, 75%, and 100% hiring of female professors, in case of a continuous third-order delay. As already implied, with a recommendation of 25% of women to be hired, the target of an equal number of professor positions filled with women will never be reached. With hiring 50% women, the goal will be reached eventually. Maintaining higher percentages of women to be hired will result in more women than men being professor.
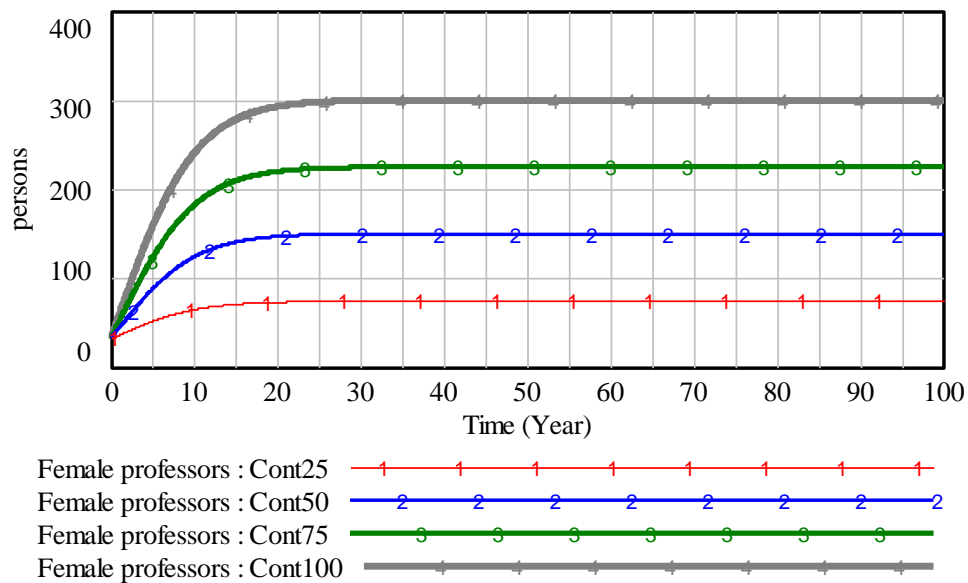
Figure 4: Simulation results for different percentages of women hired, 3rd order delay

The second part of the task (i.e. estimating the time frame to reach an equal gender balance) is more complicated because participants have to take into account the dynamics of the growth path. In our experiment for instance, female professors who are hired at a certain point in time also leave/resign/retire, slowing down the increase of the proportion of female faculty. As a result, reaching the target will take longer than might be expected.

c. Description of experiment and participants

In the experiment, two versions of the female professors task were used, representing the two experimental conditions. The two versions differed only regarding three sentences (for the full version see appendix). In the discrete delay condition the passage about the employment time of professors reads:

> "As a simplification, we assume that a full professor position is held for **exactly** 10 years (thus, all professors stay exactly the same period of time). After this period, the professor retires or accepts a position at another university, so a new professor can be appointed at that position."

The continuous delay version is formulated as follows:

> "**On average**, a full professor position is held for 10 years. This means that some professors may stay for only a couple of years and then move on to another university, while others may stay at this university for the rest of their career. From the available data one can however conclude that the

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average length of stay of a full professor is 10 years. Only after a professor

leaves, a new professor can be appointed at that position."

The two versions of the female professors task were randomly distributed to the participants, in order to get two experimental groups.

The experiment was conducted with a group of students at a Dutch university. All students followed a course on Research Methodology as part of a special pre-master teaching program to prepare them for a Master program in Business Administration. All students had completed a Bachelor study before, including courses on Human Resource Management and statistics. Thus, we consider them to have a basic idea about personnel issues and at least rudimentary mathematical skills.

The participants answered the questionnaire (including open questions) in English although English was not their native language. Not all participants answered the questions completely. The information on sex, age or recommended percentage is missing for some participants. We decided to exclude those participants from further analyses; of the original 79 participants, eight were excluded. The most important characteristics of the remaining 71 participants are presented in Table 1.

Table 1: Characteristics for all participants and the two experimental groups

	Total (n=71)	Exp. group 1 Discrete delay (n=36)	Exp. group 2 Continuous delay (n=35)
Age ($\bar{x}$)	23.5	23.3	23.7
Sex (%)			
Female	22.5	19.4	25.7
Male	77.5	80.6	84.3

Experimental groups can be assumed equal concerning average age and distribution of sexes.

