Elicitation of User Preferences by Cross Modality Matching

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Abstract

The development of autonomous multi-agent systems acting upon the interests of one or more users involves the elicitation of preferences of these users. In decision theory, models have been developed with which one is able to perform this elicitation. This paper enumerates some common anomolies to existing decision theoretic preference elicitation models. We propose an alternative elicitation model that has been successfully implemented and used for investigating positive time preference; this is the phenomenon that people prefer to get things sooner rather than later. We present new results concerning this phenomenon regarding decisions in gain and loss situations over time. The contributions of this paper are (1) the presentation of our novel preference elicitation model, and (2) new results on the phenomenon of gain-loss asymmetry in intertemporal choice.

1. Introduction

Preference elicitation is the process of extracting necessary preference or utility information from a user [1]. This process plays an essential part in the development of autonomous multi-agent systems where agents act upon the interests of one or more users. Utility functions describe the satisfaction that someone receives from consuming commodities. The relation between utilities and preferences is given by defining utility as the measurement of strength or intensity of a person's preferences [2]. Capturing this notion explicitly is imperative for systems that are delegated with, for example, making or supporting decisions, planning future actions, or advising users on the decision of choosing between products. Utility functions can vary widely from user to user, as well as from situation to situation. As such, utility functions are considered difficult to extract from users. Additionally, people usually find it hard to attach utilities to commodities. For example, although one may easily prefer one car over the other, it is often hard to express exactly how much this car is preferred over the other.

This paper presents 1) an elicitation model to assess utilities from users, and 2) a utility-based risk model for gain-loss situations. The main focus of the paper is on the presentation of the elicitation model (Section 3). Additionally, we demonstrate its usability for constructing risk models for users (Section 4).

The elication model is based on a cross-modality matching technique, removing the barrier for users to give absolute values for utilities, but allowing for alternative modalities to express utilities. This paper demonstrates theoretically how to convert the measured modality-based utilities into absolute values. The method is based on the psychophysical law stating that sensation is a power function of stimulus [11].

This paper is organised as follows. In Section 2, we elaborate on the elicitation of utilities, present various methods for utility measurement and their anomolies. Section 3 explains the new method of utility measurement by means of cross modality matching. Section 4 presents the problem of intertemporal choice and the gain-loss asymmetry in time preferences. In Section 5, we present our experimental results on the gain-loss asymmetry in intertemporal choice. Finally, Section 6 concludes our described research.

2. Utility Measurement

This Section present the theory of utility elicitation, a number of existing elicitation models from decision theory, the theory of cross modality matching and our case study of intertemporal choice.

2.1. Utility Elicitation

We let utility describe the measurement of usefulness. A value function can be used to predict one's preferences, hence it is called a *utility function*. Let this function be denoted by u. For every possible outcome C, there is a utility $u(C)$ associated with the outcome that denotes the preference for that outcome. For example, a Mercedes might be prefered over a BMW is represented as $u(\text{Mercedes}) > u(\text{BMW})$. With this function, one might also be able to express that the increase in satisfaction from BMW to Mercedes is smaller than the increase from a Mercedes to a Volvo: $u(\text{Volvo}) - u(\text{Mercedes}) > u(\text{Mercedes}) - u(\text{BMW})$. Since we can express utilities by means of its value function, a specific set of values correspond with the statements above, e.g., $u(\text{Volvo}) = 100$, $u(\text{Mercedes}) = 60$, and $u(\text{BMW}) = 40$. A user can make a decision according to the expectations of utilities. The process of obtaining these utilities is called *utility elicitation*.

2.2. Utility Measurement Methods

Essential to utility elicitation is measuring the utilities for specific goods for a user. Several well known utility measurement methods have been described previously [3] and are briefly summarised here. We conclude this overview with a list of anomalies to these methods.

