

Research article

Pleasure in decision-making situations

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Abstract

Background: This study explores the role of pleasure in decision making.

Results: In Experiment 1, 12 subjects were presented with a questionnaire containing 46 items taken from the literature. Twenty-three items described a situation where a decision should be made and ended with a suggested solution. The other items served as filler items. The subjects were requested not to make a decision but to rate the pleasure or displeasure they experienced when reading the situation described in the item. The subjects' ratings were then compared to the decisions on the same situations made by the other subjects of the studies published by other workers. The ratings of pleasure/displeasure given by our subjects correlated significantly with the choices published by other authors. This result satisfies a necessary condition for pleasure to be the key of the decision making process in theoretical situations. In Experiment 2, a new group of 12 subjects rated their experience of pleasure/displeasure when reading various versions of 50 situations taken from daily life where an ethical decision had to be made (Questionnaire I) including 200 items. This was followed by a multiple-choice test with the 50 situations (Questionnaire II) using the same 200 items and offering the various behaviors. Subjects tended to choose ethical and unethical responses corresponding to their highest pleasure rating within each problem. In all cases the subjects' behavior was higher than chance level, and thus, followed the trend to maximize pleasure. In Experiment 3, 12 subjects reading 50 mathematical short problems followed by correct and incorrect versions of the answer to the problem (Questionnaire III), including 200 items. This was followed by a multiple-choice mathematical test with the 50 problems (Questionnaire IV) using the same 200 items and offering the correct and incorrect answers. In questionnaire IV, subjects tended to choose correct as well as incorrect responses corresponding to their highest hedonic rating within each problem. In all cases the subjects' behavior was higher than chance level, and thus, followed the trend to maximize pleasure.

Conclusions: The results of the three experiments support the hypothesis according to which decisions are made in the hedonic dimension of conscious experience.

Background

In a provocative review article, Baron showed that some decisions are not made on rational grounds as the subjects do not seem to weigh the consequences of their decisions [1] This is important because if true, such a phenomenon would cast doubt on the rationality of the mental process of decision making. In a commentary on Baron's article, Cabanac proposed that this might be so because the whole process of decision making *can* be hedonic rather than rational [2]. This proposal was made on a two-fold basis:

1) because behavior is a final common path [3], various motivations competing for access to it must be able to 'talk to one another' in order to allow the brain to rank them by priority order. Therefore, there must exist in the brain a common currency allowing the trade-off between motives and their ranking to take place as postulated by McFarland & Sibly, 1975 and by McNamara & Houston, 1986 [3,4];

2) in a series of experiments, subjects were confronted with situations evoking conflicting motivations. The solutions to the conflicts were found by the subjects in maximizing the bi-dimensional sum of pleasures aroused by both of the motivations pitted against each other. Because the motivations explored in these experiments varied widely, from physiological (hunger, fatigue, thermal discomfort, pain) to psychological (eagerness to play a video-game, to earn, or to save money) it may be postulated that pleasure, and its counterpart displeasure, are the common currency allowing the trade-off necessary to achieve the ranking order for satisfying conflicting motivations [5]. Hence, if this holds true, pleasure and displeasure – a non-rational experience-should be the common currency used also for the ranking of priorities in the process of decision making.

In order to test such a hypothesis Balaskó and Cabanac studied decision-making in situations involving grammatical choice in a second-language test, i.e. a situation where no physiological motivation was involved and the process of decision making was purely mental [6]. They showed that subjects tended to choose grammatically correct as well as incorrect sentences corresponding to their highest hedonic experience. In all cases the subjects' behavior was higher than chance level, and thus, followed the trend to maximize pleasure. This result supported the hypothesis according to which the key to decision-making lies in the hedonic dimension of conscious experience. McKenna, studying risk-taking behavior, reached a similar conclusion [7]. Thus the trend to maximize pleasure seems to be an important factor of the decision-making process.

The present work tests the above hypothesis according to which the maximization of pleasure may be a substrate of decision making in mathematics and ethics, fields where one would expect pure rationality to take place. Three experiments were done. In Experiment 1, theoretical ethical decisions in unusual situations were presented in a questionnaire to subjects who were asked, not to make a decision but to rate the pleasure or the displeasure they experienced in the situation as described in the questionnaire. The items presented in Experiment I, were those used by other workers [8–11] in experiments testing theories concerning the process of decision making in non-consequential decisions. In Experiment 2, new situations of the ordinary life, including deliberately ethical outcomes, were presented and the subjects' ratings of pleasure were compared to a) the decisions they would make, and b) to their own ethical assessments. In Experiment 3, the hedonic responses of subjects, to mathematically correct and incorrect variations of the same problems were recorded and then compared to the behavioral choice of correct solutions made later by the subjects themselves. All three experiments were devised to test the hypothesis that, in the situations where subjects make non-consequential decisions or guess an outcome, they do not follow a rational mental process but rather tend to maximize mental pleasure, or minimize mental displeasure

Methods

Subjects

Thirty six students and staff members recruited on campus, males and females in equal numbers, were informed of the protocols and gave their consents. Twelve subjects served in each of the 3 experiments. The mean ages of males and females were not significantly different; the mean (\pm S.E.) age of the groups were 24.7 ± 0.8 yr in Experiment 1, 25.8 ± 0.8 yr in Experiment 2, and 33.42 ± 4.90 yr in Experiment 3. All sessions took place in the afternoon. Only subjects in healthy condition were chosen because depression, or other pathological conditions might influence the affective tone and also the process of decision making [12,13]. Each subject received fifteen Canadian dollars as compensation.

Instruction to the subjects

In all three experiments, the subjects received a questionnaire (Questionnaires 1, 2.a, and 3.a, for Experiments 1, 2, and 3) starting as follows: "Read carefully the texts below. After reading each item give a quantitative rating of the pleasure or displeasure you experience when reading the situation and decision described in each item." The rating was to be a positive, or a negative number corresponding to the magnitude of the subject's hedonic experience. A positive rating would indicate pleasure, a negative rating would indicate displeasure. Zero was to indicate indifference. The scale of the rating was left to the

judgement of each subject. The reason for not being more specific with the instructions about pleasure/displeasure rating, was that the hedonic experience being a Gestalt-type archaic phenomenon it was expected that the subjects would be able to use a little defined rating.

In Experiments 1 and 2, the following was added: "Warning: you are not asked to make a decision but simply to describe your feelings evoked by the given situation. The magnitude of the rating is left up to you; a positive rating will indicate pleasure; a negative rating will indicate displeasure; zero will indicate indifference". In Experiment 3 (mathematics), the subjects were also instructed that the rating should describe the pleasure evoked by the logic of the item not by its nature. None of the 12 subjects in Experiment 3 was discalculic [14]. All efforts were made to dedramatize the experiment as anxiety was shown to affect the mathematical performance [15]. The subjects were instructed orally to read the questionnaires item by item, slowly and attentively, and not to return to previous items to check previous ratings, nor to modify them. In all three experiments half of the subjects received Questionnaire 1 with the items presented in a randomly organized sequence; the other half subjects received Questionnaire 1 with the same items presented in reverse order. In all three experiments equal numbers of males and females received each type of questionnaire.

