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**Keywords:** medical treatments; single-play, multiple-play, repetition bias, alternation bias.

**JEL Classification**: D03, D81, I12

Department of Economics

# Randomness beliefs and decisions on risky medical treatments[1]

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**Abstract**

Theoretical predictions entails that subjective beliefs of randomness affect the aggregation of medical outcomes of multiple-play medical treatments. Particularly, those who believe in more repetition of random events would tend to believe that multiple-play treatments are riskier medical interventions. As a consequence, the level of repetition bias could reduce (increase) the willingness to accept or recommend multiple-play medical treatments if people are risk averse (risk prone). On the contrary, the repetition bias is expected to not affect single-play treatments. In an experiment we find evidence for these theoretical predictions by exploiting the between individual variation in the repetition bias for risk averse and risk prone subjects and by analysing hypothetical decisions of the Spanish general population for medical treatments in single and multiple-play scenarios. Consequences for individual decision making in the health context are considered as well as for the interpretation of the differences between single vs. multiple play treatments in previous studies.

**Keywords:** medical treatments; single-play, multiple-play, repetition bias, alternation bias.

**JEL:** D03, D81, I12.

## 1. Introduction

When individuals think of a sequence of *n* realizations of a random variable they have beliefs that differ from the precepts of statistical theory (for a review see Nickerson, 2002; Falk and Konold, 1997; Bar-Hillel and Wagenaar, 1993). They typically present the alternation or repetition bias, which is defined as the tendency to believe that outcomes alternate or repeat more often than the true underlying random generator implies. Given that risky medical treatments, i.e. those that have uncertain outcomes, can be considered as random variables this cognitive characteristic could affect people's view that bad or good health consequences will alternate or repeat more often for sequential realizations of health interventions. As a result subjective (mis)conceptions of randomness could affect the evaluation of the attractiveness of medical choices.

In experimental settings where people are assigned the task of producing a sequence of i.i.d. random variables with equally likely binary outcomes (i.e. like the tossing of a fair coin) the most extending frequency of alternation produced is about 0.6 (or equivalent probability of repetition 0.4) even though the true probability is 0.5. Therefore, people tend to produce more often heads than tails after a realization of tails (Falk and Konold, 1997; Rapoport and Budescu, 1992; Lopes and Oden, 1987; Budescu, 1985; Falk, 1981). Also people evaluate sequences with more alternation as more random than those with a higher probability of repetition (Falk and Konold, 1997; Bar-Hillel and Wagenaar, 1987; Wageneaar, 1970). Nonetheless, positive sequential correlation has been produced in other experiments with subjective randomness implying more repetitions (Ayton and Fischer, 2004; Wagenaar and Keren, 1988; Neuringer, 1986; Gilovich et al., 1985).

Interestingly subjective notion of randomness seems to vary among subjects. Some of them show more positive autocorrelation between produced items than others (Nickerson and Bluter, 2009; Rapoport and Budescu, 1997 and 1992; Budescu, 1987; Falk, 1981). In this study we want to exploit this variation at the individual level to empirically test for the effect of the alternation/repetition bias on decisions over medical treatments. The main idea is that people who believe in more repetition would expect a medical treatment that is applied to many patients, or to one patient on several

occasions, to present positive correlation between realizations, i.e. a bad (good) result will likely follow a bad (good) outcome, leading to a more risky health prospect. On the contrary, those who think that there is a high probability of alternation would predict that bad and good outcomes alternate often so that it is very unlikely to find extreme consequences like many bad (or good) outcomes in a row, reducing the variability of the aggregate prospect of the medical intervention. In short, the repetition bias increases the perceived risk of repeated treatments. Therefore we will expect the effect of the repetition bias to be interacted with intrinsic risk preferences. Specifically, we hypothesize that the repetition bias will be negatively (positively) correlated with the willingness to accept or recommend medical treatments when decision makers are risk averse (risk seeker).

An existing research line studying multiple-play and single-play medical treatments is relevant to the analysis shown here (DeKay, 2011; DeKay et al., 2006; DeKay and Kim, 2005; Redelmeier and Tversky, 1992; Redelmeier and Tversky, 1990). The empirical and normative aspects of the differential willingness to treat one patient on one occasion in comparison to treat a group of patients or one patient in several occasions has been discussed. There is some evidence that treatments with positive expected health gains are more likely to be preferred or recommended by undergraduates, the general public and physicians in repeated play scenarios (DeKay, 2011; Redelmeier and Tversky, 1992). In other studies this pattern is not so obvious (DeKay et al., 2006; DeKay and Kim, 2005) even finding the opposite result, i.e. higher preference for single-play treatments (Redelmeier and Tversky, 1990). As a result an interesting academic debate exists about the convenience of studying multiple and single treatments as two different approaches to medical decisions.

