Context Dependent Utility: Modeling Decision Behavior Across Contexts

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Abstract

One significant challenge in creating accurate models of human decision behavior is accounting for the effect of context. Research shows that seemingly minor changes in the presentation of a decision can lead to drastic shifts in behavior; phenomena collectively referred to as *framing effects*. Previous work has developed Context Dependent Utility (CDU), a framework integrating Appraisal Theory with decision-theoretic principles. This work extends existing research by presenting a study exploring the behavioral predictions offered by CDU regarding the multidimensional effect of context on decision behavior.

The present study finds support for the predictions of CDU regarding the impact of context on decisions: 1) as perceptions of pleasantness increase, decision behavior tends towards risk-aversion; 2) as perceptions of goal-congruence increase, decision behavior tends towards risk-aversion; 3) as perceptions of controllability increase, i.e., perceptions that outcomes would have been primarily caused by the decision maker, behavior tends towards risk-seeking.

Keywords: Decision; Appraisal; Context; Framing; Utility;

Introduction

Descriptive models of human decision behavior seek to accurately describe and predict the decisions people *actually* make. Creating these models is vital for advancing a more complete understanding of the human decision process and requires addressing the factors that systematically bias the perception and evaluation of decisions.

One significant challenge in creating accurate models of human behavior is accounting for the effect of context on decision behavior. Research has shown that seemingly minor changes in the presentation, or framing, of a decision problem can lead to drastic shifts in behavior; phenomena collectively referred to as *framing effects*. In a seminal study, now referred to as the *Asian Disease Study*, Tversky and Kahneman (1981) showed that when outcomes were described, or framed, as gains participants tended to be risk-averse; however, when the same outcomes were framed as losses participants tended to be risk-seeking. Subsequent studies involving domains as diverse as financial planning (Schoorman, Mayer, Douglas, & Hetrick, 1994), Acquired Immune Deficiency Syndrome (AIDS) (Levin & Chapman, 1990), Breast Self Examinations (Meyerowitz & Chaiken, 1987), taxpayer compliance (Liu, Xia, & Xu, 2011), and judgments of website quality (Hartmann, De Angeli, & Sutcliffe, 2008) have also demonstrated framing effects to varying degrees. In addition to gain-loss framing, framing can also involve the role of the decision maker (Wagenaar, Keren, & Lichtenstein, 1988), the salience of outcomes (Van Schie & Van Der Pligt, 1995),

decision domain (Vartanian, Mandel, & Duncan, 2011), and perceived need (Mishra & Fiddick, 2012).

Despite the highly multidimensional nature of context, the prevalence of framing effects in numerous domains, and the profound impact they can have on the decision process, very few decision models explicitly address the multidimensional impact of context on decisions. Existing decision-theoretic approaches which do address framing and context are generally limited by a narrow, one-dimensional view of context. For instance, Prospect Theory (Kahneman & Tversky, 1979) and Cumulative Prospect Theory (Tversky & Kahneman, 1992) model the effect of context only to the extent that it applies to outcomes perceived as either gains or losses. Therefore, to address the multidimensional effect of context on decision behavior, previous work has developed Context Dependent Utility (CDU), a framework which seeks to explicitly model the multidimensional impact of context on decision behavior through the integration of Appraisal Theory and decision-theoretic models (Ito & Marsella, 2011). This work extends previous research by presenting an experimental study exploring the behavioral predictions offered by CDU regarding the multidimensional effect of context on decision behavior. In particular, the results support the behavioral predictions of CDU and suggest that it can dramatically improve the modeling of human decision behavior across distinct contexts.

Context Dependent Utility

In previous work, Context Dependent Utility (CDU) was developed to explicitly model the multidimensional impact of context on decision behavior (Ito & Marsella, 2011). The CDU process consists of two primary components: the computational appraisal of the decision situation and an evaluation function aggregating the appraisal information into a real-valued utility.

Appraisal Theory (Lazarus, 1991) is a psychological theory which addresses the process by which emotions arise given the subjective evaluation and interpretation of a situation. Because appraisal theory provides a well-defined framework for the interpretation of features of a situation in terms of their significance, we argue that it provides the means to identify, encode, and integrate contextual information into the decision process. Appraisal as implemented by CDU consists of three distinct evaluations: pleasantness, goal congruence, and control. Each appraisal is defined over individual outcomes as a function of diminishing sensitivity evaluated with respect to some *reference point*. This follows from the

principle that emotions and appraisals arise primarily from the changes, relative to some reference point, associated with them rather than from any inherent properties of the outcomes themselves (Frijda, 2007). The general appraisal function is shown in (1), in which $0 \leq k \leq 1$, controls the sensitivity of the appraisal.

