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The Discounting of Ambiguous Information in Economic Decision Making

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ABSTRACT

In three experimental studies we investigated how decision makers respond to ambiguous information about costs and benefits. In Experiment 1, we studied the effect of ambiguity about prior costs. Experiments 2 and 3 focused on the effect of ambiguity about future outcomes. The collective results of the three studies suggest that decision makers discount ambiguous information. The findings are related to insights on the disjunction effect, the sunk cost effect, transaction decoupling, and ambiguity aversion. Copyright © 2003 John Wiley & Sons, Ltd.

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Economic decisions, such as investment or consumption decisions, are usually based on information about (expected) costs and benefits. Decision makers typically balance the information they have about these costs and benefits and make their decisions on the basis of this information. Hence, cost and benefit information is vital in economic decision making. What does this information look like? Cost and benefit information may be precisely defined and certain, but quite often, the information will be characterized by some degree of ambiguity. For example, when a manager has to decide whether or not to invest in the development of a new product, the exact size of the expected returns on the investment is hardly ever known. In a similar vein, when deciding on whether or not to continue a current research and development project, decision makers may not have an accurate picture of all the prior, current, and future investments in that project. In this article, we investigate to what extent economic decisions are affected by such cost and benefit ambiguity.

Ambiguity is omnipresent. As Kuhn (1997, p. 55) rightfully noted, many decisions 'are characterized by uncertain or vague knowledge about the probabilities of events.' How do decision makers deal with such ambiguity? One typical reaction that has been well documented in the decision-making literature is that people *avoid* situations involving ambiguity. That is, research on risky decision making has demonstrated that people avoid taking risks with ambiguous probabilities. For example, Ellsberg (1961) introduced a very simple and elegant paradigm in which participants are presented a situation involving two urns, one containing

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50 red balls and 50 black balls, and the second containing red and black balls in an unknown proportion. Participants can bet on a blind draw from one of these urns, and win a certain amount of money if they correctly predict the color of the ball. Results generally indicate that people prefer to bet on the urn containing the 50 red and 50 black balls (see also Curley, Yates, & Abrams, 1986; Camerer & Weber, 1992; Fox & Weber, 2002; Keren & Gerritsen, 1999). This phenomenon is generally referred to as 'ambiguity avoidance' (for a recent review, see Keren & Gerritsen, 1999).

These insights indicate that decision makers are motivated to choose in such a way that they avoid ambiguous situations. It is of importance to note, however, that many decisions are not characterized by a choice between an ambiguous and a non-ambiguous gamble. Often, we are simply confronted with ambiguous information, without being able to avoid this ambiguity by choosing a non-ambiguous option. In these situations, in which the behavioral repertoire does not include a possible escape from ambiguity, the question becomes how we deal with ambiguous information. Will ambiguous information strongly affect our decisions? Or will ambiguous information be discounted and thus have little effect on our decisions?

In order to answer these questions, one has to consider the psychology of ambiguity. What is ambiguity, and how is it experienced? Although formally ambiguity has to do with uncertainty about the distribution of probabilities (Bernasconi & Loomes, 1992) Frisch and Baron (1988, p. 152) define ambiguity as 'the subjective experience of missing information relevant to a prediction.' This interpretation of ambiguity suggests that decision makers may treat ambiguous, inexact, incomplete, or vague information as insufficient information; information will be discounted. An interesting implication of this could be that as a result of the discounting of ambiguous information, the decisions of people confronted with ambiguous information may resemble those of others who have no information at all. We will test this inference in a series of three experiments. However, before turning to our experiments we will discuss two hitherto separate streams of research that provide some preliminary support for our prediction that people discount ambiguous information. These research streams concern Shafir's work on the 'disjunction effect' (Shafir, 1994; Shafir & Tversky, 1992; Tversky & Shafir, 1992) and Soman and Gourville's work on 'transaction decoupling' (Soman & Gourville, 2001; Gourville & Soman, 1998).