In Experiment 1, the subjects received only Questionnaire 1. In Experiment 2, the subjects received Questionnaire 2.a, then, after completing it, they received Questionnaire 2.b, and finally, Questionnaire 2.c. In Experiment 3, the subjects received Questionnaire 3.a, then Questionnaire 3.b.

The experimental design was 'within-subject', thus canceled the noise introduced by 'between-subject' method. In addition, the method cancelled also the biases introduced by a sequence of items on the same problem in a within-subject measurement, by using counterbalanced sequences in half the group of subjects.

Results

Experiment 1

Questionnaire 1

46 items were presented to the subjects. Out of the 46 items 23 involved clear-cut decisions and are the object of the present work. The remaining 23 items described situations where the outcome did not involve decision making but rather various situations with moral outcome. They served as filler items and will not be referred to in the following.

The items were carefully selected to be difficult, but not over-complicated situations, usually pitting only two con-

flicting motives against one another. They were derived from articles in the literature where subjects had been asked to make a decision in hypothetical situations, thus testing various theories related to decision making. Each item ended with a suggested decision or action. The items presented were translated very carefully from English into French to avoid different framing in the present work from in the original experiments [16]. For the same reason, several versions of the same situations were presented, resulting in counterbalanced series of items. All subjects received a questionnaire containing all the possible alternatives. Only the order of the items presented to the subjects, differed.

a) 2 items on how much to compensate the victims of a minor train accident were taken from [11]. In the original work the subjects were asked to give a monetary compensation to the victim of a minor train accident. The engineer sees a tree on the railway. In one case, he tries to stop the train with success, but a passenger suffers from minor injury. In the other case, he decides to do nothing, and a passenger suffers from minor injury. In both cases the passenger does not suffer of any financial prejudice. Should he receive a compensation?

b) 2 items on how much financial compensation to be offered to the families whose relatives died of a vaccine given to protect the population by mass vaccination, during an epidemic although it was known that the vaccine entails some mortality of its own, were taken from [9];

c) 2 items on whether or not to vaccinate your own child during an epidemic when the vaccine entails some mortality of its own, were taken from [9];

d) 2 items on whether or not to kill a fellow prisoner, when this death will save the lives of two other prisoners, were taken from [9];

e) the decisions to pass or repeal, a law rendering vaccination compulsory (2 items), and a regulation to prevent a minor flu-type epidemic (2 items), were taken from [10];

f) the decision to redirect a loose train, or to do nothing. In one case, 2 men are working on the loose train track, but 3 other men are working on the track where you can redirect the train or do nothing. In the other case, the numbers of track-workers were reversed. This situation was taken from [8]. Altogether 4 items combined the above cases;

g) decision to operate or not, combining better or worse outcomes of surgery than the disease, with the fact that the reader was the patient or the surgeon (Annex 1), were taken from [8].

Table 1: Comparison of present hypothesis with results obtained previously by others (Experiment 1) RATIO OF POSITIVE DECISION is the number of subjects who decided to act divided by the total number of subjects in the given experiment indicated in references column; these ratios were found in previous studies as noted by references. RATIO OF PLEASURE RATINGS is the result of the present experiment: the ratio was achieved by dividing the number of subjects expressing pleasure upon presentation of the situation described in Reference, by 12 (the number of subjects).

ITEM	REFERENCE	RATIO OF POSITIVE DECISION	RATIO OF PLEASURE RATINGS
Train accident	Ritov <i>et al.</i> 1994	0.32	0.5
		0.81	0.67
A&B disease	Baron 1992	0.28	0.5
		0.69	0.67
Child vaccination	Baron 1992	0.74	0.67
		0.26	0.25
Prisoner	Baron 1992	0.12	0.08
		0.88	0.67
Compulsory vaccine	Baron & Journey 1993	0.69	0.83
		0.21	0.42
Compulsory gurgle	Baron & Journey 1993	0.66	0.5
		0.21	0.42
Redirected train	Spranca <i>et al.</i> 1991	0.28	0.08
		0.31	0.33
		0.66	0.42
		0	0

Altogether the seven topics above combined the above cases, resulting in a total of 23 items.

Statistics

The results presented by other authors were expressed as percentages derived from the population of subjects accepting or rejecting the decision presented to them. In order to compare our results with the data obtained by previous authors, we decided to simply match the numbers of positive ratings (pleased) and negative ratings (displeased), with the percentages available from the literature. Thus, our results are *ratios* similar to those of previous authors. The Spearman and the Kendall rank correlation coefficients were used to compare the pleasure experienced by our subjects to the decisions made by the other authors' subjects.

Results

As there was no difference between males and females, the results were pooled. The mean duration of the sessions was 47 ± 4 min.

Table 1 presents the results of items a to f, and Fig. 1 the results of item g. Table 1 shows the number of subjects in our experiment experiencing pleasure when reading about a given situation (and decision) and the proportion of subjects who decided to act in the same situation as used in previous studies. Both series of numbers correlated significantly: Spearman rank correlation coefficient 0.85, *P* <

0.001; Kendall rank correlation coefficient 0.75, *P* < 0.0001.

In Spranca *et al.*'s original experiment, the neurosurgery situation (item g), the subjects were asked to rate the amount of goodness of the decisions presented. With respect to this item, we were able to compare our subjects' ratings of pleasure to the ratings of goodness obtained by Spranca *et al.*'s. Fig. 1 shows the results; each dot shows the group responses in seven different situations where the proportion of risk and success were combined. The correlation between our subject's ratings of pleasure and Spranca *et al.*'s subjects' ratings of goodness was significant: Spearman rank correlation coefficient 0.82, *P* < 0.024; Kendall rank correlation coefficient 0.75, *P* < 0.011.

Discussion

The situations presented to our subjects were those which led Baron [1] to show that subjects often make non-consequential decisions. This experiment was devised to test the hypothesis that, in the situations where subjects make non-consequential decisions, they do not follow a rational mental process but rather tend to maximize their experience of mental pleasure, or minimize mental displeasure. Confirming this hypothesis, our subjects' pleasure/displeasure ratings of the theoretical situations presented to them coincided with the decisions, consequential and non-consequential, made by subjects in other experiments.