In this paper we find an additional reason to regard single and repeated treatments decisions as different paradigms. Given that the fulfillment of the repetition bias requires several realizations presenting more or less positive autocorrelation its impact will be limited to multiple-play treatments. This is so because one single application of a treatment implies only one realization of a random variable. We hypothesized that subjective beliefs of sequential dependence will not have any effect in this case. Therefore, our second main hypothesis would be that the variation in subjective randomness will not be correlated with preferences for single-play treatments but for repeated plays of the same interventions.

In our survey, we classified respondents according to their repetition bias (i.e. the degree to which they belief in more repetition or more alternation) and their risk preferences. One half of the participants responded their willingness to accept and recommend medical treatments in a multiple-play scenario. The other half was in a single-play scenario. In the multiple-play case we find that the correlation between repetition bias and preferences for medical treatments is interacted with risk aversion. Even more, the interaction is in the expected direction: the effect of repetition bias tend to be negative (or not significant) for the risk averse group, and positive (or not significant) for risk seekers. On the other hand, we find mainly no effect (and very low statistical significance) of the repetition bias in the case of single-play medical treatments. As a corollary of these results, we also find evidence that the differences between preferences for single and multiple-play treatments changes with underlying risk preferences. Specifically, risk averse individuals have a higher relative preference for multiple-play treatments in comparison to single-play interventions, especially when they believe in more alternation between random events.

What follows describes the previous literature concerned with the repetition bias and single vs. multiple-play medical treatments, along with the theoretical effect of the repetition bias on this type of medical interventions. In section 3 we explain the details of the survey. The results are shown in section 4 and finally a discussion is considered.

## 2. Background

### 2.1. Alternation and repetition bias

Psychologists have used two types of tasks to estimate de subjective beliefs on randomness: production and perception (Nickerson, 2002). In the former, subjects are instructed to generate random sequences with two or more alternatives with different lengths from 8 or 10 (Lopes and Oden, 1987; Kareev, 1992) to 300 items (Bakan, 1960). For example, Rapoport and Budescu (1997) reported production of series of random variables with two or three equally likely alternatives generated by subjects simulating the tossing of an unbiased coin, draws without replacement from a well-shuffled card deck, and the rolling of a die with three values. In the perception tasks subjects are presented several sequences that have to be judged according to their level

of randomness. In Falk and Konold (1997) subjects rated ten sequences on a scale of 0 to 10 according to their "intuition of how likely it is that such a sequence was obtained by flipping a fair coin". In other studies people have to select the sequences that they perceive to be random from a set of series with different frequency of repetition/alternation (e.g. Lopes and Oden, 1987).

The most extended result for production and perception tasks are consistent with people believing in more alternation (less repetition) than a random device is expected to generate. However, there is some variation in the specific bias estimated. For example, Rapoport and Budescu (1997) reported a probability of alternation (i.e. probability of not repeating the last outcome) from 0.58 to 0.73 for different experiments. Other study by Neuringer (1986) finds lower than 0.5 alternation (i.e. more than 0.5 repetition). Even more, within individual variation has been found by Nickerson and Bluter (2009) with 30% of subjects showing positive recency, i.e. a statistically significant propensity to repeat the last outcome, while 47% showed the more common negative recency. This heterogeneity result is consistent with those in Falk (1981), with analogous figures of 17% and 79% for repetition and alternation bias respectively, and Budescu (1987) with 8% and 62% participants showing respective beliefs.

In these studies one challenge is the description of the specific task that is required from subjects. Nickerson (2002) discusses this issue arguing that in many experiments instructions seems to be vague or incomplete. Specifically, when people are asked to produce a random sequence any sequence could be valid because any sequence is possible and could be produced by a random generator. For instance, in Rapoport and Budescu (1997) subjects were given incentives to produce series "close to computer-generated random series with the same parameters" so that they could have interpreted the task in different ways. Similar arguments could be considered when subjects have to judge the randomness of a sequence. Nickerson (2002) emphasizes that without knowing the precise task which subjects are attempting to do we cannot say much about their randomness performance. He suggests to avoid ill-defined task like "produce a sequence that is most likely to resemble a sequence produced by a fair coin". Instead instructions should be more precise requiring subjects to produce or judge sequences according to specific characteristics of random sequence like number of heads and tails, or number of repetitions. We have considered this recommendation for designing the production and perception task in our experiment.