In order to evaluate participants' performance, the potential effects of their decisions were tested with the help of a simulation model of the task (listings in the appendix). More concretely, it was tested whether and when participants' decisions would lead to target achievement, i.e. a 50% ratio of female professors. The decisions of the discrete delay group were compared with a discrete delay version of the model; the continuous delay group was compared with an continuous delay version of the model.

4.   Preliminary results of experiment

We discuss the results of our experiment in order of the three propositions formulated above.

a. *Estimation of effects of delays (P1)*

For the total group, the mean recommendation for a hiring quota for women is 54.2%. However, a surprising 29.6% of participants (21 in absolute terms) give a recommendation of hiring less than 50% female professors. With such a recommendation, the university's target of an equal gender balance never be reached. Furthermore, two participants recommend hiring more than 100% women which is inconsistent with the task (and difficult to interpret). On average, this performance is in line with the performance of participants in an earlier experimental study employing the 'female professors task' (Bleijenbergh et al., 2011). In that study, a substantially bigger share of participants was women than men. Thus, we could replicate the experiment with a group of participants, which is mostly male and not female as in the earlier study.

The estimations concerning the time it takes before the target would be achieved vary between two and 57 years for the total group. The deviation of their estimation from the correct target year—calculated using the respective simulation model—is on average 11.5 years (only calculated for those who give a reasonable percentage recommendation between 50% and 100%). When controlling for under- or over-estimation of the time needed to achieve the target of 50% female professors, results show that on average the time necessary is under-estimated (by 9.3 years), i.e. participants assume that the target can be reached faster than actually is the case (with an extreme value of an under-estimation of 37 years). Nine participants (roughly 12%) were correct with their estimate.

The scatter plot in Figure 5 summarizes the findings for the total group of participants with reasonable recommendations. It demonstrates that in particular participants with a relatively modest recommendation (at or only slightly above 50%) deviate in their estimate from the correct value. It also shows that more participants under-estimate the time it takes to achieve the targets (dots above zero line) than overestimate it (dots below zero line).
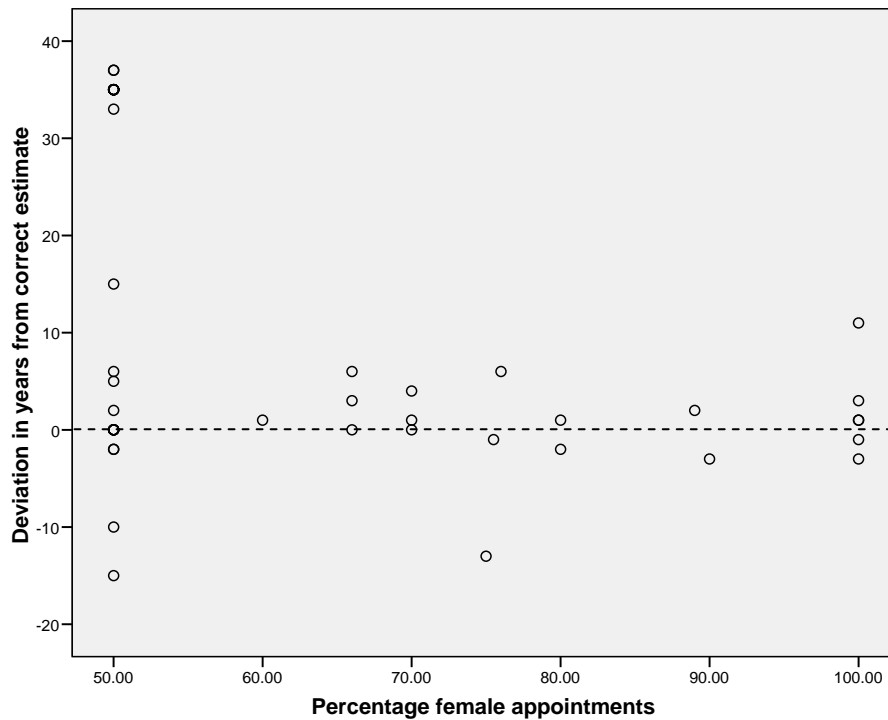
Figure 5: Scatter plot for all participants relating recommendation in percentage of women hired and deviation in estimation from correct value of target achievement

As a result concerning Proposition 1, we conclude that one third of the participants gave a recommendation that would not lead to reaching the target. Roughly another third of the participants wrongly estimates the time of reaching the target with an error of five years or more. The last third gives a valid recommendation and their estimate shows an error of less than five years. We interpret these findings to corroborate the results from earlier studies as well as preceding experiments with the specific task: people have difficulties in understanding the nature of accumulation and delays.