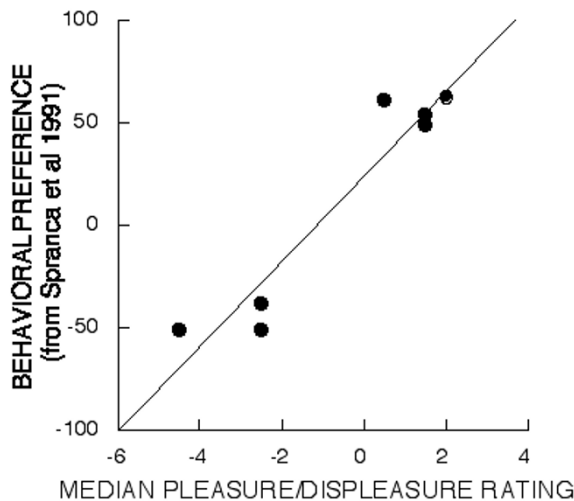


Figure 1

Experiment 1. Ordinates: median of ratings of appropriateness of various neurosurgical situations given by a group of subjects in Spranca et al. (1991); abscissae: median hedonic ratings of pleasure or displeasure given by our 12 subjects when presented with the same situations. The line indicates simple parametric regression to illustrate the relationship between both variables. Both Spearman and Kendall rank correlation coefficients indicated very significant correlation of the two variables.

Evans et al. [17] described rationality as composed of two elements: rationality 1 to reach a goal, and rationality 2 logic reasoning. For them, rationality 1 is the normal process in a concrete situation. Rationality 1 therefore may be considered the relevant rationality for our study where maximization of pleasure occurred, i.e. in situations of conflict, choice, and decision making.

As expressed by others [18,19], the highly contingent nature of decision behavior poses problems and renders the field chaotic. The hypothesis tested in the present work might cast some light on the problem, because what was explored was deliberately shifted from the measurement of behavior, or from the intention to act, to the subjects' mental experience. The results of the present work showed that the decisions made in theoretical situations presented to subjects in other studies correlated with the feeling of pleasure in our subjects. It may therefore be hypothesized that there is a causality in the correlation.

Experiment 2

Experiment 2 was devised to eliminate the artificial aspects of the situations described in the questionnaire of Experiment 1. Rather than hypothetical situations where the subject would, for example, redirect a train and never-

theless kill some workers, or vaccinate a population and cause some casualties, in Experiment 2 the subjects were presented practical situations of their daily life, such as 'I find a wallet in the street', or 'I am in a hurry and the traffic light turns red'. Four possible behavioral responses were combined in each of these situations, e.g. a) I leave the wallet in the street, b) I turn in the wallet to the lost and found office, c) I turn the wallet with the id. and credit cards but keep the money, and d) I keep the wallet.

Questionnaires 2.a, 2.b, and 2.c

200 items were presented to the subjects. The questionnaire 2.a contained 50 situations each recurring 4 times, with 4 different behaviors described (i.e. 200 items) to be rated for pleasure/displeasure. The situations were all taken in daily life and some of the behaviors were clearly unethical, such as hit and run, income tax cheating, spying on university examinations, etc. In ANNEX are some examples of these 50 situations. All subjects received a questionnaire containing all possible alternatives. Only the order of the items presented to the subjects differed.

Once the subject had completed the ratings of the 200 items of Questionnaire 2.a, Questionnaire 2.b was presented. This questionnaire gave the 50 situations each with its 4 possible behaviors as in a multiple-choice test (see examples in ANNEX). Thus, the 200 items were grouped four by four and the subjects were asked to circle the item describing what they would chose to do in the given situation.

After the completion of Questionnaire 2.b, Questionnaire 2.c was presented. It contained only twenty selected situations out of the fifty of questionnaires 2.a and 2.b, where one of the behaviors offered was unethical. The subject was asked to circle the item describing the most ethical behavior.

Thus the subjects successively rated the pleasure/displeasure evoked by the description of themselves in various situations (Questionnaire 2.a), then decided what they would actually do (Questionnaire 2.b), then they chose which action was most ethical (Questionnaire 2.c).

Data processing and statistics

Each subject's responses to the three questionnaires were compared to one another. We searched for the number of times the decision made on Questionnaire 2.a would coincide with the highest hedonic rating (most pleasure or least displeasure). Then the coincidence with the lowest hedonic rating (least pleasure or most displeasure) was sought. Since each situation on Questionnaire 2.a had 4 possible answers, the total number of coincidences occurring by chance should be 12.5. Thus, the overall probabil-

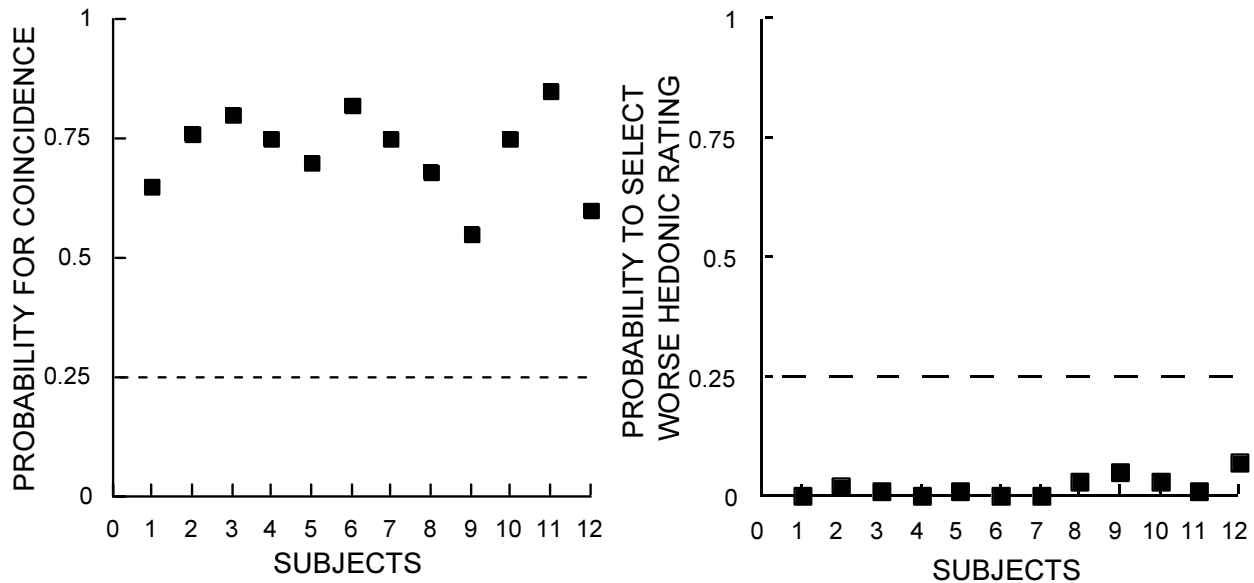


Figure 2

Experiment 2. **LEFT:** Actual probability that the coincidence between highest hedonic rating of an item of Questionnaire 2.a would coincide with the behavioral choice made in Questionnaire 2.b. Numbers in abscissae refer to the 12 subjects. The dashed line indicates random chance for coincidence. **RIGHT:** The probability that a behavior chosen from questionnaire 2.b would coincide with the worst hedonic rating in Questionnaire 2.a. The dashed line indicates random chance for coincidence.

ity of such a coincidence for the whole questionnaire would be 25%

As there was no difference between men and women regarding the behaviors selected or the duration of the tests, the results were pooled for the twelve subjects. The probability numbers obtained on each subject were simply averaged for the whole group of subjects, and compared to chance probability of obtaining the same results. Student's *t* tests were used to compare actual results with chance results. Tied ratings on a given situation were taken in consideration to estimate the actual probabilities.

