Reaction-Time Assessment of Beliefs Underlying the Irrational "Ratio-Bias" in Choice.

Kimihiko YAMAGISHI
(kimihiko@ky.hum.titech.ac.jp)

Yu NISHIMURA
(yunishi@ky.hum.titech.ac.jp)

Graduate School of Decision Science & Technology
Tokyo Institute of Technology, Box W9-21
Ohokayama 2-12-1, Meguro-Ku, Tokyo 152-8552, JAPAN

Abstract

People often judge uncertainty expressions by ratios composed of greater numbers (e.g., 100 out of 5,000) as more "probable" than consisting of smaller ones (e.g., 1 out of 50). Literature refers to this well-replicated phenomenon as the *ratio-bias*. We investigated an irrational choice reflecting the ratio-bias, wherein decision makers preferred a 9/100 chance of winning a gamble over 1/10. Our analyses went beyond previous account of this irrationality by empirically assessing decision makers' subconscious belief pertaining to this choice situation. We found that decision makers exhibiting such preferences associated the "9/100" chance to "benefits" more strongly to "1/10." Therefore, they preferred the alternative which they unconsciously evaluated as more lucrative. We shall discuss implications for decision making literature supporting the dichotomy of cognitive systems into "quick and irrational" and "slow, deliberate, and rational."

Imagine yourself preparing for a business trip. The Federal Aviation Administration (FAA) has been practicing random screening of passengers at the airport. If this occurred to you, the security personnel would pull you out of line and check you more thoroughly, taking your time. Therefore you had better go to the airport well in advance to departure. How often would it occur? After searching the Internet, you find one webpage describing the possibility as "1 in 250," whereas another page showing "10 in 2,500." Now, which webpage suggests a greater chance of running into this drudgery?

The rational answer, of course, is that both sources of information communicate exactly the same degree of uncertainty, namely 0.4%. However, people often perceive the latter representing a greater chance than the former. Literature shows numerous examples of this irrational belief affecting wide variety of judgment and choice, referring to this tendency as *ratio-bias*.

McFarland and Miller (1994) told their participants that s/he ranked at the 30th percentile on a fictitious "Social Perceptiveness Ability test." Concretely, the participants were told their rank as either 300th among 1,000 people or 3rd in 10. As the group size increased, pessimistic participants self-rated lower ability levels, whereas optimistic participants reported higher ability. In Miller, Turnbull and McFarland's (1989) vignettes, a child who adored chocolate-chip cookies successfully found such a cookie. Two vignettes differed in that the cookie jar contained chocolate-chip and less attractive oatmeal in the combination of either 1 and 19 or 10 and 190. The participants judged the child who succeeded in picking up 1 chocolate out of 20 as more suspicious of cheating, expressing their belief that a "1 in 20" chance was less likely to actualize than "10 in 200." Moreover, ratio-biases extended to cases of uneven odds. In risk perception, Yamagishi (1997) reported that people rated cancer as more seriously life-threatening when they read that cancer kills "1286 out of 10,000" people in the population than "24.14 out of 100."

Perhaps the most straightforward example of irrationality due to the ratio-bias may be found in the experiment of Denes-Raj and Epstein (1994). Denes-Raj and Epstein presented participants with a pairwise choice of gambles. Option 1 offered a 1-out-of-10 chance (10%) of winning $1. Option 2 offered a 9-out-of-100 chance (9%) of winning the same amount. The majority of participants preferred Option 2 despite that Option 1 offered a superior percentage to win. In response to the experimenter's interview for justifications of the choice, the participants admitted the irrationality in their preference. In contrast, when the same participants faced another gamble situation with negative payoffs (i.e., the chance was to lose their money), the majority chose the option offering a smaller chance to lose, thereby performing rationally. The current investigation focuses exclusively on this phenomenon, and we refer to this study as the DRE experiment.

We regard the ratio-bias instantiated by the DRE experiment, especially favoring a 9/100 chance to win over 1/10, as a striking example of irrationality for the following reasons. First, the irrationality is self-evident such that a naïve person without formal training on rational theories of choice would easily comprehend why such preference is logically indefensible [1]. Second, despite the simplicity in the observed phenomenon per se, influential explanatory theories of decision making such as Prospect Theory (Kahneman & Tversky, 1977) fail to explain the DRE experimental result.