Pleasantness is implemented as an evaluation of value made with respect to the value of the *status quo*, v_{sq}, as in (2). Goal congruence is implemented as an evaluation of value made with respect to the value of the *aspiration outcome*, v_{ao}, as in (3). Control is a measure of the degree to which an outcome will be perceived to have been primarily caused by the decision maker and is implemented as an evaluation of *decumulative* probability, i.e., the total probability of obtaining an outcome at least as preferred as it, made with respect to the probability of the *control threshold*, p_{ct}, as in (4). Note that the decumulative probability representation given in (5) requires that outcomes are in ascending order of value, i.e., $v_i \leq v_{i+1}$.

$$appraise\,(x, ref, k) = \begin{cases} (x - ref)^k & \text{if } x - ref \geq 0 \\ -(ref - x)^k & \text{if } x - ref < 0 \end{cases} \quad (1)$$

$$pleas\,(v_i) = appraise\,(v_i, v_{sq}, k_{pleas}) \quad (2)$$

$$gc\,(v_i) = appraise\,(v_i, v_{ao}, k_{gc}) \quad (3)$$

$$ctrl\,(D_i) = appraise\,(D_i, p_{ct}, k_{ct}) \quad (4)$$

$$D_i = \sum_{j=i}^{n} p_j \quad (5)$$

The decision evaluation component of CDU is implemented using rank-dependent utility (Quiggin, 1982) as seen in (6). Rank-dependent utility models allow for nonlinear decision weights while maintaining stochastic dominance. The utility function consists of a linearly weighted combination of pleasantness and goal congruence as seen in (7). Outcome weight, π_i, is defined in the standard rank-dependent manner as seen in (8). Additionally, it is important to note that the weighting function w, as seen in (9), simply normalizes the control appraisal such that $w\,(0) = 0$ and $w\,(1) = 1$.

$$CDU = \sum_{i=1}^{n} \pi_i u\,(v_i) \quad (6)$$

$$u\,(v_i) = (\beta pleas\,(v_i) + (1 - \beta)\,gc\,(v_i)) \quad (7)$$

$$\pi_i = \begin{cases} w\,(D_i) - w\,(D_{i+1}) & \text{if } i < n \\ w\,(D_i) & \text{if } i = n \end{cases} \quad (8)$$

$$w\,(D_i) = a\,(ctrl\,(D_i)) + b \quad (9)$$

Since appraisals are implemented as functions of diminishing sensitivity with respect to reference points, the underlying utility function becomes increasingly concave as perceptions of pleasantness and goal-congruence increase. Similarly, the underlying weighting function becomes increasingly concave as perceptions of controllability increase. Furthermore, according to the principles of the rank-dependent utility formalization employed in CDU, a concave utility function is associated with risk-aversion whereas a concave weighting function is associated with risk-seeking. Therefore, CDU offers the following set of behavioral predictions regarding the effects of pleasantness, goal congruence, and control on the decision process:

Hypothesis 1 As outcomes are perceived as increasingly pleasant, behavior will tend towards risk-aversion

Hypothesis 2 As outcomes are perceived as increasingly goal-congruent, behavior will tend towards risk-aversion

Hypothesis 3 As outcomes are perceived as increasingly controllable, behavior will tend towards risk-seeking

This work presents the results of an experimental framing study designed to test the hypotheses offered by the CDU framework. The study presents participants with a scenario in which they are asked to decide between two competing plans to prevent school dropouts.

Method

Participants

For the study, 525 participants from the United States were recruited through Amazon Mechanical Turk.

Each participant received a payment of $0.40 for participation. The sample had a self-reported gender distribution of 319 male (61%) and 206 female (39%). The median age range was 22 to 34 years with 85% of participants below 45 years of age. The majority of participants self-identified as white (78%). Approximately half of participants (50%) have also completed a 2 year college degree or higher.

Risk propensity, measured using the Subjective Risk Assessment instrument (Dohmen et al., 2005), uses a 7-point scale in which 1 represents being very prepared to take risks, 4 represents being risk-neutral, and 7 represents very unwilling to take risks. The mean of the subjective risk assessment measure for all participants was 3.46 with a median value of 3 and a standard deviation of 1.4 representing a slight overall self-reported tendency towards risk taking.

Additionally, only 42 participants (8%) self-identified as possessing some real-life expertise involving the prevention of school dropouts.