The disjunction effect, and its relevance to the current research on how people deal with ambiguous information, can best be illustrated by discussing an example taken from Tversky and Shafir (1992). In a scenario study, participants had to imagine that they had taken an exam. Next, they had to either imagine that they failed the exam, or that they passed the exam, or that they did not know whether they had passed or failed the exam. The main dependent variable was the willingness to purchase a vacation to Hawaii. The results showed that both participants who had learned that they passed the test and participants who had learned that they failed the test were willing to purchase the vacation. Interestingly, those who were ignorant about their test result were unwilling to purchase the vacation. It appears that these participants discounted the ambiguous information when making their decision. After all, should the participants have taken the consequences into account, they would have purchased the vacation. They would buy the vacation if they failed, also if they passed the exam, so it would be plausible to also purchase the vacation when being ignorant about the test outcome.

The research on the disjunction effect thus suggests that people discount ambiguous information. Clearly, this phenomenon is different from the discussed reluctance to participate in ambiguous gambles. The issue here is not that people avoid being in a situation that is characterized by ambiguity. The issue is that decision makers are not so likely to base their decisions on ambiguous information.

Let us now turn to the research on transaction decoupling, which provides additional support for the idea that people discount ambiguous information. Soman and Gourville (2001) examined the effect of price bundling on consumption behavior. Price bundling refers to the practice of combining multiple products or multiple units of the same product for one bundled price. A season ticket for the theater, for example, can be viewed as an example of price bundling in which consumers purchase a series of tickets for one single (bundled) price. In their article, Soman and Gourville argued that price bundling may lead to a disassociation

or 'transaction decoupling' (cf. Prelec & Loewenstein, 1998) of costs and subsequent consumption. To illustrate the effect of price bundling on subsequent consumption, Soman and Gourville used a scenario in which participants had to imagine that they purchased lodging and lift tickets for a four-day ski vacation. These costs were either presented as a bundled transaction or as an unbundled transaction by either informing the participants that they had purchased a single four-day ski pass of $160, or by informing them they had purchased four one-day ski tickets of $40 each. After this, they were informed that the weather conditions were poor on the last day of the vacation, due to warm rain hitting the area. The main interest was in whether participants would or would not decide to ski on this last day of their vacation.

The results of this scenario study indicated that participants were more willing to ski (i.e. to consume) after having purchased four single $40 tickets than after having purchased the bundled four-day $160 ski pass. In more theoretical terms, the explanation was that price bundling reduced people's willingness to ski under poor weather conditions because it led to ambiguity with regard to the cost of skiing for one day. As Soman and Gourville (2001, p. 31) put it: 'This ambiguity should result in a dissociation or ''decoupling'' of the cost and the benefit of skiing on the fourth day' (see also Gourville & Soman, 1998; Prelec & Loewenstein, 1998). Although Soman and Gourville did not aim to study ambiguity, and they did not cast their theorizing as such, it is important to note that their reasoning of price bundling effects fits with the notion we put forward here: people discount ambiguous information.

The insights of decoupling and the disjunction effect—although being derived in two distinct research traditions—both support the notion that decision makers are less likely to base their decisions on ambiguous information. At this point it is relevant to note that insights on decoupling and the disjunction effect are not only similar with regard to the possibility that people may discount ambiguous information. They are also similar with regard to the potential explanations of this phenomenon. Both insights suggest that the observed effects of ambiguity are caused by a combination of cognitive and motivational factors. As for the cognitive factor, both lines of research suggest that situations of ambiguity may be more complex. For example, with regard to the effect of price bundling on subsequent consumption, it is assumed that the costs–consumption link in the case of price bundling is weaker. Referring to the ski example, Soman and Gourville (2001, p. 36) stated that in the case of a bundled four-day ski pass it is 'cognitively difficult to allocate the costs of the pass over the four days of skiing.' In a similar vein, theorizing on the disjunction effect acknowledges that people may not base their decision on ambiguous information because thinking through ambiguous situations may be cognitively too complex. It 'tends to blur the picture and makes it harder for people to see through the implications of each outcome' (Tversky & Shafir, 1992, p. 306). In addition to this cognitive explanation, both lines of research also offer a motivational account. Soman and Gourville (2001) suggested that decoupling in a situation of price bundling might occur because people may 'use' the ambiguity to opportunistically decouple the costs from the benefits (i.e. people decouple because they want to have a reason to avoid skiing under poor weather conditions). In their theorizing of the disjunction effect, Shafir and Tversky (1992) suggested that people may also lack the motivation to think through how they would react on ambiguous outcomes because 'it requires people to assume momentarily as true something that may in fact be false' (p. 469). For example, in the vacation example, people might not want to think through what they would do if they would pass the exam, because it might turn out that this assumption would be false, and that they actually failed the test.