Farquhar [3] has surveyed a number of utility measurement methods. The purpose of the survey was to provide an integration of existing methods of assessing single-attribute expected utility functions and to present some new assessment methods that may be appropriate for further applications and research. If a person were truly to maximise expected utility, the methods described in the survey would elicit utilities exactly. Wakker and Deneffe [13] describe the certainty equivalent and probability equivalent methods. A short description of these methods follows below. Furquhar describes these methods as standard-gamble methods. Another method we will describe, the lottery equivalent method, would be called a paired-gamble method. McCord and de Neufville [9] extensively describe the method. Finally, the gamble tradeoff [3] is described, which was designed to enable eliciting utilities when probabilities are distorted or unknown.

2.2.1. Certainty Equivalent Method Let us denote by $(x, p; z)$ a two-outcome lottery that assigns probability p to outcome x and probability $1 - p$ to outcome z. In all three described equivalent methods, we can elicit utilities by obtaining indifference points from a user. In the certainty equivalent method, the analyst asks the client to compare a lottery $(x, p; z)$ with a certain outcome. The analyst varies the certain outcome until the client reveals indifference between the certain outcome y and the lottery $(x, p; z)$. If we have obtained the indifference point, then $u(y) = pu(x) + (1 - p)u(z)$. The basic procedure for eliciting utilities is as follows. First, two outcomes $M > m$ are fixed such that the range of outcomes between them includes all outcomes of interest. One then sets $u(m) = 0$ and $u(M) = 1$. When the client shows the indifference $y \sim (M, p; m)$, then $u(y) = pu(M) + (1 - p)u(m)$. Because $u(m) = 0$ and $u(M) = 1$, $u(y) = p$. Now, we have elicited the utility of X. We can use this procedure for a number of y's ($m < y < M$). In that way we can elicit the utilities of y's over a specific range.

2.2.2. Probability Equivalent Method In the probability equivalent method, the used procedure is almost identical to the one of the certainty equivalent method. Again, the analyst asks the client to compare a lottery $(x, p; z)$ with a certain outcome y ($x < y < z$). But now x, y and z are fixed and the analyst varies the probability p until the client reveals indifference between the lottery and the certain outcome. The indifference point reveals the equality $u(y) = pu(x) + (1-p)u(z)$. In the basic probability equivalent procedure, one again fixes two outcomes $M > m$, with $u(m) = 0$ and $u(M) = 1$. Then for any outcome y, the probability p is found such that $y \sim (M, p; m)$. And like explained in the previous Section, we can derive from this the equality $u(y) = p$. And so can one elicit the utility of y using the probability equivalent method.

2.2.3. Lottery Equivalent Method The lottery equivalent method works somewhat different than the two previous methods. McCord and de Neufville [9] describe the method. It involves the notion of an elementary lottery and is based on the following logic. Again, one first fixes two outcomes $M > m$ which represent the maximum and minimum of plausible values for which utility is being assessed. One lets the maximum plausible value have a utility of 1 and the minimum a utility of 0. This means that (like with the previous described methods) $u(m) = 0$ and $u(M) = 1$. For example, if utility is being assessed over dollars with a maximum value of $\$1,000$ and a minimum value of $\$0$, then $u(\$1,000) = 1$ and $u(\$0) = 0$. We let the user consider an elementary lottery that gives him a p chance of gaining $\$X$ and a $(1 - p)$ chance of gaining nothing, where $0 < X < 1000$. This can be denoted by $(X, p; 0)$. Next, we present a second elementary lottery that gives the client a q chance of gaining $\$1,000$ and a $(1 - q)$ chance of gaining nothing. This can be denoted by $(\$1,000, q; 0)$. The client has to state his preferences for one of the two lotteries in the following way. X and p are fixed and the analyst varies q until the client reveals indifference such that $(X, p; 0) \sim (\$1,000, q; 0)$. In more general terms, we have to obtain the indifference $(X, p; m) \sim (M, q; m)$. Now, from this indifference we can derive the equality $pu(X) + (1 - p)u(m) = qu(M) + (1 - q)u(m)$. Because

$u(m) = 0$ and $u(M) = 1$, we can derive $pu(X) = q$, which means $u(X) = q/p$.

When we want to assess an utility function over a variable X that has a maximum plausible value M and a minimum plausible value m, we need the following basic procedure to obtain this function.