b. Comparison between discrete and continuous delay group (P2)

When comparing the recommendations and estimations given in the two experimental groups, we find no differences between those groups despite the different formulation about the order of the delays in their tasks. On average, participants in the discrete delay condition recommend to hire a slightly higher percentage of female professors than their counterparts in the continuous delay condition (56.5% vs. 52.4%). Analogously, the discrete delay group estimates to achieve the target a bit earlier than the continuous delay group (in 9.2 years vs. 10.8 years). However, these differences are statistically not significant. Table 2 shows the results of a t-test with the discrete vs. continuous delay condition as the controlling variable.

Table 2: Results of t-tests to check for differences between experimental groups: recommendations and estimations

		Levene's Test for Equality of Variances		t-test for Equality of Means			
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference
Percentage women appointed	Equal variances assumed	1.302	.258	.611	70	.543	4.08083
	Equal variances not assumed			.611	67.453	.543	4.08083
Target achievement in	Equal variances assumed	.336	.564	.886	68	.379	-1.571
	Equal variances not assumed			.886	51.907	.380	-1.571

Thus, with regard to Proposition 2 we conclude that indeed participants' decisions are not different for the two experimental conditions. Assumingly, no matter what the formulation of the task is, they use the same kind of cognitive representation of delay in their decision making on a hiring percentage and their estimation of the time it takes to reach the target.

c. Comparison of group results to simulated results (P3)

While participants' decisions are comparable despite the two different conditions, their performance might be different in relation to the content of the task, i.e. whether they have to deal with a discrete or with a continuous delay. For this reason we tested for differences in the absolute deviation of their estimation of the target year with the actual target year (given their individual recommendation). To do this, a simulation model of the condition was run, parameterised with the different recommendations. In the discrete delay version, for instance, it takes ten years to achieve a gender balance, in case 50% female professors are hired; in the continuous delay version, it would take about 45 years with the same hiring percentage.[2] In other words, while the participants use a comparable cognitive representation of the delay involved, the actual situations the two tasks refer to, are very different in terms of the orders of the delay of the effect of hiring percentages .

When comparing the goodness of the estimations between the two groups, differences between the experimental conditions become obvious. On average, participants in the discrete delay group wrongly over-estimate the time it takes to achieve the target by a mere 1.1 years. However, the continuous delay group under-estimates it by 21.6 years on average. Needless to

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[2] Technically, after this period the difference between the number of female and male professors is below two, which we defined as goal achievement (since for continuous delays, the numbers in the 50% case are approaching each other but a small rest remains).

say, differences between the groups concerning the absolute deviations are statistically significant, as the t-test reported in Table 3 shows.

Table 3: Results of t-tests to check for differences between experimental groups: estimation against actual target achievement—first-order delay system in continuous condition

		Levene's Test for Equality of Variances		t-test for Equality of Means			
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference
ABSDeviation CorrectEstimate	Equal variances assumed	171.110	.000	-5.822	45	.000	-18.825
	Equal variances not assumed			-5.500	23.596	.000	-18.825

Since a first-order delay is the most "extreme" form of a continuous delay, we also calculated the performance of the participants in the continuous delay group against the results when a third-order delay is assumed to exist in the system.[3] In this case, it takes roughly 25 years until a gender balance is achieved, when 50% female professors are hired in each year. Table 4 shows the results of a t-test comparing the discrete group against the continuous group, when its performance is evaluated relative to a third-order delay system. As one can see, differences between the groups are still significant; thus, our results do not change when the order of the continuous delay is moderately increased. However, differences between the groups become smaller: the continuous delay group under-estimates the time it takes to close the gap by 7.9 years (results for the discrete groups remain the same since nothing was changed in the calculation of the estimation error for this group).

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[3] See Roy (1999) for an estimation method for delay order when building system dynamics models. Furthermore, Özgun and Barlas (2009) have demonstrated how results of discrete and continuous simulation methods approach each other when the number of items in a system is increased.