From the above, one might conclude that—for a combination of cognitive and motivational reasons—people are likely to discount ambiguous information. In the current article, we wish to further explore the consequences of this discounting of ambiguous information in various domains of economic decision making. In Study 1, we focus on the sunk cost effect. This study deals with the effect of ambiguity of prior costs on subsequent decisions. In Studies 2 and 3, we will expand our analysis by also looking at the effect of ambiguity concerning expectations for future outcomes. The basic hypothesis, however, will be identical for all three studies. That is, we expect that ambiguous information will be discounted.

EXPERIMENT 1

Our study on ambiguity effects in economic decision making starts with an investigation of the effect of ambiguity in the domain of sunk costs. The sunk cost effect refers to the tendency 'to continue an endeavor once an investment in money, effort, or time has been made' (Arkes & Blumer, 1985, p. 124). In more general terms, it refers to people's inclination to let their current decisions be influenced by costs made at an earlier time, even when these prior costs do not affect the objective outcomes of current decisions. The typical context for research on sunk cost effects is that of managerial decision making in which decisions often have far-reaching consequences. To illustrate, the tendency to 'throw good money after bad' appears to have started the recent collapse of the Barings bank in which Nick Leeson took higher risks and invested more and more money in the stock market to make up for prior losses. In a similar vein, the sunk cost effect has been used to explain the construction of nuclear plants (Arkes & Blumer, 1985), the continuation of expensive waterway projects (Arkes & Blumer, 1985), oil and gas exploration (Garland, Sandefur, & Rogers, 1990), and the continuation of research and development (R&D) projects (Arkes & Blumer, 1985; Garland, 1990).

The results of experimental studies and theorizing (e.g. Arkes & Blumer, 1985; Frisch, 1993; Garland, 1990; Garland & Newport, 1991; Garland, Sandefur, & Rogers, 1990; Tan & Yates, 1995; Zeelenberg & van Dijk, 1997) suggest that the driving force behind the sunk cost effect is that people do not like the prospect of having invested in vain. In their seminal article on the sunk cost effect, Arkes and Blumer (1985) explained the sunk cost effect on the basis of Kahneman and Tversky's (1979) prospect theory (see also Garland, 1990; Northcraft & Neale, 1986; Thaler, 1980; Zeelenberg & van Dijk, 1997). More specifically, it is generally assumed that after having made some initial investments, investors may reason that if they would decide not to continue their investments, these investments would be lost. Prospect theory assumes that people are risk-seeking for losses. In keeping with this theorizing, it is reasoned that after having incurred sunk costs, people are prepared to take the risk of further losses that continuation may bring them (Arkes & Blumer, 1985; Thaler, 1980; Zeelenberg & van Dijk, 1997).

How may ambiguity about prior costs affect the magnitude of the sunk cost effect? For example, what if people only know by approximation how much money they have invested, and have to rely on an interval estimate about the size of the sunk costs? Would people still be as susceptible to the sunk cost effect? Based on our current theorizing, we suggest that decision makers will discount ambiguous sunk costs information. In Experiment 1, we investigated the possibility that ambiguity about the size of incurred sunk costs may reduce susceptibility to the sunk cost effect in the sense that it may reduce the tendency to make additional investments. We used a scenario of an R&D setting in which the participants owned an enterprise and had started a new project. In the control condition they had not incurred sunk costs. In addition, we included three conditions in which they had incurred sunk costs. We manipulated the size of the sunk costs. Some of the participants learned that the sunk costs were Fl. 500 000 (i.e. approximately US$ 200 000), some of them learned that the sunk costs were Fl. 1.5 million (i.e. approximately US$ 600 000). To test our ideas on the relation between the sunk cost effect and ambiguity about the sunk costs, we also included a condition in which we gave the participants an interval estimate: participants learned that the costs amounted to Fl. 500 000 or Fl. 1.5 million, or any amount in between.