- Set $u(m) = 0$ and $u(M) = 1$.
- Choose a convenient value of p such as .5 to ask in all questions.
- Divide the range from m to M into a number of points X_i.
- Obtain the lottery equivalent q_i's for all the X_i's.
- Plot the q_i/p values directly on the a graph of the utility function.
- Draw the utility function over the whole range of X by interpolating between the assessed values.

2.2.4. Trade-off method Next to the discussed equivalent methods, we discuss another method called the gamble trade-off method, or trade-off method for short. This method is proposed and extensively described by Wakker and Deneffe [13].

The main advantage of the trade-off method is that it minimises the role of probabilities while preserving full validity when used in the expected utility criterion. Therefor, the elicitation of utilities, to be used in the expected utility criterion, turns out to be possible even if probabilities are ambiguous or unknown. A disadvantage of the method is that it is somewhat more laborious than the other discussed methods.

The method draws inferences from indifferences between two-outcome gambles (like in the lottery equivalent method). The client is asked to compare the lotteries $(X, p; r)$ and $(x, p; R)$ for $X > x$ and *reference outcomes* $R > r$. The values p, r, x and R are fixed and the analyst varies X until the client reveals the indifference $(X, p; r) \sim (x, p; R)$.

Next, the client is asked to compare another pair of lotteries, $(Y, p; r)$ and $(y, p; R)$ for $Y > y$ and the same reference outcomes $R > r$. Again p, r, y and R are fixed and now Y is varied until the client reveals the indifference $(Y, p; r) \sim (y, p; R)$.

From the first indifference we can derive $pu(X) + (1 - p)u(r) = pu(x) + (1 - p)u(R)$. This equation we can rewrite to $p(u(X) - u(x)) = (1 - p)(u(R) - u(r))$. In the same way we derive from the second indifference $p(u(Y) - u(y))) = (1 - p)(u(R) - u(r))$. From these two equations we can derive $u(X) - u(x) = u(Y) - u(y)$. The combination of indifferences has revealed an equality of utility differences that can be used for utility elicitation.

Instead of the probability p the method uses a subjective probability for an event A. Without knowing the clients' subjective probability of A, the decision analyst can derive from the indifferences $(X, A; r) \sim (x, A; R)$ and $(Y, A; r) \sim (y, A; R)$ the equality $u(X) - u(x) = u(Y) - u(y)$.

Again, we fix two outcomes $M > m$ which represent respectively the maximum and minimum plausible outcome and set $u(M) = 1$ and $u(m) = 0$. For a number of x_j's ($x_0 = m, x_n = M$ and $m \leq j \leq M$), we can now elicit the utilities $u(x_j) = j * \sigma$ (with $j = 1 \ldots n$ and σ being any arbitrary positive scale parameter) through the indifferences $(x_j, A; r) \sim (x_{j-1}, A; R)$.

2.2.5. Anomalies The discussed methods have several similar characteristics. Some of these characteristics make it difficult for using the methods in certain applications. These anomalies to the discussed methods are listed here.

- **Necessity to define minimum and maximum** In all procedures used in the discussed methods, it is necessary to limit the possible outcomes by a minimum and maximum. When extending the range for which we want to elicit utilities, we cannot automatically add new elements to this range and compare utilities with each other. Instead, the client has to go through the whole procedure again for the analyst to assess the utilities for the new range.
- $|U(X_{max})| = | - U(-X_{max})|$ Because it is necessary to limit the range for plausible values by a minimum and maximum, it is not possible to elicit utilities for amounts the client loses instead of gains. That is, when one assumes that 'losses loom larger than gains'. This is for the following reason. When we want to assess utilities for amounts with a range from X_{min} to X_{max} (with $X_{min} = -X_{max}$), it is possible to cut this in two subranges $[-X_{max}, 0]$ and $[0, X_{max}]$ and to assess the utility functions for those two ranges. But then $u(-X_{max}) = u(X_{max})$ and this would go against the observed gain loss asymmetry [6].
- **Tendency to calculate outcomes** Because of the way lotteries are represented in the certainty, probability and lottery equivalent, it is not very hard for a subject to calculate the expected values of the lotteries. From the experiments we ran with these methods, it can be seen that utility functions are almost linear for all subjects. This could indicate that subjects indeed calculate expected values and decide on basis of those calculations. Even when asked not to calculate expected values, it was very hard for subjects not to calculate. It is very questionable if people decide on basis of calculations in real life. With the trade-off method, subjects eliminated the probabilities completely. The probabilities used in the trade-off method were not concrete, but were vaguely described. Most subjects just added the outcomes of the two lotteries and made a decision on basis of those calculations.
- **Based on expected utility theory** All discussed methods are based on expected utility theory, i.e. all as-