Procedure and Design

The study was administered as an anonymous online questionnaire implemented via Qualtrics (Qualtrics Labs Inc., Provo, UT). Before presentation of the decision scenario, demographic information including gender, age, race/ethnicity, and highest level of education was collected along with a measure of subjective risk propensity. Instructions adapted from previous studies administered by Schneider (1992) were

then presented to participants regarding the upcoming decision task. In addition, an embedded Instructional Manipulation Check originally developed by Oppenheimer, Meyvis, and Davidenko (2009) was adapted and employed in the present study to ensure that the instructions were read and to encourage participant attentiveness.

The decision scenario was then presented to the participants. The scenario was based on one originally designed by Fagley, Miller, and Jones (1999) to test standard gain-loss framing, but subsequently expanded in the present study to include additional considerations of context. It presented participants with two possible plans to prevent school dropouts: one plan always results in *some* students dropping out whereas the other plan results in either *all* students dropping out or *no* students dropping out. According to decision-theoretic formalizations of risk, a preference for the plan which always results in the same outcome (some students dropping out) is characterized as a preference towards risk-aversion whereas preference for the plan which results in one of two potential outcomes (one good and one bad) is characterized as a preference towards risk-seeking. As in most framing studies, regardless of frame, the underlying values, i.e., numbers of students dropping out or staying in school and outcome occurrence probabilities, associated with the scenario remain unchanged.

The framing of each scenario involved the explicit manipulation of the context associated with the appraisal dimensions of pleasantness, goal congruence, and control. The manipulation of pleasantness was associated with the description of outcomes as gains or losses such that outcomes described as losses were presumed to be relatively unpleasant whereas outcomes described as gains were relatively pleasant. Therefore, in the loss condition, outcomes were described by the number of students that drop out of school; for the gain condition, outcomes were described by the number of students that stay in school; for the neutral condition, outcomes were described using both the number of students that drop out and stay in school.

The manipulation of goal congruence was based on a previous study conducted by Payne, Laughhunn, and Crum (1981) and involved specifying different evaluation criteria to establish what constitutes a successful, or goal-congruent, outcome. In particular, participants were informed that their performance would be evaluated in comparison to the average retention rate, i.e., the percentage of students that stay in school, of other schools in the district. Therefore, in the low retention condition the expected retention rate was 5% (50 students stay in school or 950 drop out); in the neutral retention condition the retention rate was 40% (400 students stay in school or 600 drop out); and in the high retention condition the expected rate was 75% (750 students stay in school or 250 drop out).

The manipulation of control, derived from research on loci of control (Rotter, 1966), involved depicting the source of uncertainty as either arising from chance events or from the ability of the decision maker. Uncertainty arising from chance events suggests that outcomes are uncontrollable and therefore not caused by the decision maker whereas uncertainty regarding the ability of the decision maker suggests that outcomes are controllable and will be perceived as having been caused by the decision maker. Therefore, in the chance condition, uncertainty was depicted as arising from the random selection, i.e., lottery, of funding applications; In the ability condition, the source of uncertainty was described as arising from the hypothetical ability of the participant to write a persuasive funding application; and the neutral condition involved a mixture of the two. A full listing of a school dropout scenario in which outcomes are described as gains, retention rate is low, and the source of uncertainty is depicted as arising from one's ability is given in Appendix .

The primary dependent variables in the decision task consisted of both a dichotomous choice between plans, as found in most standard framing studies, and a continuous strength-of-preference response, which included an option indicating indifference, as advocated by Levin, Gaeth, Schreiber, and Lauriola (2002).

After completion of the decision task, participants were asked to directly evaluate the pleasantness, goal congruence, and control of the three potential outcomes, i.e., the sure outcome of the risk-averse alternative and the two potential outcomes of the risky alternative. This served as a manipulation check to ensure that the contextual manipulations employed in the scenario were effective. Participants were then offered the opportunity to express any additional factors that may have influenced their decisions. Finally, participants were asked to indicate whether or not they perceived themselves as possessing any type of expertise relating to school dropouts.

The study was conducted as a 3x3x3 between-subjects factorial in which both the presentation order of the two dropout prevention plans and the ordering of the two potential outcomes of the risky alternative were balanced. Table 1 illustrates the various factors and the number of participants that were assigned to each combination of factors. To ensure the integrity of the data, responses deemed *inconsistent* by an automated consistency-verification program were ignored. An inconsistent response was defined as one in which the dichotomous response regarding participant preference between plans does not agree with the associated continuous strength-of-preference measure. For example, a stated dichotomous preference for the sure alternative coupled with a strength-of-preference score favoring the risky alternative was deemed inconsistent.