Similar to scenarios used in previous research on sunk cost effects in R&D settings (Arkes & Blumer, 1985; Garland, 1990; Garland & Conlon, 1998; Garland & Newport, 1991; Tan & Yates, 1995), participants learned that they just found out that another enterprise would launch a product that would probably be superior to their product. The main question was whether participants would decide to continue their plans on the project, or whether they would terminate the project.

In agreement with prior research on the sunk cost effect, we expected that, compared to participants learning they had not incurred sunk costs, the participants learning that they had already invested Fl. 500 000 and the participants learning that they had already invested Fl. 1.5 million would be more willing to continue the project (despite the slim chances of success). As for the size of the sunk costs, we expected willingness to

continue to increase with the size of the incurred sunk costs (cf. Garland, 1990; Garland & Newport, 1991). Thus, we anticipated that participants might be more willing to continue the project when learning that they had already invested Fl. 1 500 000 than when learning they already invested Fl. 500 000.

Finally, and more importantly, we expected that ambiguous information would be discounted. Thus, we predicted that compared to participants learning the sunk costs amounted to Fl. 500 000 and participants learning the sunk costs amounted to Fl. 1.5 million, participants being informed that the size of the sunk costs would fall between Fl. 500 000 and Fl. 1.5 million would be less susceptible to the sunk cost effect. Their decisions should resemble the decisions of participants under the control condition.

Method

Design and participants

The participants, 124 students at Leiden University, participated voluntarily. They were randomly assigned to one of the four conditions: control; low sunk costs; high sunk costs; or ambiguous sunk costs. There were 31 participants in each condition.

Procedure

The participants were presented a written scenario, describing a situation in which they were the president of a small factory. Participants in the *control* condition read:

> As a president of a relatively small factory in the health sector you are developing several new health products. As part of this endeavor, you are preparing to market a new medicine against migraine. You are considering whether or not to go ahead with introduction of the medicine. The costs of such a course of action would be Fl. 1 million. At this moment you learn that one of the world's largest suppliers of health products is also planning to introduce a medicine against migraine. There is an apt possibility that their medicine will outperform yours. Now, what would you decide? Would you continue the development and introduction of the medicine against migraine? Or would you stop the migraine project, and use your funds for development of an alternative product?

In addition to this information, participants in the other conditions learned that the factory had already made investments. In the *low sunk costs* condition, the participants learned that these prior investments amounted to Fl. 500 000. In the *high sunk costs* condition, the prior investments amounted to Fl. 1.5 million. In the *ambiguous sunk costs* condition, the participants learned that the exact size of the sunk costs was at this moment not known. It could be Fl. 500 000, or Fl. 1.5 million, or any amount in between.

After having read the scenario, participants could indicate whether they would continue the development and introduction of the medicine against migraine or whether they would terminate the project.

Results

The results are presented in Table 1. In agreement with our predictions, willingness to continue the project was affected by our manipulations. Both in the control condition and in the ambiguous sunk costs condition,

Table 1. Number of participants continuing and terminating the project, Experiment 1

		Sunk costs		
	Control	Low	High	Ambiguous
Continue	9 (29%)	20 (65%)	22 (71%)	10 (32%)
Terminate	22 (71%)	11 (35%)	9 (29%)	21 (68%)

For the whole table $\chi^2(3, n = 124) = 17.4$; $p < 0.001$.

the majority of the participants decided to terminate the project. In the low sunk costs condition and in the high sunk costs condition, the majority of the participants opted to continue the project. More specifically, the sunk cost effect manifested itself in the finding that, compared to the control condition, willingness to continue the project was higher both in the low sunk costs conditions, $\chi^2(1, n = 62) = 7.8; p < 0.01$ and in the high sunk costs conditions, $\chi^2(1, n = 62) = 10.9; p < 0.001$. Moreover, and in agreement with our predictions, willingness to continue the project was significantly lower in the ambiguous sunk costs condition than in the low sunk costs condition, $\chi^2(1, n = 62) = 6.5; p < 0.05$, and the high sunk costs condition, $\chi^2(1, n = 62) = 9.3; p < 0.01$. The difference between the low sunk cost and the high sunk cost condition was not significant, $\chi^2(1, n = 62) = 0.3$; *n.s.* Willingness to continue the project did not differ significantly between the control condition and the ambiguous sunk costs condition, $\chi^2(1, n = 62) = 0.08$; *n.s.*, suggesting that the ambiguity about the size of the sunk costs prevented participants from falling prey to the sunk cost effect.