sume that the person's responses are consistent with expected utility theory. But Kahneman and Tversky [6], together with many others since then, argue that expected utility theory is not an adequate descriptive model for decision making. They describe a number of anomalies to expected utility theory and propose a new theory: prospect theory. Because we are particularly interested in gain loss asymmetry, we also cannot take expected utility as an underlying descriptive theory on decision making. That means that we cannot use methods that assume expected utility.

- **Need for contextual experimental settings** All methods need an experimental context to be tested in. It is not easy to make real life decision for subjects when the methods are given without context. With the equivalent methods, it means that the analyst has to describe lotteries very thoroughly for the subject so that the decision-making problem becomes concrete. With the trade-off method, it means that the problem needs a very well described context, so that it is clear to subjects what is meant for example by the vaguely described probabilities.

These anomalies to the discussed methods for utility measurement are the cause that we cannot use the methods in our model. Therefor, we propose another methods for utility measurement. This method is based on cross modality matching and is described in the following Section.

3. Utility Measurement by Cross Modality Matching

In this Section we describe a method that can be used for measuring utilities. We use a technique called cross modality matching that comes from psychophysics and is described extensively by Stevens [11].

We want to avoid that subjects have to use numerical values to directly represent utility. This is for the following two reasons. The first being that people tend to calculate expected values using existing methods for utility measurement (see Section about utility measurement methods) and this might not be a realistic reflection of reality. The second reason is that the use of direct scaling to measure utilities lacks a theoretical justification (Wakker and Deneffe, 1996). Therefor we use an intervening variable: e.g. the area of a circle. What follows in this Section is a theoretical justification for the use of cross modality matching for utility measurement.

3.0.6. The Psychophysical Law Stevens [11] has shown that whenever a stimulus increases, the intensity of sensation grows in accordance with a common basic principle: in every sense modality, sensation is a power function of stimulus. That statement is the basic principle that underlies the psychophysical law. The basis of the psychophysical law comes from a paradox that is directly connected to subjective value of money. This paradox, the St. Petersburg paradox (Stevens, 1975) was puzzled over by Cramer (in 1728). Cramer concluded that the utility, or subjective value, of money grows less rapidly than the numerical amount of money. Cramer suggested that the subjective value of money grows as the square root of the numerical amount of money and proposed this founding as a possible explanation of the St. Petersburg paradox.

Galanter [4] demonstrated the correctness of Cramer's power function. Students were asked what amount of money would make them twice as happy as when receiving $\$10$. Classes of students gave answers that ranged from $\$35$ to $\$50$. Thus, when utility has to be doubled, the amount of money has to be 3.5 to 5 times as large. The average of 4 times is exactly what Cramer's power function predicts.

3.0.7. The Magnitude Estimation Method We first have to let subjects make a magnitude estimation of the area of a circle. According to Stevens [11], sensation magnitude ψ grows as a power function of the stimulus magnitude ϕ. In terms of a formula, we may write $\psi = k\phi^{\beta}$. The constant k depends on the units of measurement and is not very interesting; the value of exponent β serves as a kind of signature that may differ from one sensory continuum to another. In the years between 1953 and 1975 more than three dozen continua have been examined and were found to fit the power function. We could thus describe the growth of the sensation magnitude of the area of a circle ψ_0 as a power function of the stimulus magnitude of the area of a circle ϕ_o as $\psi_o = k{\phi_o}^m$.