Results

As discussed earlier, two distinct but related dependent measures were assessed: a dichotomous choice between alternatives and a continuous strength-of-preference measure. According to the dichotomous measure, 327 participants (62%) preferred the sure alternative while 198 participants preferred the risky alternative (38%). Similarly, according to the strength-of-preference measure, in which 1 indicates very

Table 1: Number of Participants per Condition

Gain/Loss	Retention Rate	Source of Uncertainty		
		Chance	Neutral	Ability
	Low	20	18	23
Loss	Neutral	20	26	18
	High	26	23	22
	Low	20	18	17
Neutral	Neutral	21	21	21
	High	21	22	19
	Low	20	19	15
Gain	Neutral	15	17	20
	High	13	16	14

Figure 2: Experiment 1 Effect of Retention Rate on Preference with 95% Confidence Intervals and Significance Levels (0 *** 0.001 ** 0.01 * 0.05)

strong preference for the sure alternative, 4 indicates indifference, and 7 indicates very strong preference for the risky alternative, mean choice preference was 3.61 with a median of 3 and a standard deviation of 1.71. This indicates a slight preference for the sure alternative.

Using the continuous strength-of-preference measure as the dependent variable, a 3-way ANOVA found significant main effects for retention rate $F(2,498) = 25.99$, $p < 0.001$, $\eta^2 = 0.09$, and source of uncertainty $F(2,498) = 6.53$, $p < 0.01$, $\eta^2 = 0.02$, while the effect of gain/loss descriptions $F(2,498) = 1.84$, $p = 0.16$, $\eta^2 = 0.01$ approached significance.[1] Figures 1, 2, and 3 show respectively the main effects of gain/loss description, retention rate, and source of uncertainty on mean preference strength. No significant interactions were detected.
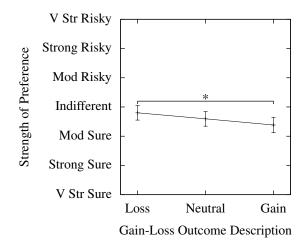

Figure 1: Experiment 1 Effect of Gain/Loss Descriptions on Preference with 95% Confidence Intervals and Significance Levels (0 *** 0.001 ** 0.01 * 0.05)
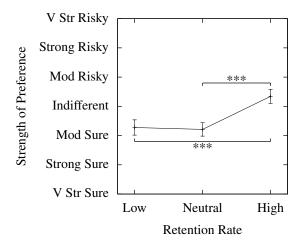
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[1]Using the dichotomous choice response as the dependent variable, logistic regression and likelihood ratio tests found similar results

Post-hoc t-tests on the effect of gain/loss description on preferences revealed a significant difference between the loss and gain conditions, $t(332.59) = 2.29$, $p < 0.05$. For the effect of retention rate on preferences, t-tests revealed that the difference between the low and high conditions $t(340.55) = -5.93$, $p < 0.001$ and between the neutral and high conditions $t(352.21) = -6.69$, $p < 0.001$ were significant. For the effect of source of uncertainty on preferences, the differences between the chance and the ability conditions $t(328.1) = 3.31$, $p < 0.01$ and between the neutral and ability conditions $t(347.17) = 2.39$, $p < 0.05$ were significant.

In addition to the primary dependent variables, direct evaluations of pleasantness, goal congruence, and control over each outcome were assessed to ensure that the contextual manipulations had the intended effect on their associated appraisals. A one-way MANOVA on the effect of gain/loss descriptions on appraisals of pleasantness for each of the three outcomes showed an effect approaching significance $F(6,1042) = 1.74$, $p = 0.11$. Similar MANOVAs showed significant effects for retention rate on appraisals of goal congruence $F(6,1042) = 18.65$, $p < 0.001$ and source of uncertainty on appraisals of control $F(2,1042) = 16.5$, $p < 0.001$ for each of the three outcomes.

Discussion

The goals of the study were to examine how different aspects of context affect decision behavior and whether shifts in preference in response to contextual changes, i.e., framing effects, are consistent with the predictions offered by CDU.