Results

The mean duration of the sessions was 59.6 ± 2.1 min. Fig. 2-left, compares the responses to Questionnaires 2.a and 2.b. The 12 subjects are on the abscissa. The ordinates show the probability that the behavior selected would coincide with the highest hedonic rating (either the highest positive rating, pleasure, or the lowest negative rating, displeasure) experienced when reading the item. It can be seen that the subjects' behavior coincided with maximal pleasure (or minimal displeasure) in a very significant way. The dotted line indicates chance behavior (there were 4 possible items with each situation, hence 25% chance that the behavior selected would coincide with the

highest rating of pleasure). The difference between actual coincidence and chance coincidence was highly significant (Student's *t* test = 16.56, df 22, *P* < 0.001).

Figure 2-right, gives complementary information by comparing the worst ratings of items 1 to 200 of Questionnaire 2.a, to the chosen items in Questionnaire 2.b. It can be seen that the subjects did not chose the behaviors that had been rated as most unpleasant. On the average they selected 0.96 ± 0.32 items that had been rated the worst out of the four possible items on a given situation, i.e. less than 2%, although the random chance of such a coincidence would be 0.25.

Figure 3 compares the responses of subjects 1 to 12 to Questionnaires 2.a, and 2.b. The number of times a subject had selected a clearly unethical behavior in Questionnaire 2.a appears as a digit above each dot. This was known from the responses given by the subjects themselves to Questionnaire 2.c. The ordinates of Figure 4 show the probability that behavioral choices would coincide with the highest ratings of pleasure. The dotted line indicates random chance. It can be seen that subjects 2 and 6 did not select any unethical behavior and that the responses of subject 4 coincided only once out of four unethical responses. However, all other subjects chose sever-

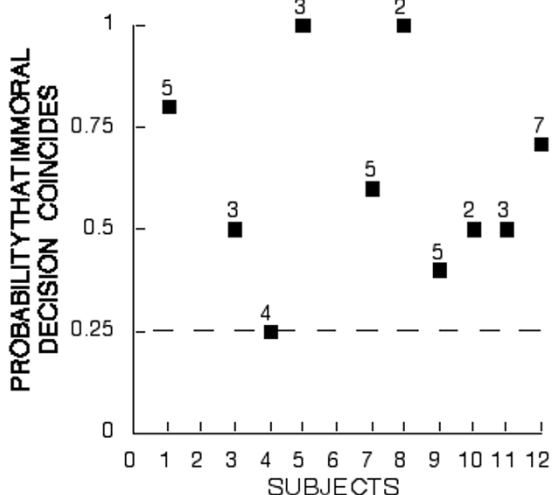


Figure 3
 Experiment 2. Actual probability that the immoral choices made in Questionnaire 2.c, would coincide with the highest hedonic rating for this item in Questionnaire 2.b. Numbers on abscissa refer to the 12 subjects. The dashed line indicates random chance for coincidence. On top of each dot the number of clearly unethical decisions made by the given subject. There are only 10 dots because two subjects (subjects 2 and 6) did not select any unethical behavior.

al unethical behaviors, and the probability of coincidence with maximal pleasure was well above the line of random chance (25%). The difference between actual coincidence and random coincidence was highly significant (Student's *t* test = 5.07, *df* 18, *P* < 0.001).

The worst ratings of the items in Questionnaire 2.a were also compared to the assessments of the most ethical behavior given by the subjects with Questionnaire 2.c. Comparing the results to both questionnaires showed that, out of the 20 situations selected for Questionnaire 2.c, 1.33 ± 0.33 (i.e., almost 7%) were considered by the subjects as both the most ethical and the most unpleasant or the least pleasant.

Discussion

Experiment 2 recorded the pleasure/displeasure experience of subjects who read statements describing themselves in situations of their daily life. The subjects then indicated which items they would choose when the 4 possible behaviors were offered simultaneously, and this behavioral choice was compared to their hedonic responses. Subjects chose the items which corresponded to the scores

describing the highest hedonic experience for this entry (Fig. 2). The subjects also avoided the items which corresponded to their lowest hedonic scores for this entry (Fig. 3). Such results are a prerequisite for the working hypothesis to be true. However, these results do not permit us to give a firm answer to our initial question: do subjects predominantly follow the direction given by their hedonic responses in their choices, i.e. does the correlation between hedonic experience and decision indicate causality? Because the pleasure of choosing a behavior might simply reflect a rational acceptance of social moral rules, the correlation higher than random chance reported above between chosen behavior and pleasure, may simply indicate that pleasure occurred *after* the most ethical answers had been selected by the subjects.

In this regard the answers to Questionnaire 2.c provided clear information. Although the number of unethical behaviors (as assessed from Questionnaire 2.c) chosen in Questionnaire 2.b was never very high, these behaviors selected were still highly correlated with their higher hedonic ratings (Fig. 4). The percentage of unethical choices corresponding to the highest hedonic rating was well above random chance level. Thus, our subjects seemed to rely upon their pleasure/displeasure response to choose a behavior.

Yet, the subjects' behavior does not completely exclude compliance to social rules from behavioral choices, even in the situation involving unethical answers. The subjects might still be basing their choices partly on ethical considerations. For instance, a rule recognized ethical by the subject might be considered more as a social convention than a deeply personal moral conviction. The fact that the most ethical behaviors received in Questionnaire 2.a the worst hedonic ratings in 7% of the cases would indicate that an individual's ethics does not necessarily coincide with social ethics. The facts that the subjects chose 3.91 unethical responses out of 20 (i.e. about 20%) and that 64% of these unethical responses corresponded to the highest hedonic rating within their entry would support the hypothesis that hedonic experience may have priority over ethics and that decisions are made by maximizing pleasure. This result provide a first evidence that the link between pleasure and decision making can be direct rather than mediated by a link between between ethics on the one hand, and both decision making and pleasure on the other hand. One may assume that compliance to one's own ethics provides more pleasure than compliance to social ethics.