[1] Compare the DRE experimental finding to, for example, the oft-cited "Allais paradox" in decision making literature (Allais, 1953). It requires profound understanding of the normative desiderata of rational choice (e.g., von Neumann and Morgenstern (1944)) to appreciate why preference in the Allais paradox lacks logical coherence.

The Original Account and Our Challenge

Denes-Raj and Epstein offered their account for the DRE experiment from the standpoint of Cognitive-Experiential Self-Theory (CEST). They remarked: "According to CEST, individuals apprehend reality by two interactive, parallel processing systems. The *rational system,* a … deliberative, verbally mediated, primarily conscious analytical system that functions by a person's understanding of conventionally established rules of logic and evidence. The *experiential system,* which is considered to be shared by all higher order organisms... operates in an automatic, holistic, associationistic manner, is intimately associated with the experience of affect, represents events in the form of concrete exemplars and schemas inductively derived from emotionally significant past experience" (Denes-Raj & Epstein, 1994, p. 819).

Denes-Raj and Epstein's CEST-based explanation of the DRE experiment argued as follows. Regarding the gain outcome, their participants' irrational preference for the 9/100 bet indicated that the experiential system dominated the rational system in choice. They explained the decrease of such irrationality regarding negative payoffs that: "associations to losing are more highly motivating than associations to winning,... The second reason, which may not be independent of the first, was that research has demonstrated that positive affect favors spontaneous, intuitive processing" (p. 826). In gist, CEST characterized people's cognition as switching back and forth from the experiential system to the rational system between gains and losses, due to motivation and affect.

We criticize here that the above-cited explanation remains a post-hoc rationalization of the observation, rather than a theoretical conclusion. We develop this criticism because Denes-Raj and Epstein's (1994) argument remains circulatory: People chose irrationally in gains because the experiential system dominated. How did they know the dominance of the experiential system? Through observing the irrational preferences. The circularity stems from the lack of empirical indice of "motivation" or "affect." If in the DRE experiment, independently of observing preferences, Denes-Raj and Epstein had measured some affective variables and found that such indice evincing her/his ir/rationally, then we would more willingly accept the CEST vindication. Furthermore, our skepticism extends to the status of CEST as a theory in empirical science. Recall that CEST assumes rational and irrational agents in human cognition, and advocates are allowed to make post-hoc arguments as to which agent dictated. Attempts to empirically falsify such a theory would easily face difficulties because, regardless of how ir/rationally people behave, proponents can always claim, "CEST explains this."

We attempt here to overcome the circularity in Denes-Raj and Epstein's explanation by empirically assessing the automatic and associationistic cognitive operation. As a technique to detect how such associationistic system functions, we adopt the "Implicit Association Test," or IAT for short.

The Implicit Association Test

Greenwald and colleagues (e.g., Greenwald, McGhee, & Schwartz, 1998) invented IAT in a motivation to measure people's often subconscious social presumptions such as prejudice, attitude, or self-concept. For instance, Nosek, Banaji, and Greenwald (2002) observed implicit characterization of mathematics as a "male subject" among female college students. Nosek et al. suggested that the females' identification with femininity and such math-male presumption might jointly discourage them from choosing mathematics major. Later, Banaji told *U. S. News & World Report* that taking the IAT herself revealed that "she unconsciously favored white over black, young over old, and associated females with home rather than work" ("Don't race to judgment," 2006).

IAT is a reaction-time (RT) test. Typically in IAT, a computer controls presentation of test stimuli as well as measures testee's RT. The testee's task is to categorize each target word (stimulus) appearing in the middle of the computer display into either of two target categories, appearing at top edges of the display. Consult Figure 1. In the example, the proper category for "LISA" is "female," so the testee should respond "female OR home." Notice that in Figure 1, the response categories represent conventionally prejudicial association between femininity and housework (and masculinity and business matters).

female OR home		male OR work
	LISA	

Figure 1: IAT display in a prejudice-congruent trial.

male OR home		female OR work
	SARAH	

Figure 2: IAT display in a prejudice-incongruent trial.