The experimental results support both the multidimensional effect of context on decision behavior and the predictions offered by CDU with respect to the effects of context. In particular, the present study finds strong support that the contextual dimensions associated with pleasantness, goal congruence, and control do affect decision behavior in the direction
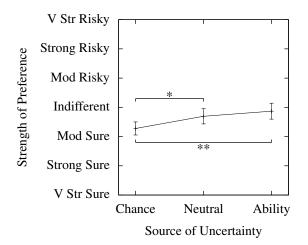
Figure 3: Experiment 1 Effect of Source of Uncertainty on Preference with 95% Confidence Intervals and Significance Levels (0 *** 0.001 ** 0.01 * 0.05)

predicted by CDU. CDU predicts that when outcomes are described as gains opposed to losses, decision makers will tend to act in a more risk-averse manner to maintain pleasantness. CDU also predicts that when the standards for success, i.e., retention rates, are low, decision makers tend to act in a more risk-averse manner to maintain goal congruency compared to when standards of success are high. Finally, CDU predicts that when the source of outcome uncertainty is depicted as arising from ability, e.g., persuasive writing ability, decision makers tend to act in a more risk-seeking fashion to capitalize on the perceived controllability of the situation compared to when the source of uncertainty is depicted as arising from chance events.

Conclusion

One significant challenge in creating accurate, descriptive models of human behavior is accounting for the effect of context on decision behavior. Existing approaches at modeling context and its effects on decision behavior, i.e, framing effects, are generally limited by a one-dimensional view of contextual influence and therefore lack the descriptive flexibility to account for a broad range of behavior. Therefore, this work extends previous research (Ito & Marsella, 2011) on Context Dependent Utility (CDU), a decision framework which seeks to explicitly model the multidimensional impact of context on decision behavior, by presenting experimental data supporting the need for accurate, multidimensional models of contextual influence on decision behavior. In particular, this work presents the results of a study in which participants are asked to choose between two alternative plans (one risky and one risk-averse) to prevent school dropouts. Additionally, to examine the effect of context on overall decision behavior, the context of the decision task is varied between subjects along the following dimensions: whether outcomes are de-

scribed in terms of gains or losses; the retention rate used to determine the degree to which an outcome is considered successful; and the portrayal of the source of uncertainty in the scenario, i.e., whether outcome variability depends on chance or ability-based factors.

The present study shows strong support for all of the behavioral predictions offered by CDU regarding the impact of context on decision behavior: 1) as the overall perception of pleasantness increases, which is associated with the description of outcomes as gains rather than losses, decision behavior tends towards risk-aversion; 2) as the overall perception of goal-congruence increases, which is associated with lower retention rates implying lower standards of success, decision behavior tends towards risk-aversion; 3) as the overall perception of controllability, i.e., the perception that outcomes would have been primarily caused by the decision maker, increases, which is associated with depicting the source of uncertainty as arising from one's ability, behavior tends towards risk-seeking. In sum, the present study illustrates the need for models which explicitly represent the multidimensional affect of context on behavior, such as CDU, especially when modeling decision behavior across contextually distinct situations.

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School Dropout Scenario

Initial Scenario Presentation

Imagine that you have been hired by the school district of a major city to combat the high number of student dropouts. It is projected that 1000 students in your district will drop out of school during the next year if nothing is done.

Action Description

Two plans exist to address the student dropout problem. Both plans require similar investments of money, time, and effort from your district. However, only one can be implemented. Based on other districts? experiences with these plans, estimates of the outcomes that can be expected from each plan can be made. Assume for purposes of this decision that these estimates of are accurate and are as follows:

Dropout Prevention Plan A Invest currently available funding in a smaller, relatively affordable dropout prevention program. This plan results in the following outcome:

- 400 of the 1000 students stay in school

Dropout Prevention Plan B Invest currently available funding in a larger dropout prevention program. However, the school district's current funding is insufficient to cover the full cost of this program. Therefore, its success is dependent on obtaining additional funding from the government. Funding approval for your dropout plan depends primarily on your ability to write a persuasive funding application. Historically, 2/5 of your previous applications have been persuasive enough to receive funding. This plan results in one of two possible outcomes:

- 2/5 chance that you are able to write a persuasive funding application. This results in sufficient funding and 1000 of the 1000 students staying in school
- 3/5 chance that you are not able to write a persuasive funding application. This results in insufficient funding and 0 of the 1000 students staying in school

Evaluation Criteria

The standard used to evaluate your performance will be the average student retention rate (the percentage of students that stay in school) obtained by other school districts in the state. Last year, the average retention rate for the other districts in the state was **5%**. The same rate is expected this year.

If you select a dropout prevention program that ultimately leads to a higher retention rate than those obtained by other districts in the state, you will be evaluated as being successful. Of course, the higher the retention rate is in your district, the more successful you will be evaluated. On the other hand, if you select a dropout prevention plan that ultimately leads to a lower retention rate than the average rate of other districts, your own evaluation will be diminished. Again, the more retention rates are below the average level, the more diminished will be your own evaluation.

Which plan would you adopt?