Finally, Cabanac [20–22], showed that behaviors involving some sensory displeasure could be selected by subjects when the outcome was yoked to a larger sensory pleasure in another sensory modality, and theorized that the final decision was reached according to the algebraic sum of the

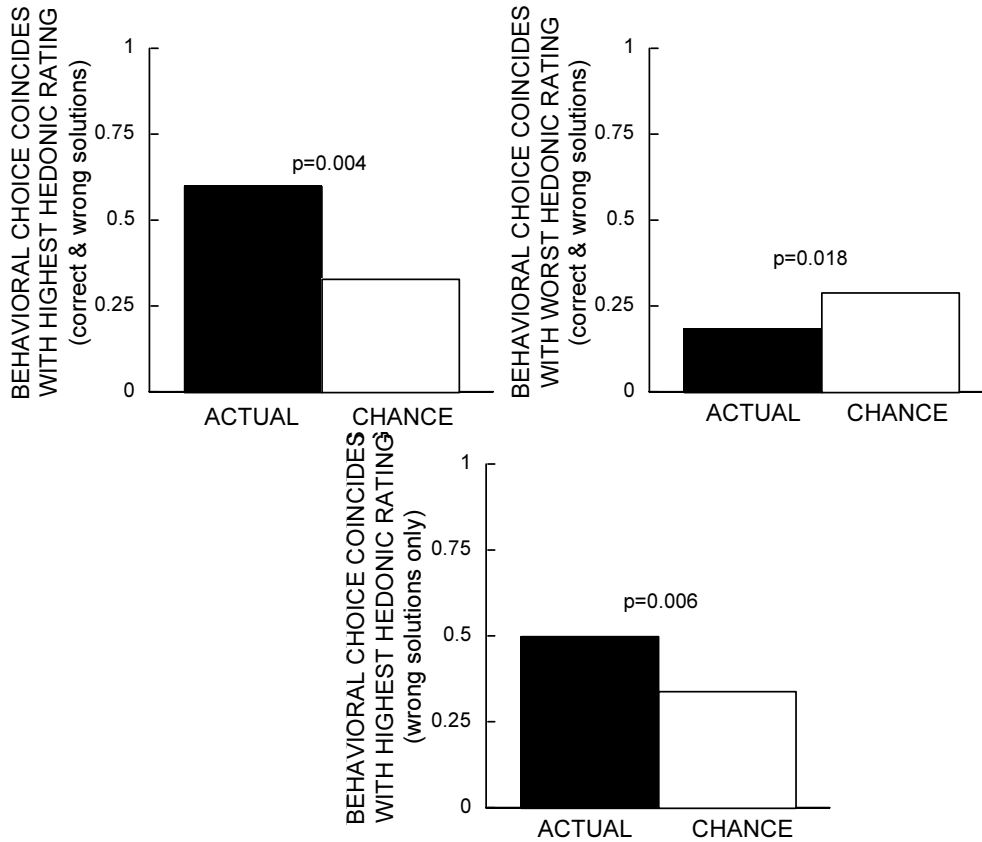


Figure 4

Experiment 3. **TOP LEFT:** Group median of behavioral choices from the 50 items in Questionnaire 3.b coinciding with the *highest* hedonic rating to one of the four mathematical items proposing a different solution in Questionnaire 3.a. This figure pools the right and wrong choices. The chance behavior is higher than 0.25 because the tied ratings, which increased the probability for coincidence, are taken into account. Wilcoxon matched pairs sign rank test = 5, P = 0.004. **TOP RIGHT:** Group median of behavioral choices from the 50 items in Questionnaire 3.b coinciding with the *lowest highest* hedonic rating to one of the four mathematical items proposing a different solution in Questionnaire 3.a. This figure pools the right and wrong choices. The chance behavior is higher than 0.25 because the tied ratings, which increased the probability for coincidence, are taken into account. Wilcoxon matched pairs sign rank test = 5, P = 0.018. Experiment 3. Proportion of coincidence of highest hedonic rating in Questionnaire 3.a with behavioral choice of wrong solutions in Questionnaire 3.b, plotted against the number of correct choices, i.e. mathematical proficiency. Each dot is the result obtained for a given subject. For the group: $Y = 0.011 X + 0.21$, $F=5.9$, $r = 0.61$, $P = 0.035$.

common currency, pleasure plus displeasure [5]. It may be suspected that, when subjects selected clearly unethical options in the present experiment, they also experienced some degree of guilt. If they selected the unethical behavior it was because the pleasure of it was larger than the displeasure of guilt. Because the hedonic experience is the common currency for decision making, whatever their experience, their hedonic ratings represented the algebraic sum of pleasure and of displeasure. However, in order to eliminate completely any motivation implying a behavioral outcome Experiment 3 was devised with mathematical problems, i.e. a purely mental mechanism.

Experiment 3

To test the hypothesis that purely mental processes might operate under the same mechanism as other decision making processes, simple mathematical problems were used in this experiment.

Questionnaires 3.a and 3.b

During the experimental session the subject received two questionnaires, the first at the outset of the session, the second after completing the first one. Questionnaire 3.a contained 200 items containing 50 short mathematical problems followed by their solutions in four different forms (A, B, C, and D), i.e. 50 problems \times 4 solutions = 200 items. Only one of the four A, B, C, and D solutions of each problem was true (e.g. B). The categories A, B, C, and D were arranged so that each category contained the same number of true responses. Annex 3 (left) gives examples, in various fields of mathematics, of the problems presented under the items A, B, C, and D. The degree of difficulty of the problems was below the average competency of a fifth year secondary student. The four items A, B, C, and D of a given problem followed by its solution were separated by forty nine other items. Questionnaire I began with the A variation of question and solution N° 1 and ended with the D variation of question N° 50.

Subjects were then instructed to give a magnitude estimation rating of the amount of pleasure or displeasure they experienced when reading the problem followed by its solution. No special instruction was given on the rating, except that the rating should describe the pleasure evoked by the logic of the item not by its nature. N.B.: subjects might have rated 'pleasure' of reading an item on the basis of nature as well as logic (e.g. if they preferred geometry to arithmetic, or to algebra); however, this should make no difference on the overall conclusion since each item was judged against itself in its A, B, C, and D variations. The instructions given to the subjects about ratings were understood by the subjects who apparently had no difficulty rating overall pleasure/displeasure aroused by mathematical problems since none asked for more information about the methods.

When Questionnaire 3.a was completed, it was withdrawn from the subject who then received Questionnaire 3.b. In this second part subjects received the same questions, this time in the form of a multiple choice mathematics test with 50 entries. Each entry contained the four A, B, C, and D proposed solutions to the given problem (example in Annex, right). Among these four A, B, C, and D alternative items in each entry, they were asked to choose the one that they thought to be correct. The subject was not allowed to write and was limited to mental calculation. As each subject was his/her own control, no attention was paid to the time of the sessions which were held throughout the day. Half of the subjects received Questionnaire 3.a in a given order and Questionnaire 3.b with the same 50 problems listed from 1 to 50. The other subjects received both Questionnaires with the items presented in reverse order.