We invite the reader to contrast Figures 1 and 2 to comprehend the basics underlying IAT. In Figure 2, the target categories combine the characteristics contrary to the conventional gender stereotypes. Assuming that people respond faster to the category configuration more readily compatible with their subjective association, IAT detects that a testee connecting femininity stronger to home than work (either tacitly or tangibly) more quickly matches the stimuli to the "female" category in Figure 1 than Figure 2. In essence, IAT uncovers people's association by comparing categorization RTs between preconception-congruent versus incongruent categories.

Goals in the Current Study

We aim at offering a simpler account for the DRE experimental result by using IAT. Concretely, what does it mean that the participants in the DRE experiment chose irrationally in gains and rationally in losses? They preferred the "9/100" gambles constantly in gains and losses. Therefore, if we could detect an association between "9/100" and "benefit" in both contexts of gains and losses, such an association could explain the DRE result by saying that the decision makers always preferred what appeared to them as beneficial. We would like to emphasize that this interpretation does not require assuming different mood states in gains and losses ("fear evoked in the participants' psyche," as Denes-Raj and Epstein argued without measuring fear). Therefore, Occam's razor should favor the IAT-based account.

In the experiment below, our participants first faced the DRE experimental choice task. Afterwards, we measured which chance, "9/100" or "1/10," the participants strongly associated with benefits. We administered this set of tasks both under gains and losses.

Experiment

Participants

Twenty Japanese undergraduates participated in this experiment. They volunteered in the experiment for an offer of monetary compensations (detailed later).

Procedure

Each participant was run individually. In the beginning of the experiment, the experimenter offered 1,000 yen in cash for participation. The experimenter told that the participant would play gambles with actual monetary payoff. First, each participant faced pairwise choice. Afterwards, the participant performed an IAT task. Each participant went through the choice-IAT combination twice. The choice involved either positive payoff of winning 1,000 yen or negative payoff of losing 1,000 yen. We counterbalanced the order of administering the gain or loss condition across participants.

Pairwise Choice Figure 3 shows a photo of the actual experimental apparatus.

Each translucent Tupperware contained transparent and colored glass balls. The left Tupperware materialized "1 in 10" as the proportion of blue ball to the total. Likewise, the right Tupperware showed "9 in 100." We used the Tupperwares to make the content visible for the participants. The experimenter instructed each participant that s/he could win (lose) 1,000 yen if a randomly selected ball was colored. Also, the experimenter informed of the exact numbers of the colored and total balls in each Tupperware. The experimenter instructed the percentage for each Tupperware as well. Upon each trial, the participants choose whichever Tupperware of her/his choice, and s/he blindfoldedly picked up a glass ball at random. If they picked up a color ball, they immediately received (lost) 1,000 yen.

Figure 3. The gamble device in the Experiment.

RT Measurement in IAT Right after the pairwise choice and experiencing a gain/loss outcome, each participant underwent an IAT. Figure 4 shows an IAT display.

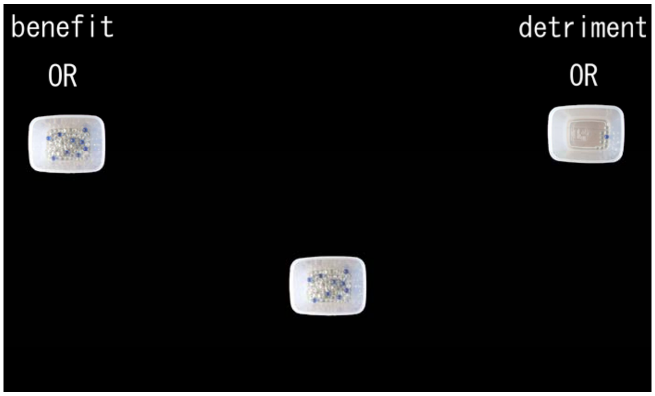

Figure 4. An IAT display.

We followed the standard IAT procedure (e.g.,. Greenwald et al., 1998, Nosek et al., 2002) to administer five blocks of RT measurement. In the first two blocks, we presented "benefit-detriment" categories and "1/10-9/100" categories (in pictures), respectively. The participant's task was to categorize words such as "advantage" or "damage" in Block 1, and the Tupperware images and other filler images in Block 2. Block 3 administered the categorization task as in Figure 4 ("benefit" appearing over the "9/100"). In Block 5, the response categories at the top display showed an opposite combination, wherein "benefit" appeared at the top of "1/10" and "detriment" at the top of "9/100." [2]

[2] Block 4, a filler block, required the same task as in Block 2, except that the left-right assignment of the response categories was reversed.