3.0.8. Cross Modality Matching Next, we have to make a cross modality matching between the utility of the amount of money and visual area (the subjective value of the area of the circle). Cross modality matching uses two different sense modalities. It assumes that in the first sense modality the sensation ψ_1 is related to its stimulus ϕ_1 by a power function with the exponent m, i.e.,

$$\psi_1 = k{\phi_1}^m. \tag{1}$$

Likewise, in the second sense modality, a similar equation is assumed, but with a different exponent n, i.e.,

$$\psi_2 = k'{\phi_2}^n. \tag{2}$$

Now, if ψ_1, i.e. visual area, is matched to ψ_2, i.e. subjective value of monetary amounts, at several different values over a range of stimuli, for these stimuli we then can write $\psi_1 = \psi_2$. This implies that for the equated values ψ_1 and ψ_2 we can substitute the stimulus values, so that $k{\phi_1}^m = k'{\phi_2}^n$.

It is possible to rewrite this equation to

$$\phi_1 = \sqrt[m]{\frac{k'}{k}}\phi_2^{\frac{n}{m}}. \tag{3}$$

3.1. Integrating Utility Measurement and Cross Modality Matching

We have shown that when we want to use the magnitude estimation method and cross modality matching method, we have to decide power functions that describe sensation magnitudes. In this Section we describe how to do this.

We use the form a power function assumes when we plot the curve in log-log co-ordinates: the graph of a power function then becomes a straight line and all the curvature disappears. Also, the slope of the straight line becomes a direct measure of the exponent. The power law equation becomes: $log\psi = \beta \log \phi + logk$. This formula describes a straight line in log-log co-ordinates, and the exponent β is the slope of the line. When we know a number of outcomes for the values of ψ and ϕ, it is possible to estimate the values of β and k, using the method of least squares. Assuming a linear relation, $y = ax + b$, between variables y and x, we can estimate the values of a and b by minimising the sum of the squared deviations of the outcomes of this relation.

Using the method of least squares, we estimate a power function when having obtained a number of outcomes for the values of ψ and ϕ. When we use the magnitude estimation method, it is now possible to estimate the power function that relates ψ and ϕ: $\psi = k\phi^m$. It is now also possible to estimate the power function that relates ϕ_1 and ϕ_2 when using the cross modality matching method:

$$\phi_1 = \sqrt[m]{\frac{k'}{k}}\phi_2^{\frac{n}{m}}. \tag{4}$$

Combining the functions of magnitude estimation and cross modality matching, we can derive the value of n: the exponent of the power function that describes the sensation magnitude of the second sense modality.

4. Case Study: Intertemporal Choice

The utility-based risk model is built around the gain-loss asymmetry saying that people have different risk attitudes towards gain and loss situations. This asymmetry has been observed in experiments [6] by letting subjects choose between receiving $\$3,000$ dollars for certain and receiving $\$4,000$ with 80% chance on the one hand, and choosing between losing $\$3,000$ dollars for certain and losing $\$4,000$ with 80% chance on the other hand. Most subjects chose to receive the certain risk-free sum of $\$3,000$, while also most chose to lose the risky sum of $\$4,000$. The modelling of such risk reversal has been done by incorporating the absolute monetary values. In this paper, we argue that utilities should be taken as the basis for such risk models, leading to other models.

Many decisions in real life involve outcomes which may occur not immediately, but at some moment in the future. For example, a person might have to choose between a car that is available immediately, and a car in a desired colour for the same price, but that is available after a period of time. These kind of decisions are called *intertemporal choices* [7]: Intertemporal choice is a decision in which the realisation of outcomes may lie in the imminent or remote future.

Recently, intertemporal choice has caught the attention in the literature on behavioural decision-making [8]. Before this, results on the subject were mainly due to the research contributions in related fields, like economics and animal-psychology. The general phenomenon of this research was the following: individuals -man or animal- portray a systematic preference for receiving a commodity immediately rather than at some later moment in time. This phenomenon is generally referred to as *positive time preference*.