Discussion

In agreement with previous research on sunk cost effects, participants were more willing to continue the project after having incurred sunk costs. Willingness to continue was not significantly higher in the high sunk costs condition than in the low sunk costs condition. This, however, may have been the result of the fact that in both cases the sunk costs were relatively large.

More importantly, the results indicated that participants in the ambiguous sunk costs conditions were less susceptible to the sunk cost effect than were participants in the low and high sunk costs conditions. That is, participants strongly favored continuing the project if the sunk costs were Fl. 500 000, and if the sunk costs were Fl. 1.5 million, but after being informed that the size could be any amount between Fl. 500 000 and Fl. 1.5 million, the majority opted to stop the project. It thus seems that ambiguity about sunk costs reduces the tendency to fall prey to the sunk costs effect. The fact that participants in the ambiguous sunk costs condition did not differ from participants who had not incurred sunk cost lends support to the notion that ambiguous information is discounted.

EXPERIMENT 2

Experiment 1 suggests that ambiguity about prior costs may be a blessing for decision makers, because it may reduce their susceptibility to falling prey to the sunk cost effect. Note, however, that the discounting of ambiguous information does not always result in sound decisions. That is, in many economic settings one would expect decision makers to use all of the relevant information, even if it concerns ambiguous information. For example, part of the expenditures on R&D is spent on market research. In the context of R&D, one may conduct market research in order to learn about a new product's market potential. Now, what would happen if the results of that research indicate ambiguity about the market potential for their product? In more general terms, this introduces the question of how decision makers deal with ambiguity concerning *future* outcomes? In order to investigate the effect of this type of ambiguity, we presented participants a scenario in which they had to imagine that they were considering whether or not to continue their plans to set up a new enterprise, and that they had just learned the results of two surveys on the market potential for an enterprise similar to the one they were considering. In order to manipulate ambiguity, we either informed participants that the surveys indicated that the market potential was low (15%), high (35%), or that there was uncertainty about the market potential, with one survey indicating that it would be 15%, the other indicating that it would be 35%.

As for the effect of market potential, we expected participants to be more willing to continue the project when learning the market potential would be 35% than when learning it would be 15%. Our main interest was

in how decision makers would react to ambiguity about the market potential. In agreement with the reasoning and findings of Experiment 1, we expected that the participants facing ambiguity about the market potential would be less willing to continue the project. Because we reasoned that ambiguous information about the market potential may be discounted, we also included a control condition in which there was no mention of market research. We expected that the decision made by participants facing ambiguity about the market potential would resemble the decisions of participants lacking information about the market potential.

Method

Design and participants

The participants, 128 students at Leiden University, participated voluntarily. They were randomly assigned to one of the four conditions: control; low market potential; high market potential; or ambiguous market potential. There were 32 participants in each condition.

Procedure

The participants were presented a written scenario, describing a situation in which they were the owner of two restaurants considering opening up a third restaurant. Participants in the *control* condition read:\

> As an owner of two restaurants, you are considering whether or not to expand and to start a high quality Cantonese restaurant. In downtown Leiden there is a building for sale that seems to meet your demands. At this moment, you find out that downtown a Chinese restaurant of high quality is to be opened, with chefs from China who are specialized in the Cantonese food. Now, what would you decide? Would you continue your plans on the Cantonese restaurant? Or would you stop the project, and focus on possible alternatives?

In addition to this information, participants in the experimental conditions read that they had acquired market reports from two market research companies on the potential demand for Cantonese food (the costs of these market reports were FL. 30 000). Participants in the *low market potential* conditions learned that the marketing surveys indicated that 15% of the regular visitors to restaurants were interested in Cantonese food. In the *high market potential* conditions the percentage was 35%. In the *ambiguous market potential* condition, the participants learned that one survey indicated a percentage of 15% and the other a percentage of 35%.

After having read the scenario, participants indicated whether they would continue their plans for the Cantonese restaurant or whether they would terminate the project.