Prediction

Our predictions were twofold:

One: After Denes-Raj and Epstein, we expected to observe the participants prefer "9 in 100" gamble consistently in the gain and loss conditions.

Two: The participants would exhibit stronger association between "benefit" and the "9 in 100" picture than the "1 in 10" picture through faster RT in categorizing the former picture.

Results

Gamble Preference

Table 1 shows the number of participants divided by their preferences and the experimental conditions.

Table 1. Number of participants categorized by their preferences.

Our Results

Condition	1 in 10	9 in 100
Gains	7 (35%)	13 (65%)
Losses	6 (30%)	14 (70%)

Denes-Raj and Epstein (1994, p. 822)

Condition	1 in 10	9 in 100
Gains	32 (40.5%)	47 (59.5%)
Losses	32 (40.5%)	47 (59.5%)

Notice that the majority preference echoed the trend in the original DRE experiment. Thus, our Prediction One gained support.

IAT Reaction Time

Figure 5 shows the mean reaction time in the IAT, as well as the 95% confidence intervals for the cell means.

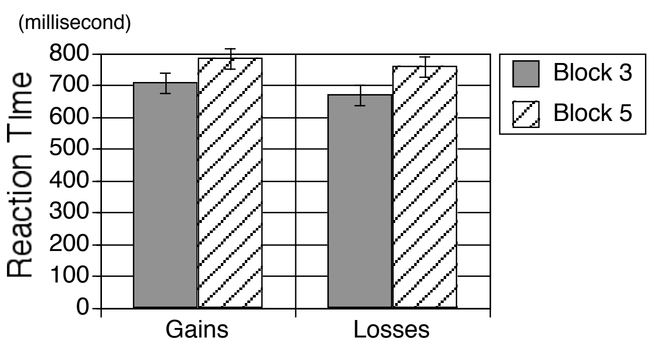

Figure 5. Mean Reaction Time in the IAT.

In Blocks 3 and 5, we measured the association between "benefit & 9/100" and "benefit & 1/10," respectively. The shorter RTs for Block 3 (the shaded bars shorter than the stripe bars), irrespective of the gain-loss conditions, reflected the participants' implicit association between "9/100" and *benefit*.

We submitted the Figure 5 data onto a 2 by 2 ANOVA. The results showed only the main effect of the blocks as statistically significant ($F(1, 19) = 8.535$, $MSE = 334.90$, $p < .01$). Hence, we positively confirmed our Prediction Two.

We scrutinized the RT data through classifying the participants according to a "rational" versus "irrational" criterion. In gains, we categorized those who chose the "9 in 100" gamble as *irrational* and the rest *rational*. Likewise, those who chose the "9 in 100" in losses were *rational* while the rest *irrational*. Figure 6 shows the mean RTs for the participants classified in these criteria.

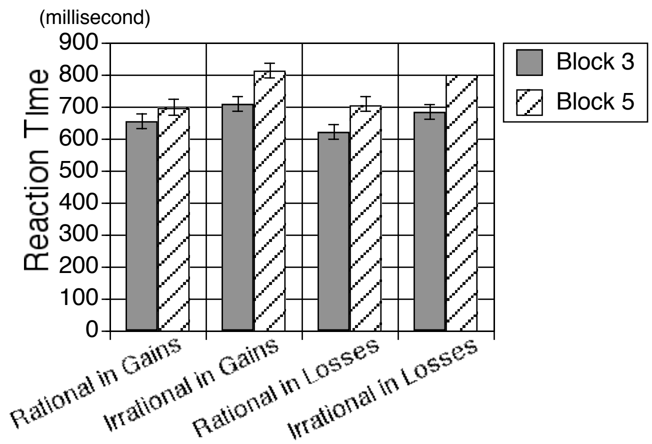

Figure 6. Mean Reaction time for the Rational and Irrational Participants.

We performed a three-way (block by gain-loss by rational-irrational) ANOVA on the Figure 6 data. The block was the only factor achieving a statistical significance ($F(1, 36) = 6.257$, $MSE = 294.38$, $p < .05$). This result shows that, regardless of the ir/rationality in her/his choice, the participants unanimously regarded the "9/100" as beneficial.