The standard model for decision-making over time is a framework called time discounting. The underlying presumption by time discounting is that the present equivalent of a future outcome is the future amount discounted in accordance with the present value formula

$$A_0 = \frac{A_t}{(1+r)^t} \tag{5}$$

where A_0 represents the monetary value at time 0, A_t the monetary value at time t, r the discount rate and t the number of periods from the present until the time that A_t will be received. The discounted utility model is also based on this present value formula. A description of the discounted utility model can be found in [10].

4.1. Integrating discounting and utility

Positive time preference is the label for the familiar phenomenon that people prefer to get things sooner rather than later. The standard normative economic model of time preference is the discounted utility model [10]:

$$U_0 = \frac{U_t}{(1+r')^t} \tag{6}$$

where U_0 represents the utility at time 0, U_t the utility at time t, r' the discount rate and t the number of periods from the present until the time that U_t will be received. Observe that this function is defined over utility and not over absolute amounts. For example, a decision maker for whom r = .5 will not necessarily be indifferent between $1 now and

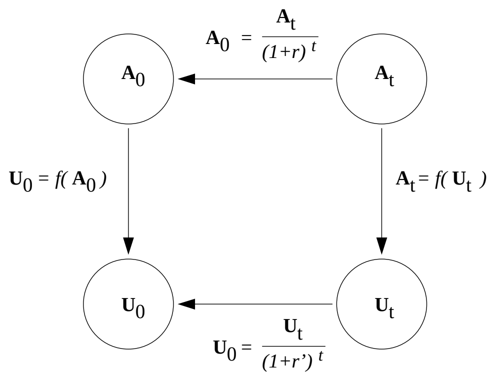

Figure 1. Integrating the utility function and discount value function.

$\$.5$ in the next period, because the utility from $\$1$ is unlikely to be twice the utility from $\$.5$. Surprisingly, however, all attempts to measure individual discount rates have involved measuring discount rates for amounts rather than utilities. We are aware of no previous study in which empirical measures of individual utility functions have been combined with measures of time preference. The utility function and discount value function can be integrated as shown in Figure 1.

If A_0 represents the monetary value at time 0, A_t the monetary value at time t, and U_0 the utility of A_0 then the value function $f(A_0)$ and the discount function can be integrated into U_0 as:

$$U_0 = f(A_0) = f\left(\frac{A_t}{(1+r)^t}\right) = f\left(\frac{f^{-1}(U_t)}{(1+r)^t}\right) \quad (7)$$

where U_t is the utility of A_t, $0 < r < 1$ and f is a non-linear and monotonic function. An important question then is: does the following equation hold:

$$f\left(\frac{f^{-1}(U_t)}{(1+r)^t}\right) = \frac{U_t}{(1+r')^t} \quad (8)$$

Assuming this equation holds, how must then the discount rate for money (r) and the discount rate for utility (r') be related to each other?

The distinction between discount rates for money and utility has important implications. Firstly, from a methodological point of view it can be argued that studies using the discount rate for money contain a serious flaw. Secondly, the distinction has important theoretical implications as well. A general finding in the empirical literature concerning intertemporal choice is the gain/loss effect. The discount rate for monetary losses is smaller than the discount rate for monetary gains. Thaler [12], for example, observed that discount rates were 3 to 10 times larger than the corresponding loss outcomes. Loewenstein and Elster [8] observed a discount discrepancy between gains and losses in the order of 15-20% for small and moderate dollar amounts delayed by one year. All of these studies give discount rates for money and not utilities. However, it is well known that, independent of the time dimension, the evaluation of gains and losses differs greatly: if someone loses and gains the same amount of money, the pain from the loss will outweigh the pleasure from the gain. In the much-cited words of Kahneman and Tversky, 'losses loom larger than gains' [6].