Results

The results are presented in Table 2. In agreement with our predictions, willingness to continue the project was affected by our manipulations. Willingness to continue the project was lower in the ambiguous market potential condition than in the low market potential condition, $\chi^2(1, n = 64) = 6.5$; $p < 0.02$, and the high market potential condition, $\chi^2(1, n = 64) = 14.1$; $p < 0.0002$. Moreover, the participants in the ambiguous market potential condition did not differ in their decisions from participants in the control condition, $\chi^2(1, n = 64) = 0.31$; *n.s.*

Table 2. Number of participants continuing and terminating the project, Experiment 2

		Market potential		
	Control	Low	High	Ambiguous
Continue	10 (31%)	18 (56%)	23 (72%)	8 (25%)
Terminate	22 (69%)	14 (44%)	9 (28%)	24 (75%)

For the whole table $\chi^2(3, n = 128) = 18.5$; $p < 0.001$.

A final finding, not pertaining to the current issue of ambiguity effects, was that participants in the high market potential conditions were more willing to continue the project than were participants in the low market potential conditions, $\chi^2(1, n = 64) = 3.78$; $p < 0.03$, one-tailed.

Discussion

The results of Experiment 2 corroborated our hypotheses. Participants adhered to economic principles in the sense that they were more likely to continue with their plans when learning 35% of the regular visitors of restaurants indicated that they were interested in Cantonese food than when learning that only 15% of these visitors were interested in Cantonese food. However, when facing ambiguity, participants were less likely to continue their plans. In agreement with the notion that people discount ambiguous information, the results indicated that the decisions of participants facing ambiguity resembled those of participants lacking information about market reports.

EXPERIMENT 3

In Experiment 2, we handed our participants information about the market potential. One could argue that market potential is a proxy for future returns. In Experiment 3, we introduced ambiguity about future costs. We developed a scenario in which participants had to imagine that they had obtained membership of a tennis club, which had to be paid in 12 monthly terms. The monthly costs were said to be €50.[1] After two months they developed tennis elbow, and now had to decide whether they would retain their membership for the months to come or not. Should they decide to continue their membership, the costs for the 10 months to come would amount to €500. However, if they decided to cancel their membership, the future costs would be lower because they would get a refund. We manipulated the future costs by the size of the refund. In the low future costs condition, the costs to be paid over the next 10 months would amount to €300. In the high future costs condition, the costs to be paid over the next 10 months would amount to €400. In the ambiguous future costs condition participants learned that the future costs would be €400 maximum and €300 minimum. In addition to these conditions, we also included a control condition, in which participants would not have to pay any costs for the next 10 months should they decide to cancel their membership.

As for the size of the future costs to pay, we anticipated that participants would be more willing to continue playing tennis when the future costs to be paid after cancellation would be €400 rather than when the future costs would be €300. We again expected that ambiguous information would be discounted. Therefore, we expected that, compared to participants in the low and high future costs conditions, participants in the ambiguous future costs condition would be less likely to base their decision the size of the costs. We predicted that these participants would opt to cancel their membership. That is, they should behave similar to the participants in the control condition.

Method

Design and participants

The participants, 200 students at Tilburg University, participated voluntarily. They were randomly assigned to one of the four conditions: control; low future costs; high future costs; or ambiguous future costs. There were 50 participants in each condition.

[1]In Experiment 3, the amounts were expressed in euros. In Experiments 1 and 2, the amounts were expressed in Dutch guilders. This was because Experiment 3 was conducted after introduction of the euro whereas Experiments 1 and 2 were conducted before introduction of the euro.

Table 3. Number of participants continuing and stopping to play tennis, Experiment 3

		Future costs		
	Control	Low	High	Ambiguous
Continue	8 (16%)	19 (38%)	26 (52%)	11 (22%)
Stop	42 (84%)	31 (62%)	24 (48%)	39 (78%)

For the whole table $\chi^2(3, n = 200) = 18.2$; $p < 0.001$.