Discussion

In this study, we replicated the unjustifiable preference in the ratio-bias originally found by Denes-Raj and Epstein. More importantly, we discovered that decision makers unanimously associated the "9 in 100" chance to "benefits." Hence, we argue that, regardless of gains or losses, decision makers preferred what appeared to them as implicitly beneficial. Consequently they irrationally chose "9/100" in gains and rationally chose "9/100" in losses.

It is noteworthy to reject a learning-based counterargument against our conclusion. An alternative account would hypothesize if the participants first experienced the negative payoff gamble, thereby learned an association between 9/100 and benefit, then such an association could carry-over to the positive payoff gamble. Our experimental procedure, wherein we counterbalanced administering of the gain-loss conditions, makes this learning interpretation inappropriate. Moreover, our supplementary ANOVA with the block order as a factor failed to detect a significant interaction between block order and block type, in disagreement with the learning interpretation. A second alternative possibility would be to hypothesize that IAT detected an association between "balls in a particular color" and benefit. Hence, faster RT for more balls in a particular color. We would like to accommodate this concern by pointing out that, in our choice experiment and IAT, the color ball was blue in the gain condition and red in the loss condition. Therefore, color association faces difficulty because regardless of colors, RT was shorter for the "9/100 OR benefit" category.

Skeptics might want to criticize that the current IAT results do not support our claim, because in Figure 6, the RT for the rational participants also exhibited the association readily compatible with the ratio-bias choice. In rebuttal, we maintain that our contribution lies in demonstrating the uniform association capable of explaining the majority preferential pattern to choose irrationally in gains and rationally in losses. Since the anecdotal observations by Sigmund Freud, intellectuals have recognized the dynamism of the unconscious as sometimes functioning independently of prescriptions of the conscious mind. As a recent and empirically solid example, Adams, Lester, and Lohr (1996) investigated homosexual arousal in exclusively heterosexual homophobic men and nonhomophobic men. Surprisingly, faced with male homosexual video stimuli, the homophobes were more likely to show an increase in penile erection. This finding led Adams et al. to remark; "Homophobia is apparently associated with homosexual arousal that the homophobic individual is *either unaware of or denies*." (p. 440, italicization added). In line with Adams et al., we regard it reasonable to observe minor discrepancies between implicit beliefs and superficially deliberate preferences for some participants. Thus, we see the stronger association in Figure 6, exhibited by a minority of the participants who chose 1/10 in gains, as no surprise.

Furthermore, we would like to stress the virtue of simplicity in our argument. Recall that the account by CEST relies on a number of unobserved psychological concepts, such as the dichotomy between the experiential and rational systems, as well as participants' fear evocation only in the loss conditions. All we need to clarify the asymmetry in rationality between the gains and losses is an implicit association. Therefore we offer a simpler, scientifically more desirable account.

Recent theorists support the view to regard human cognitive systems as consisting of the "quick, associative, and effortless" system and "slow, deliberate, and thoughtful." In his Nobel Prize lecture, Daniel Kahneman depicted two systems of decision-making. System 1, the experiential system, is fast, automatic, effortless, associative, and difficult to control or modify. System 2 is analytical, and is slower, serial, effortful, and deliberately controlled (Kahneman and Frederick (2002), Kahneman (2003)). Sloman (1996) and Stanovich (1999) proposed highly analogous conceptualization. More classically, Zajonc (1980, p. 152) noted the discrepancy between "logical thinking" and "automatic feeling" as follows:

> *We sometimes delude ourselves that we proceed in a rational manner and weight all of the pros and cons of various alternatives. But this is seldom the actual case. Quite often "I decided in favor of X" is no more than "I liked X" . . . We buy the cars we "like," choose the jobs and houses we find "attractive," and then justify these choices by various reasons.*

We regard CEST as an example of this conceptualization. A common denominator among this school of thought is to comprise separate thinking systems (see also Bechara, Damasio, Tranel, and Damasio (1997) Slovic, Finucane, Peters, and MacGrdegor (2002), and Evans (2003)).

Having proposed an alternative account of the ratio-bias to CEST, by emphasizing the advantage of relying on fewer assumptions, are we challenging the "System 1 versus System 2" school of thought altogether? Our response is negative. Instead, we would like to promote the use of IAT as a tool to tap onto how System 1 functions. As we introduced above, many theorists recognize the need to conceptualize two distinct cognitive mechanisms. Yet in our evaluation, many such proposals remain speculative for the same reasons we had criticized CEST: Most of such proposals do not prescribe as to how we empirically know when System 1 functioned and when System 2, aside from the observation of ir/rational judgment and choice.