I. General Results of Experiment 3

Presentation of the different scores

1) The number of mathematically correct answers to the 50 problems of Questionnaire 3.b were counted. This number gave a score of the mathematical proficiency of each subject. This score was compared to the mean value of the 200 hedonic ratings given by the subject in Questionnaire 3.a, as a systematic checking of inter-individual variability. This score was also compared to the mean range of the subjects' hedonic ratings (i.e. the mean difference between the highest and the lowest rating within each of the 200 entries). These comparisons were carried out to check whether the mathematical proficiency of the subjects would correlate with the scale the subjects used to describe their pleasure/displeasure evoked by the items, or with the difference between their maximal and minimal rating within the same entry. The correlations were calculated across the twelve subjects. There was no significant difference between the mean performance of women and men (men 29.17 ± 3.0 correct answers; women 26.8 ± 2.9 correct answers; Student's *t* test 0.56, *P* = 0.589). For these reasons all results were pooled.

2) The hedonic ratings of Questionnaire 3.a given to each of the A, B, C, and D items within each of the 50 problems were compared to the actual choice among A, B, C, and D items made by the subject on Questionnaire 3.b. That permitted us to see whether the hedonic responses of the subject, evoked by the different versions to each problem in Questionnaire 3.a, corresponded to the actual behavioral choice made by the subject in Questionnaire 3.b.

Dynamic assessment of pleasure/displeasure during the task

The mean duration of Questionnaire 3.a was 68 ± 6 min. Analysis of the results showed that the ratings degraded with the number of items read from Questionnaire III, irrelevant of whether the subjects read them in order 'a'

(from 1 to 200), or in order 'b' (from 200 to 1). The mean ratings \pm s.e. of items 11 to 20, pooling items a and b, was 1.7 ± 0.98 ; the mean ratings of items 181 to 190, pooling items a and b, was significantly lower -2.15 ± 1.13 (Student's paired t 2.47, $P = 0.031$). Therefore, the ratings degraded with time irrelevant of the nature of the items presented since the items were the same for all subjects, just the order of items changed).

The subjects took an average of 30 ± 4 min to complete Questionnaire 3.b.

Mathematical proficiency

The number of correct choices in Questionnaire 3.b indicated the mathematical proficiency of our subjects. The minimal score should not be lower than 25%, i.e. 12.5 out of 50 problems with 4 solutions each, since there was only 1 correct answer out of 4 possible choices to be made in each of the 50 problems. The number of correct answers given by our subjects fell between 15/50 and 38/50, i.e. well above chance level (group mean result, 28 ± 2 , Student's $t = 7.6$, $P < 0.001$), but the broad range between scores, 15 to 38 reflects broad differences in subjects' mathematical proficiency. The subjects' mathematical proficiency did not correlate significantly with either duration to complete Questionnaire 3.a ($F = 0.37$, N.S.), or the amplitude of hedonic ratings ($F = 0.34$, N.S.), or with mean ($F = 3.1$, N.S.), maximal ($F = 0.70$, N.S.), and minimal ($F = 0.1$, N.S.) ratings.

II. Specific Comparisons relative to Hedonic Ratings and Solution's Choice

Behavioral Choice

Table 2 gives the matching of the 12 subjects' behavioral decisions for all 50 problems of Questionnaire 3.b, with their maximal hedonic ratings obtained from Questionnaire 3.a. The presence of tied ratings to the various answers (in Questionnaire 3.a) to given problems led us to calculate the actual probability of coincidence of behavioral decision with highest hedonic rating, for each problem and each subject. Table 2 presents also these chance behaviors taking into account these tied votes; chance behaviors were always higher than 25%, i.e. 0.25 because of the tied votes. Such a table should test the working hypothesis. Figure 4 (top left) presents the median of Table 2 results for the 12 subjects. The coincidence of the subjects' actual decisions with their highest hedonic experience was significantly higher than chance for coincidence (Wilcoxon matched pairs sign rank test = 5, $P = 0.004$).

As a complement of the above result, Table 3 and Figure 4 (top right) test the worst outcome of the working hypothesis: the matching of behavioral choice in Questionnaire 3.b with the *worst rated* items. Figure 4 (top right) shows both actual and chance behavioral choice of items: the group median of the actual behavior was significantly lower than chance (Wilcoxon matched pairs sign rank test = 11, $P = 0.014$).

Table 2: Comparison of actual number of coinciding maximal hedonic rating of an item in Questionnaire V, with behavioral decision in Questionnaire VI of Experiment 3. The 'Chance coincidence numbers are higher than the 0.25 one would expect, because they were obtained taking into account the tied votes.

Subject	1	2	3	4	5	6	7	8	9	10	11	12
Actual coincidence	0.74	0.47	0.48	0.64	0.78	0.56	0.54	0.41	0.68	0.63	0.39	0.82
Chance coincidence	0.26	0.33	0.38	0.32	0.30	0.28	0.42	0.33	0.33	0.32	0.54	0.28

Wilcoxon matched pairs sign rank sign test = 5, $P = 0.004$

Table 3: Comparison of actual number of coinciding worst hedonic rating of items in uestionnaire 3.a, with actual behavioral decisions in Questionnaire 3.b of Experiment 3. The 'Chance coincidence numbers are higher than the 0.25 one would expect, because they were obtained taking into account the tied votes.

Subject	1	2	3	4	5	6	7	8	9	10	11	12
Actual coincidence	0.61	0.50	0.42	0.54	0.58	0.43	0.50	0.30	0.60	0.46	0.36	0.75
Chance coincidence	0.26	0.32	0.38	0.38	0.34	0.25	0.5	0.32	0.35	0.34	0.50	0.31

Wilcoxon matched pairs sign rank test = 11, $P = 0.014$

Table 4: Comparison of actual number of coinciding maximal hedonic rating of items in Questionnaire 3.a, with choosing the wrong answers in Questionnaire 3.b. The 'Chance coincidence numbers are higher than the 0.25 one would expect, because they were obtained taking into account the tied votes.

Subject	1	2	3	4	5	6	7	8	9	10	11	12
Actual coincidence	0.61	0.50	0.42	0.54	0.58	0.43	0.50	0.30	0.60	0.46	0.36	0.75
Chance coincidence	0.26	0.32	0.38	0.38	0.34	0.25	0.5	0.32	0.35	0.34	0.50	0.31

Wilcoxon matched pairs sign rank test = 5, P = 0.006

Choice of wrong solutions

Among the 50 problems of Questionnaire 3.b, subjects sometimes chose wrong mathematical solutions. Of course, the number of incorrect responses decreased with increasing proficiency in mathematics. These incorrect responses provided important information because they were a better test of the working hypothesis, since they were not based on a rational knowledge of mathematics. Table 4 presents the number of incorrect choices corresponding to the highest hedonic ratings within their entry (from Questionnaire 3.a) and the total chance to reach the highest hedonic rating for each subject. Since not all subjects chose the same total number of incorrect responses, and since there were tied ratings, this result is expressed as a ratio to allow between-subjects comparison. Figure 4 (bottom) shows both actual, and chance behavioral choice. There was a significant difference between the median of actual decisions and that of chance that the subjects' actual decisions would coincide with the highest hedonic ratings (Wilcoxon matched pairs sign rank test = 5, P = 0.006).