Moreover, both the gain and loss function are concave towards the origin, with both the first and second derivative of the loss function greater than the corresponding derivatives of the gain function. In general, if the second derivative of the loss function is higher than that of the gain function, then even if the discount rate (for utility) is identical for losses and gains, the observed discount rate for money will be greater for gains. This means that the observed discrepancy between discount rates for losses and gains of money is compatible with three relationships between discount rates for utility. Firstly, it may be true that even when discounting for utility is measured, gains are still discounted more rapidly than losses; secondly, there may be no difference between the discount rates; thirdly, losses could actually be discounted more rapidly than gains. The latter possibility is supported by a series of classic studies on what are called 'approach-avoidance gradients' (Miller, 1956; Busemeyer and Townsend, 1993). The well-known finding is that the approach gradient, which corresponds to discounting of gains, is shallower than the avoidance gradient, which corresponds to discounting of losses.

When assuming that equation (8) holds, how do the discount rates of money relate to the discount rates of utility? As explained above, this relationship is one of three: gains are still discounted more rapidly than losses, there is no difference, or losses are discounted more rapidly than gains.

5. Experiments

5.1. Methodology

This Section presents the method of the conducted experiment. We focus on the design of the experiment, with which subjects we conducted the experiments, which stimuli we gave the subjects and the procedure that we followed. In Figure 2 are the different tasks shown that each subject carried out. The numbers in the measurement and calculation columns (between brackets) refer to the formulas in Section 2. All tasks were carried out with the Util (version 1.0) software package[1].

1 Available at http://www.cs.vu.nl/∼schut/Util/setup.exe.

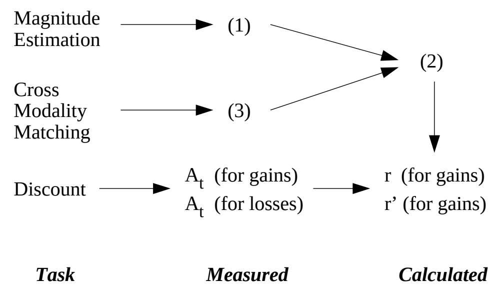

Figure 2. Overview of experimental tasks. The numbers in the measurement and calculation columns (between brackets) refer to the formulas in Section 2.

5.1.1. The discount task The discount task implements the staircase method [5]. This method elicits an indifference value for monetary value X in $(1000, \text{now}) \sim (X, 4$ weeks$)$. The indifference value is determined based on a number of hypothetical cases in which the user states its preference for one or two sitations. Iteratively X is varied based on the user's previour preference, eventually arriving at the indifference value.

The discount task concerned a within subjects design. The experiment was conducted under two different conditions. These conditions have to do with the modality the subjects got in the magnitude estimation task and the cross modality matching task (circle or line). Therefor, these conditions will be explained in the next Section. Both conditions were given to every subject. The discount task however was the same under both conditions. It considered deriving the discounted value of Fl 1.000,-. The discounted value is related to the initial monetary amount the subjects get as a stimulus. The staircase method begins with an initial choice situation. The stepsize was set to 1000. This task was performed for gain and loss situations.

The dependent variable in this task is the choice the subject makes. This variable is used to base the following question on. When the staircase method stops, one can determine the discount rate for a specific monetary amount – hence, an indirect dependent variable.

5.1.2. The magnitude estimation task This task was different under the two conditions, in the first condition the modality used was a circle and in the second condition the modality was a line. We only describe the circle condition here. In the magnitude task, the subject adjusts the area or length of the modality in such a way it would correspond with the magnitude of a specific number. The magnitude task concerned a within subject design. In total, the subject responds to 5 stimuli in both conditions: 25, 50, 200, 400, 600 and 800. With every stimulus, a standard circle was presented first. This circle had an area of 50. Stimuli were presented linearly.

The independent variable in this task is the number the subject has to respond to and the dependent variable is the size of the circle when the subject presses the spacebar.