IAT was originally developed as a tool to identify people's implicit association among social concepts (Greenwald, McGhee, & Schwartz, 1998). Here, we have demonstrated that one can use IAT to detect people's intuitive grasp of more abstract concepts. Thus, we envision that similar IAT measurement can offer converging evidence to a wider variety of phenomena that require multiple systems to explain why humans sometimes behave irrationally. For instance, take Yamagishi's (1997) ratio-bias in risk perception. Would it be possible to discover a stronger association between "fear" and "1,286 in 10,000" than "24.14 in 100?" We close our paper by pointing out the potential of IAT to offer plausible explanation to a variety of human ir/rationality.

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References

Adams, H. E., Lester, W., & Lohr, B.A. (1996). Is homophobia associated with homosexual arousal? *Journal of Abnormal Psychology, 105*, 440-445.

Allais, M. (1953). Le comportement de l'homme rationnel devant le risque: Critique des postulats et axiomes de l'ecole americaine. *Econometrica, 21*, 503-546.

Anonymous (2006). Don't race to judgment. *U.S. News & World Report* (Jan. 2), 90-91.

Bechara, A. Damasio, H., Tranel, D., & Damasio, A. R. (1997). Deciding advantageously before knowing the advantageous strategy. *Science, 275*, 1293-1295.

Denes-Raj, V. & Epstein, S. (1994). Conflict between intuitive and rational processing: When people behave against their better judgment. *Journal of Personality and Social Psychology*, *66,* 819-829.

Evans, J. St. B. T. (2003). In two minds: Dual process accounts of reasoning. *Trends in Cognitive Sciences, 7*, 454-459.

Greenwald, A. G., McGhee, D. E., & Schwartz, J. L. K. (1998). Measuring individual differences in implicit cognition: The Implicit Association Test. *Journal of Personality and Social Psychology, 74*, 1464–1480.

Kahneman, D. & Frederick, S. (2002). Representativeness revisited: Attribute substitution in intuitive judgment. In T. Gilovich, D. Griffin, & D. Kahneman (Eds.), *Heuristics and biases: The psychology of intuitive judgment* (pp. 49-81). Cambridge: Cambridge University Press.

Kahneman, D. (2003). A perspective on judgment and choice: Mapping bounded rationality. *American Psychologist, 85*, 697-720.

Kahneman, D., & Tversky, A. (1979). Prospect Theory: An analysis of decision under risk. *Econometrica, 47,* 263-292.

McFarland, C. and Miller, D. T. (1994). The framing of relative performance feedback: Seeing the glass as half empty or half full. *Journal of Personality and Social Psychology, 66*, 1061-1073.

Miller, D. T., Turnbull, W. & McFarland, C. (1989). When a coincidence is suspicious: The role of mental simulation. *Journal of Personality and Social Psychology*, *57*, 581-589.

Nosek, B. A., Banaji, M. R., & Greenwald, A. G. (2002). Math=Male, Me=Female, therefore Math≠Me. *Journal of Personality and Social Psychology, 83*, 44-59.

von Neumann, J., & Morgenstern, O. (1944). *Theory of Games and Economic Behavior*. New York: Wiley.

Sloman, S. A. (1996). The empirical case for two systems of reasoning. *Psychological Bulletin, 119*, 3-22.

Slovic, P., Finucane, M., Peters, E., & MacGregor, D. G. (2002). The Affect Heuristic. in Gilovich, Griffin, and Kahneman (eds.) *Heuristics and biases: The psychology of intuitive judgment.* Cambridge, UK: Cambridge University Press, pp. 397-420.

Stanovich, K. E. (1999). *Who is Rational? Studies of Individual Differences in Reasoning.* Mahwah, NJ: Lawrence Erlbaum Associates.

Yamagishi, K. (1997). When a 12.86% mortality is more dangerous than 24.14%: Implications for risk communication. *Applied Cognitive Psychology*, *11*, 495-506.

Zajonc, R. B. (1980). Feeling and thinking: Preferences need no inferences. *American Psychologist, 35*, 151-175.