Figure 5 shows that the number of coincidence of maximal hedonic ratings with wrong solutions increased with mathematical proficiency ($y = 0.011x + 0.21$, $F = 5.9$, $r = 0.61$, $p = 0.035$).

Discussion

This present study recorded the hedonic experience of subjects who read simple mathematical statements mentally, problem and solution, without the help of paper/pencil or pocket calculator. All efforts were made to minimize the emotional stress which has been shown to impair the mathematical performance [15].

Then, the subjects had to choose which items were correct and this behavioral choice of correct answers was compared to their own hedonic responses. Subjects chose items which corresponded to their highest hedonic scores for this entry (Fig. 4, Table 2). Such a result is a prerequisite for the working hypothesis to be true. The same conclusion may be reached from the behavior regarding the

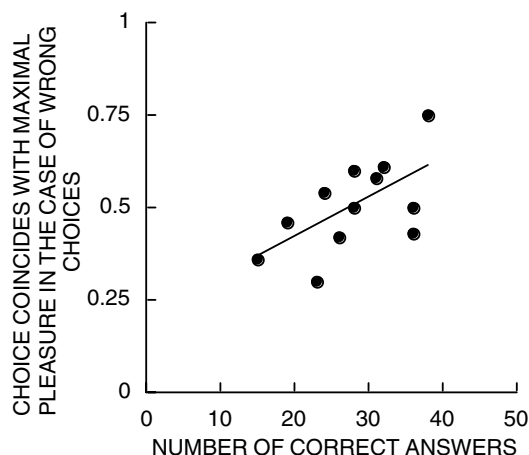


Figure 5
Experiment 3. Proportion of coincidence of highest hedonic rating in Questionnaire 3.a with behavioral choice of wrong solutions in Questionnaire 3.b, plotted against the number of correct choices, i.e. mathematical proficiency. Each dot is the result obtained for a given subject. For the group: $Y = 0.011X + 0.21$, $F = 5.9$, $r = 0.61$, $p = 0.035$.

worst rated items: Table 3 and Figure 6 show that the subjects tended to avoid choosing the items that arose the least pleasure or the maximal displeasure.

Although, these results are a pre-requisite for our initial question ('do subjects predominantly follow the direction given by their hedonic responses in their choices?') to be true, they do not permit us to give a firm answer to it, because the correlation between hedonic experience and decision does not necessarily indicate causality. Pleasure might simply reflect a rational knowledge of Mathematics, the correlation higher than chance reported above between correct choice and pleasure, and that lower than chance between displeasure and wrong choice, may sim-

ply indicate that pleasure/displeasure occurred after the known correct answers had been selected by the subjects.

Pleasure may occur after a behavior, or may serve as a clue occurring before the behavior. Pleasure occurring after a response would be a reward. If this was the case in our subjects, then we would not be allowed to assign a function to pleasure, other than a reward allowing the law of effect to take place. Thus, the process of decision-making could have been exclusively rational, i.e. according to an algorithmic process.

In this regard the incorrect answers (from Questionnaire 3.b) provided clearer information. The percentage of incorrect choices corresponding to the highest hedonic rating was well above chance level. Although the number of mistakes in choosing answers in Questionnaire 3.b decreased, by definition, with increasing proficiency in Mathematics, the percentage of our subjects' reliance on their hedonic judgement did not change with their proficiency in Mathematics; on the contrary good mathematicians (i.e. those who picked up more correct answers) tended to rely more on their hedonic experience (Fig. 5). Our subjects, even those subjects who were 'good' in mathematics, seemed to rely upon their hedonic response to indicate their choice of item. The subjects' behavior does not completely exclude rationality from behavioral choices, even in the situation involving incorrect answers. The subjects might still be basing their choices partly on rational considerations. For instance, perhaps of the four choices, two might have been clearly recognized as wrong, and the correct answer was misinterpreted because of incomplete knowledge of Mathematics. In this scenario, it would be clearly incorrect to maintain that the "only" criterion for choice was the pleasure experienced in reading the chosen answer. However, incorrect responses corresponding to the highest hedonic rating within their entry would support the hypothesis that hedonic experience has priority over rationality and that decisions are made by maximizing pleasure.

In these cases pleasure alone motivated the subject to choose the response. This was true even though fatigue tended to lower the hedonic ratings; indeed, this influence did not suppress the gradients of hedonicity aroused by the various A, B, C, and D possible solutions to each of the 50 problems. Furthermore, as shown in Fig. 5, the coincidence of choice of *incorrect* answers with highest hedonic rating increased with mathematical proficiency. Therefore, rationality as the key factor in the decision making process is likely to be excluded. The large individual differences in fraction skills reported by Hecht [23] were conceptual rather than procedural. Hedonic experience is more likely to be involved in a conceptual than in a pro-

cedural mechanism, because the former is more global and the latter more mechanistic.

The above conclusion would support previous results showing that animals [24,25] and humans [26] readily develop strong preferences for objects that have become familiar through repeated exposure. Such an exposure effect [27] can take place even when the exposures are so degraded that recognition is precluded [28]. Such a mechanism might have taken place in our subjects' decisions to pick up the A, B, C, or D answer of a given item when they were not sure of the right solution. If this was the case, such a mechanism would confirm that the decision took place in the hedonic dimension of our subjects' consciousness rather than as a rational process.

General discussion

The fact that behavior is a final common pathway entails that the brain needs a common currency to compare all motivations in order to rank priorities [3,4]. Thus we can assume that pleasure is the universal common currency, as already observed in the cases of several dissimilar motivations such as thermal comfort, pain, fatigue, hunger, money [5], pleasure of playing a video game [22], and grammatical choice [6].