Table 4: Results of t-tests to check for differences between experimental groups: estimations against actual target achievement—third-order delay system in continuous condition

		Levene's Test for Equality of Variances		t-test for Equality of Means			
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference
ABSDeviationCorrectEstimate3rd	Equal variances assumed	22.389	.000	-4.308	45	.000	-6.78000
	Equal variances not assumed			-4.189	34.622	.000	-6.78000

Thus, with regard to Proposition 3 we conclude that the participants with the discrete delay condition do much better than the participants with the continuous delay condition when it comes to estimating the effect of the delay. In other words, while both groups seem to use the same cognitive representation to make their recommendation and estimate the target year, this cognitive representation is much more appropriate in the discrete delay condition. To substantiate this argument, we also compared the estimations of the continuous delay group against a 20th order continuous delay. In this case, it takes approximately 14 years until gender balance is achieved, given a 50% hiring of female professors. For this comparison, no significant differences between the groups can be found anymore (although the estimations of the discrete delay group are on average still better than the estimations of the continuous group). In other words, the quality of the estimations of the two experimental groups can be considered equally good, when we compare the estimations of the continuous delay group against a higher-order delay that resembles a discrete (i.e. an infinite-order) delay.

Therefore, our preliminary finding is that people tend to cognitively represent delay as a discrete delay conceptualisation, at least when performing a simple dynamic task on personnel hiring, even in the case that the task rather explicitly refers to a continuous delay. Of course, if the situation really involves a discrete delay, their performance is appropriate; however, if the situation actually consists of a continuous delay, as many processes in human resource management, a cognitive representation based on a discrete delay understanding can yield only inferior results.

5. Conclusions and further research

In line with previous experiments in system dynamics and psychology, we find that people have a general tendency to underestimate the effect of delays in dynamic systems. As such, we can support our first proposition which is in line with existing research. However, our

major contribution to research is related to Proposition 2 and 3, stating that participants use a comparable cognitive representation of delay, namely a discrete delay, in either tasks that refer to a discrete and task that refer to a continuous delay.. It is important to point out that representing delay as discrete is not necessarily an issue: in case the actual situation is characterised by this type of delay, this is fine. However, problems occur when the actual situation comprises continuous delays and not discrete delays, like for example in human resource management and personnel hiring in particular.[4]

A general answer to the question 'which form of delay better represents reality' cannot be given; it depends on the characteristics of the actual situation. Nevertheless, our results are relevant since we would postulate that many issues that are subject to strategic decision-making include continuous delays; rather than having a fixed and absolute delay time, many such issues follow a stochastic, on-average form of behaviour. For instance, in strategic human resource management, hiring and training new employees takes a certain number of months on average: there will always be personnel that can be recruited easily and that picks up the necessary skills virtually immediately; they will finish their training long before the average time. On the other hand, there will also be positions that can only hardly be filled or people that take longer to understand the necessary knowledge; they will finish their training (maybe even long) after the average time. The same continuous delay patterns must be assumed for many other processes in strategic management: the development of new products, the effectiveness of marketing activities, or, more general, the development of strategic resources and capabilities. Our results suggest systematic problems when managers have to make decisions on these processes based on their intuition; they might cognitively represent delays as being discrete.

The results of this study are also interesting in terms of teaching system dynamics skills. When educating future system dynamicists, we have experienced that the concept of continuous delays is usually difficult to understand for novices. However, continuous delays are the usual way to model non-instantaneous phenomena in system dynamics (for the reasons outlined in the paragraph just above). Our study provides the warning that students of system dynamics may frequently run into difficulties when initially introduced to the idea of continuous delays: cognitively, they may be just better prepared to understand discrete delays.

Of course, the repetition of the experiment to achieve a higher number of participants and to allow for a better differentiation between the two conditions concerning the task

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[4] An assumption of why people generally might use discrete delay representations instead of continuous delay representations would be that a discrete understanding of delays causes less cognitive load. However, what could be evolutionary or other reasons for this phenomenon is outside our current understanding.

formulation are worthwhile ways to proceed with this research. One may argue that the results of the task are context specific, since the task is politically loaded. However, the comparison is done between two random selected groups that both experience this context. Nevertheless, the test can be repeated to check if participants make a comparable estimation with a neutral task.

This study reiterates the finding that people are not well-equipped to deal with dynamic issues in general and delays in particular and sheds some additional light on how people conceptualise delay structures. However, stating that people are just not very well capable to deal with delays should of course not be the end of our endeavours. Rather, we want to continue our research in order to improve (strategic) decision making. For example, decision making tasks with delays can be re-designed in a way that allow "normal people" to understand the dynamics caused by the delays and, thus, make successful decisions (Forrester, 1961). In other words, a practical implication of this study is the demand to find "nudges" (Sawicka and Rydzak, 2007; cf. Thaler and Sunstein, 2008) that are necessary to improve real-world decision making when delays are involved. However, our study makes clear that this is not a trivial endeavour since participants even failed to understand delays correctly when cues in the task were quite unequivocally favouring discrete or continuous delays.