5.1.3. The cross modality matching task In the cross modality matching task, the subject adjusts the area of a circle in such a way it corresponds with the utility of a specific monetary amount. The cross modality matching task concerned a within subject design. Like the discount task and the magnitude estimation, two different conditions were given to all subjects. In total, the subject responds to 5 stimuli in both conditions: Fl 1, Fl 10, Fl 100, Fl 1,000 and Fl 10,000. The stimulus was an amount between Fl 1 and Fl 10,000. With every stimulus, a dot was presented first. Stimuli were presented linearly. This task was performed for gain and loss situations. In both situations the area of the circle represented the intensity of feelings. That is, in gain situations the circle grew larger when a subject became happier and in loss situations the circle grew larger when a subject became sadder or less happy. The independent variable in this task is the monetary amount the subject has to respond to and the dependent variable is the size of the circle when the subject presses the spacebar.

5.1.4. Experimental Setup The complete experiment, including the three previously described tasks, has been conducted with 15 subjects. All subjects were students and ages varied from 18 to 26. The results of all subjects were used for analysis. All subjects executed the tasks without technical difficulties. We conducted the experiments individually.

The apparatus that we used for the experiment was the computer the tasks ran on. The computer was connected to an extra monitor, keyboard and mouse. In this way, the researcher could see what the subject did without the subject knowing he was being followed. The different tasks were conducted in the same order for all subjects. The whole experiment took approximately an hour to complete.

5.2. Results

The results of the conducted results are described in this Section. In Table 1, the obtained results are summarised. The Table shows the averages (AVG), medians (MED) and significances (sign) of the areas of the circles (in pixel^2) from the subjects that are calculated according to the results of the discount task (for the discount values) and the utility function.

We performed a paired samples t-test on the differences between gains and losses considering areas.The difference between the areas for gains and losses is significant for both U_0 and U_t. For the discount rates, the difference between

	Amount			Utility		
	Gain		**Loss**	**Gain**		**Loss**
	r		r'	R		R'
avg	0.26	$>$	0.18	0.13	$=$	0.13
med	0.27	$>$	0.18	0.14	$>$	0.13
sign	*0.003*			*1.000*		

	Gain	**Loss**	**Gain**	**Loss**
	U_0	U_0	U_t	U_t
avg	427	684	481	755
med	359	528	392	570
sign	*0.015*		*0.020*	

Table 1. Measured discount rates for amounts and utilities (above) and circle areas (below)

gains and losses is significant when measuring amounts, this is not the case when measuring utilities.

5.3. Analysis

We have elicited discount rates for amounts and the utility functions for monetary amounts of subjects. The experiments show that although discount rates for monetary amounts differ for gain and loss situations, discount rates for utilities are the same for gain and loss situations. We need to mention here that this conclusion can only be drawn carefully, because more experimenting will be needed to prove the conclusion.

The implications of this research can have effect on applying discount utility theory. Results of research that has been done on this subject would need to be reconsidered. When for example, Thaler [12] and Loewenstein and Elster [8] observe that the discount rate for monetary gains is larger than the discount rate for monetary losses, it is questionable if this would still be so when we consider discount rates for the utilities of monetary amounts.

6. Discussion

Preference elicitation is essential in multi-agent systems that are acting upon the interests of their users. Examples of such systems are widely known, ranging from user profiling agents to action-based agent-mediated marketplaces. To obtain preferences from users is a difficult and elaborate task, but rewards itself by the better alignment between buyer and seller.

We have presented a preference elicitation model that can be used for the design of multi-agent systems. The main idea of this model is that it enables users to state their preferences in some given kind of modality, e.g., circle sizes, removing the need to quantify preferences. Besides this removal, the model deals with other anomolies of existing elicitation methods as explained in this paper.

Additionally, the paper includes a preliminary investigation into the phenomenon of positive time preference: people prefer to get things sooner rather than later. This investigation was motivated from the disciplines of social science and decision analysis. Although this investigation did not have as its primary goal to validate our elicitation model, subjects indicated that the cross modality matching method was better than having to quantify preferences.

For future research, we foresee the application of our new model in agent-mediated e-commerce settings as to obtain preferences from clients autonomously. Additionally, we extend the experiments presented here to include other modalities and pursue more detailed decision-theoretical results on time preferences in gain-loss situations.

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