Procedure

The participants were presented with a written scenario, describing a situation in which they were had become member of a tennis club. Participants in the *control* condition read:

> Earlier this year you decided to exercise, and opted for tennis. You purchased a one-year season ticket at a luxurious tennis club in your neighborhood. This means that during the year you can play on each Wednesday afternoon. The membership fee is €600 for the entire year, and the costs have to be paid monthly (€50 per month). After a few weeks you injure your elbow, and the pain progresses. After two months it appears that you have developed tennis elbow. There are two options: either you continue to play and retain your season ticket for the year; or you quit, and return the season ticket to the club. The club has a standard arrangement: if you decide to return the season ticket, you are granted a refund so that you would not have to pay for the months to come. What would you do?

In the *low future costs* condition, the participants learned that if they decided to quit, they would only have to pay €300 membership fee for the next 10 months because there would be a partial refund. In the *high future costs* condition, the participants learned that they would have to pay €400 membership fee for the next 10 months, because of the partial refund. In the *ambiguous future costs* condition, the participants learned that for the next 10 months they would have to pay €300 minimum and €400 maximum. The exact size of the costs would depend on whether their regular hours could be sold to another person or not. After having read the scenario, participants could indicate whether they would continue to play or whether they would stop and return the season ticket back to the club.

Results

The results are presented in Table 3. In agreement with our predictions, willingness to continue playing tennis was affected by our manipulations. Both in the control condition and in the ambiguous future costs condition, the majority of the participants decided to stop. In the low future costs condition the number of participants who decided to continue was already much higher, and in the high future costs condition the majority of the participants opted to retain their membership. In agreement with our predictions, willingness to retain the membership and continue playing was significant lower in the ambiguous future costs condition than in the low future costs condition, $\chi^2(1, n = 100) = 3.0$; $p < 0.05$; one-tailed, and the high future costs condition, $\chi^2(1, n = 100) = 9.7$; $p < 0.001$. The difference between the low future costs and the high future costs condition was marginally significant, $\chi^2(1, n = 100) = 2.0$; $p < 0.08$, one-tailed. Willingness to continue playing did not differ significantly between the control condition and the ambiguous future costs condition, $\chi^2(1, n = 100) = 0.6$; *n.s.*, suggesting that the participants in the ambiguous future costs condition indeed acted similarly to participants who did not have to consider any future costs should they decide to quit.

Discussion

The results of Experiment 3 provided further support for our theorizing. In agreement with our predictions, participants in the ambiguous future costs condition acted like participants in the control condition, and

decided to cancel their membership. Participants in the low future costs and high future costs conditions, were the least likely to cancel their membership.

GENERAL DISCUSSION

We investigated the effect of ambiguity on decision making in three different economic settings. In Experiment 1, we investigated the effect of ambiguous sunk costs. In Experiment 2, the ambiguity pertained to expected returns (i.e. the market potential). In Experiment 3, the ambiguity pertained to the costs that would have to be paid in the future. The results of these three studies are supportive of the notion that decision makers may discount ambiguous information. Moreover, in the three studies the decisions of the participants in the ambiguous conditions resembled the decisions made by participants in the control conditions (i.e. in Experiment 1, the participants who had not incurred sunk costs; in Experiment 2, the participants who had not received information about the market potential; and in Experiment 3, the participants who did not have to pay future costs should they decide to cancel their membership).

At this point it is appropriate to discuss possible alternative explanations for our current findings. As we noted in our general introduction, it has been documented that people may try to avoid ambiguous situations (e.g., Curley, Yates, & Abrams, 1986; Camerer & Weber, 1992; Ellsberg, 1961; Fox & Weber, 2002; Highhouse, 1994; Keren & Gerritsen, 1999; Kuhn, 1997). Could this ambiguity avoidance serve to explain our findings? In order to answer this question one should assess to what extent the behavioral options in the experiments allowed for an escape from ambiguity. One might argue that in Experiment 2, where ambiguity pertained to the market potential, participants could have regarded the option of not continuing the plans for an additional restaurant as a way out of the ambiguous situation. Note, however, that in Experiment 1, where the ambiguity pertained to the size of the sunk costs, stopping the project did not constitute an escape from the ambiguity. That is, the size of the sunk costs would remain as relevant to the decision maker deciding to stop the project as to the decision maker deciding to go through with the project. The results of Experiment 3 are even more telling, because in the tennis scenario, one could argue that if people were mainly motivated to avoid ambiguity, it would yield them an extra premium to retain the membership in the ambiguous future costs condition. After all, in that study, one would only have to face the uncertainty of how much the future costs would be if one were to quit playing tennis. That participants were more likely to quit in the ambiguous future costs condition suggests that ambiguity avoidance, as it is generally conceived in previous research, cannot account for the current findings.