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Female Professors task – discrete delay condition

Experiment "Appointment of female professors"

The Board of a university has decided to drastically increase the number of female full professors. The target is to have 50% female full professors at the university in the long run. Currently, the percentage of female full professors is 11%. For 15 years already, the percentage of female students is around 50% while 45% of the current PhD students are female. It is expected that this percentage will increase in the years to come. This situation has lead to the target being set at 50% for female full professors. Considering the financial situation at institutions for higher education the assumption is that the number of full professor positions will not increase. The change therefore has to occur within the current number of full professor positions.

Currently, the number of positions for full professors at the university is 300. As stated, it is expected that this number will not change in the future. In 2010, there are 33 female and 267 male full professors. As a simplification, we assume that a full professor position is held for **exactly** 10 years (thus, all professors stay exactly the same period of time). After this period, the professor retires or accepts a position at another university, so a new professor can be appointed at that position. As mentioned, the target is to have 50% female full professors at the university.

Within the Board there has been a long discussion about the strategy that has to be pursued to achieve this target and the Board is convinced they have to implement a quota. This means that faculties will be forced, as of 2010, to annually appoint a certain percentage of women on vacant professor positions.

The Board asks your advice about how high this percentage should be and when you think the target (of 50% female and 50% male professors) will be achieved.

My advice on annual percentage of female appointments:……...%

Using this percentage the target will be achieved by the year 20....

Could you please briefly explain your choices below?

Finally we would like to ask you a couple of additional questions.

Gender: man/woman

Year of birth: 19..

Study:

Thanks for your participation!

Female Professors task – continuous delay condition

Experiment "Appointment of female professors"

The Board of a university has decided to drastically increase the number of female full professors. The target is to have 50% female full professors at the university in the long run. Currently, the percentage of female full professors is 11%. For 15 years already, the percentage of female students is around 50% while 45% of the current PhD students are female. It is expected that this percentage will increase in the years to come. This situation has lead to the target being set at 50% for female full professors. Considering the financial situation at institutions for higher education the assumption is that the number of full professor positions will not increase. The change therefore has to occur within the current number of full professor positions.

Currently, the number of positions for full professors at the university is 300. As stated, it is expected that this number will not change in the future. In 2010, there are 33 female and 267 male full professors. **On average**, a full professor position is held for 10 years. This means that some professors may stay for only a couple of years and then move on to another university, while others may stay at this university for the rest of their career. From the available data one can however conclude that the average length of stay of a full professor is 10 years. Only after a professor leaves, a new professor can be appointed at that position. As mentioned, the target is to have 50% female full professors at the university.

Within the Board there has been a long discussion about the strategy that has to be pursued to achieve this target and the Board is convinced they have to implement a quota. This means that faculties will be forced, as of 2010, to annually appoint a certain percentage of women on vacant professor positions.

The Board asks your advice about how high this percentage should be and when you think the target (of 50% female and 50% male professors) will be achieved.

My advice on annual percentage of female appointments:……...%

Using this percentage the target will be achieved by the year 20....

Could you please briefly explain your choices below?

Finally we would like to ask you a couple of additional questions.

Gender: man/woman

Year of birth: 19..

Study:

Thanks for your participation!

System dynamics model: Female Professors task – discrete delay condition

```
Female professors=INTEG (hiring women-leaving women, Ini Female);
    Units: persons
FINAL TIME=100; Units: Year
hiring women=percentage women*hirings necessary; Units: persons/Year
hiring men=(1-percentage women)*hirings necessary; Units:
persons/Year
hirings necessary=leaving women+leaving men; Units: persons/Year
Ini Female=33; Units: persons
Ini Male=267; Units: persons
INITIAL TIME=0; Units: Year
leaving women=DELAY FIXED (hiring women, time at university, Ini
    Female/time at university); Units: persons/Year
leaving men=DELAY FIXED (hiring men, time at university, Ini
Male/time at university); Units: persons/Year
Male professors=INTEG (hiring men-leaving men, Ini Male); Units:
persons
percentage women=0.5; Units: Dmnl
time at university=10; Units: Year
TIME STEP=1; Units: Year
```

System dynamics model: Female Professors task – continuous delay condition (1st order

delay; only differences to discrete delay model shown)

```
leaving women=Female professors/time at university; Units:
    persons/Year
leaving men=Male professors/time at university; Units: persons/Year
```