It may be suspected that apparently paradoxical behaviors, such as impulsive behavior [29], maladaptive behaviors [30], absurd risk taking [7,31], reversal of decisions [16], irrational (in the economist's acceptance of the word) behavior [32], non-consequential decisions reviewed by Baron (1) and studied here in Experiment 1, and the unethical choices made in Experiment 2, would enter into the model if all the variables were under control. It would be of interest to explore these paradoxical behaviors in the light of the present hypothesis. Tversky and Kahneman [33] described choice as a maximization process but reached the conclusion that the logic of choice does not provide an adequate basis for a descriptive theory of decision making. It may be suggested, therefore, that what is maximized is pleasure. Such a suggestion moves deliberately from the point of view of behavior or of the quantification of external reward, i.e. to expected pleasure, to that of actual mental experience. Finally, although they were clearly instructed to rate the "pleasure they experience", the subjects might have rated the pleasure they would expect from the decision described in the questionnaires. If this were the case the causality would run in the opposite direction as that which is proposed in the present work. However, such a hypothesis may likely be rejected because in other experiments where no moral outcome nor behavioral action was expected (video game, grammar, mathematics) the subjects behaved in a way similar to that of ethical decisions, although in these ex-

periments no *expected* pleasure could have taken place in their minds [6,34].

"Pleasure has a central role in human life" [35]. The results of the present experiments allow a tentative generalization on the role of pleasure in the process of decision-making. The optimization of behavior (from a physiological point of view) was demonstrated previously to be based on the maximization of sensory pleasure [5]. Prince and Smolensky [36] recently proposed that grammar corresponds to some optimal function of the nervous system. As well, in decisions involving grammar in a second-language test, ratings of experienced pleasure indicated the decision, right or wrong, the subjects would eventually make [6]. Such an optimization of mental functioning was also suggested by studies of pleasure experienced during the reading of poems, and the playing of video game [34]. In these experiments where subjects were asked to assess their comprehension of poems and, independently, to record their pleasure/displeasure reactions to the same poems, pleasure was found to be a good indicator of comprehension. In a video-game of golf, a purely mental exercise, higher performance coincided with more positive hedonic responses. Thus, pleasure was correlated with efficient mental functioning. These series of results, as well as the present ones, would support the hypothesis that decision making is not, or is not totally, a rational process tending to maximize *expected* pleasure as emerges from the recent literature, but rather is a non-rational process tending to maximize *experienced* pleasure. Recent reviews on judgement and decision making have underlined the limits of rationality in decision making.

The influence of pleasure/displeasure on the decision-making process was already proposed for humans [7,18], and for animals [37,38], because a decision is pleasant as such when it permits to escape unpleasant conflicts of motivations [39]. Kahneman and Tversky attempted to describe choices in terms of numerical functions-utility and weights over probabilities. They called these "prospect theory" and "cumulative prospect theory" [40,41]. Thaler and Johnson [42] called "hedonic editing" the fact that subjects deliberately put their options in the best possible frame. Khrennikov [43] proposed a mathematical model "which is not based on the rule of reason". Fantino [44] theorized that humans "are practical information processors who select good or useful news but avoid bad news." More to the point of our present conclusion, Roth and Erev proposed that decisions are made on a low rationality process, essentially from a maximized reinforcement [45,46]. Of course we do not suggest that rationality plays no role in mathematics or in ethics. However the present results suggest that hedonicity is also involved. Yates et al. recently showed that when subjects could rationalize their decisions, cultural differences took place in

their decisions (between Japanese subjects on the one hand, and both Chinese and American subjects on the other hand); however these cultural differences disappeared completely when subjects had to guess a solution [47]. This would suggest that two processes can take place in decision making, a rational one when the subject is equipped with the necessary information and cultural background, and hedonic when the subject cannot rationalize. This hedonic mechanism being more archaic, for obvious reasons provided by physiology and zoology [5,47], would be common to all humans and would take place when rationality does not provide a solution.

Mellers et al. recognized that frameworks alternative to rationality must be proposed: "These frameworks view decisions as more reasonable and adaptive than previously thought. For example, "rule following," which occurs when a rule or norm is applied to a situation, often minimizes effort and provides satisfying solutions that are "good enough," though not necessarily the best. When rules are ambiguous, people look for reasons to guide their decisions. They may also let their emotions take charge" [48]. In the same line of reasoning, it was recently suggested that emotions, i.e. a process related to the hedonic sphere, are the clue leading to efficacious decision making [49,50]. Furthermore, in neurological patients with damage to ventromedial prefrontal cortices, it has been shown that the absence of emotion/feeling can produce very detrimental effects on decision-making [51,52]. Moreover, it has been shown that the influences of emotion/feeling on decision-making can actually precede conscious rational cognitive processes [53]. The study of mental experience may be a way to solve all the apparent contradictions to rationality pointed out by the various authors above. Kahneman and Tversky [54] have shown that an option may depend on a negative consequence experienced as a cost, i.e., expected displeasure. They proposed the term 'experience value', to distinguish the hedonic dimension of motivation from the more algorithmic 'decision value'. Roth and Erev proposed also that decisions are made on a low rationality process, essentially from a maximized reinforcement [45,46]. Linville [55] suggested that affectivity enters into play in a somewhat additive process in a way similar to that occurring between various conflicting motivations, both physiological and psychological ones as proposed by Cabanac [5,21,22].

The neural substrate of pleasure is still little known. Neurophysiological evidence though, pointing to the existence of a common currency in rats between palatable taste and intracranial electrical reward, was recently reported [56]. The influence of pleasure/displeasure on decision making is therefore likely to be a phylogenetically inherited mechanism.

Conclusions

In conclusion, our present results show that the pleasure experienced when reading the written description of a given behavior or of the solution of a mathematical problem was correlated with the subjects' eventual decision regarding this item. They suggest that the pleasure/displeasure experienced indicates the right solution at the time of a choice in ethical tests or other decisions and provides the clues for decisions whether the appropriate rules for a correct choice are known or not. The coincidence of choices of behaviors recognized as unethical by the subjects, and of wrong mathematical solutions with highest hedonic experience, is especially eloquent from this point of view. The present results support the hypothesis that maximization of experienced pleasure (i.e. experience value), and its counterpart minimization of displeasure, occurs in the process of decision making. The results are consistent with the claim that non-rational processes contribute to decision making, but the results do not support any claim stronger than that. We do not know the nature of these non-rational processes. They could be hedonic or they could be more general. They could be informational or they could be motivational. Neuroscientific studies by Damasio, Bechara and colleagues, have addressed the physiological basis of these processes [51–53]. These studies have provided compelling evidence for the role of visceral/somatic states, or brain representations of these body states, in biasing decisions in a way that is advantageous to the organism. This is quite consistent and supported by the evidence presented here that pleasures and hedonics play an influential role in decision-making.

Of course, when all the needed information is provided to subjects rationality and hedonicity tend to coincide [57]. It follows that the present results do not *prove* the point under test, i.e. they do not satisfy a *necessary and sufficient* condition to reach the conclusion that this is the mechanism allowing decision. However, the fact that they satisfy a *necessary* condition for this conclusion to be true, entails that the hypothesis that the key to decision-making lies in the hedonic dimension of the mental experience [5] must be taken as a serious possibility.

Additional material

Additional File

Examples from the various Questionnaires, of the questions asked in Experiments 1, 2, and 3.

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