Another thing that ambiguity may accomplish is that it may affect people's estimates. In particular, it has been suggested that people make more favorable estimates in the case of ambiguity (see for example, Highhouse, 1994). However, such favorable estimates would not explain the current findings on the effects of ambiguity either. In Experiments 1 and 3, we provided participants in the ambiguous sunk costs condition with an interval estimate, and we compared their decisions with the decisions made by participants believing the correct estimates to be either the lower endpoint of the interval or the higher endpoint of the interval. As a result, the issue of whether people are more likely to make unfavorable or favorable estimates is less relevant. For example, in the scenario of the tennis player in Experiment 3, participants in the low future costs condition learned that if they quit, their future costs would be €300; participants in the high future costs condition learned that they would pay €400, and participants in the ambiguous future costs condition received information about the interval, as they learned that the costs would be €300 minimum and €400 maximum. Whether people in this latter condition would make favorable (e.g. by estimating the costs to be below the midpoint of the interval; in the €300–€350 region) or unfavorable estimates (e.g. by estimating the costs to be above the midpoint of the interval; in the €350–€400 region), is not so relevant, because in either way it could not explain why they would be less willing to continue than participants believing they would have to pay €300 *and* less willing to continue than participants believing they would pay €400. Biased estimates

could only have explanatory power if one were to assume that participants in the ambiguous future costs condition expected the size of the future costs to lie outside the €300–€400 interval we presented to them. For example, one might reason that participants in the ambiguous future costs were willing to cancel their membership because they inferred that if they did so, they would only have to pay €100. This, however, seems unlikely because we explicitly informed them that the costs would be €300 minimum and €400 maximum. To be sure, we even tested this possibility with an additional pool of participants ($n = 20$) to whom we presented the ambiguous future costs condition. None of these participants estimated the actual future costs to be outside the €300–€400 interval.

In addition, one might wonder whether our results might have been dependent on specific aspects of the scenarios we used. For example, one might argue that in a business scenario like that of Experiment 1, the information presented to participants in the ambiguous sunk costs condition may have in fact communicated more to the participants than just the existence of ambiguity. One might argue that participants in Experiment 1 may have interpreted the ambiguity about the size of the sunk costs as an indication of bad management, and thus as a signal that they should stop the whole project. Note, however, that such an explanation does not hold for the scenarios used in the other experiments. The fact that we were able to obtain similar findings in such a wide variety of scenarios suggests that the most parsimonious explanation is that people discount ambiguous information.

To conclude, the current findings suggest that the tendency to discount ambiguous information may have profound consequences for decision making. In our studies, we concentrated on demonstrating the effect of discounting ambiguous information on economic decision making. We did not concentrate on identifying the exact nature of the process underlying the discounting of ambiguous information. As a result, we cannot provide conclusive evidence on what causes people to discount ambiguous information. As we noted in our introduction, we feel—like previous researchers on the disjunction effect (Shafir & Tversky, 1992; Tversky & Shafir, 1992) and transaction decoupling (Soman & Gourville, 2001)—that a combination of cognitive and motivational factors may be at work here. In particular, it may be cognitively more complex to base your decisions on ambiguous information. As for the motivational account, part of the answer may be provided by Shafir and Tversky who suggested that people may be reluctant to think through situations of ambiguity, because it requires them to assume something as true that may be false. We do not wish to claim, however, that this is the only motivational account possible. In this respect, future research might also benefit from insights of previous research on ambiguity avoidance. In their query for the psychological basis of ambiguity avoidance, Curley, Yates, and Abrams (1986) concluded that one of the main motives for people to avoid ambiguous situations is that they may anticipate that their choices will be evaluated by others. This explanation presupposes that people may find it difficult to justify a choice for ambiguity. In a similar vein, one could posit that people may find it difficult to justify basing their decisions on ambiguous information. Research along these lines may be the next step towards a better understanding of the differences and similarities between ambiguity avoidance, as observed in previous research, and the currently documented discounting of ambiguous information.

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