### 2.2. Single and repeated treatments

In the medical decisions literature concerned here the single-play treatment consists in the application of a treatment to one patient on one single occasion. Two main types of repeated-plays can be used for comparison: a) the application of a treatment to an individual on several occasions; b) the application of a treatment to a group of patients on one occasion. For example, Redelmeier and Tversky (1992) asked practicing physicians to consider a patient suffering between 5 or 7 hours of knee pain due to a type of arthritis. There exists a medication that could reduce pain in 3 hours or increase in 2 hours with a 50/50 chance every day. In the single-play scenario the medication will be administered one or two days. In the multiple-play scenario the medication will be used for several weeks, i.e. this scenario implies the application of an individual repeated treatment. Interestingly much more physicians were willing to recommend the multiple-play treatment than the single-play (42% vs. 15%). Also in DeKay (2011) physicians, medical administrators and voters were more willing to recommend the multiple-play (one patient on 12 days) version of this treatment than the single version (1 day), especially when the aggregate results of the repeated treatment was presented.

On the other hand, group treatments have also been considered by DeKay (2011). A treatment with 50/50 probabilities of increasing (in 4 years) or decreasing (in 2 years) a patient's life expectancy was considered in a single-play version (one patient treated) and in multiple-play (10 patients treated). Again the multiple-play scenario made participants (physicians, medical administrators and voters) to be more willing to recommend the treatment. However, other studies find mainly no differences for the multiple-patients vs. one-patient comparison. In DeKay et al. (2006) risky flu shots with positive expected health gains were mainly equally preferred when applying to many patients (1000) rather than to a single one. The latter result jointly with the previous one reported by DeKay and Kim (2005), who find little differences for group and single treatments, were considered by the authors as evidence for repeated and single decisions

in the medical context to be essentially different from the single vs. repeated monetary lotteries decision process.[3]

Differences between repeated and single treatments seems to rely on the concept of fungibility, i.e the extent to which bad health consequences (like the reduction of two years of life expectancy for one patient) can be compensated by good outcomes (like the increase of four years of life for another patient). Evidence suggests that repeated treatments are more attractive than single ones mainly when subjects (physician or the general public) regard health outcomes as fungible (DeKay, 2011; and DeKay, 2005). Another relevant result is that people seem to be more prone to recommend repeated treatments when risky treatments are presented in a frequency frame, i.e. 50 out of 100 patients will be better off with this treatment, rather than as a probability distributions, i.e. there is a 50% chance to be better off (see DeKay et al., 2006). In this sense, we try to contribute to this literature by presenting an innovative analyses of how preferences for multiple and single medical interventions can be moderated by subjective beliefs of randomness, i.e. we study the effect of a new factor (like *outcome fungibility* or the *frequency/probability* frames) on the appealing of single and repeated-play treatments.

### 2.3. Repetition bias and the perceived risk of multiple-play treatments

In order to illustrate the plausible effect of randomness beliefs on the appealing of multiple-play treatments we will use a binomial Markov model (Edward, 1960) to describe the subjective sequential dependence for realizations of a binary random variable. The specific characteristics of this model are exposed by Budescu (1987 and 1985) (see similar descriptions in Nickerson, 2002, and Rabin, 2002). In this framework each realization $X_i$, $i = 1,\ldots,n$, takes value 0 or 1. The sequence of these realizations forms a Markov chain with unconditional probabilities $P(X_i = 1) = p$, and $P(X_i = 0) = q = 1 - p$. The belief in non-independence is determined by the matrix of transition probabilities in Table 1, i.e. the probability of value 1 or 0 for variable $X_i$ after a realization of 1 or 0 for $X_{i-1}$.

[3] There is a wide amount of evidence that people are willing to play positive expected value monetary lotteries more often when these are repeated rather than when one single realization is played (see for example Klos et al., 2005; DeKay, 2005; Thaler et al.,1997; Gneezy and Potters, 1997).

**Table 1. Transition matrix for a binomial Markov model**

| | Trial *i* | |
|---|---|---|
| Trial *i-1* | 1 | 0 |
| 1 | $p + rq$ | $q(1 - r)$ |
| 0 | $p(1 - r)$ | $q + rp$ |

This model relies on three parameters, the two unconditional probabilities, i.e. $p$ and $q$, and the correlation coefficient between adjacent trials, $r$. The probabilities of repetition are $P(X_i = 1|X_{i-1} = 1) = p + rq$ and $P(X_i = 0|X_{i-1} = 0) = q + rp$ for values 1 and 0 respectively. While probabilities of alternation are $P(X_i = 1|X_{i-1} = 0) = p(1 - r)$ and $P(X_i = 0|X_{i-1} = 1) = q(1 - r)$ for values 1 and 0 respectively. In this study we will assume that people have different beliefs on $r$. They could have a repetition bias with $1 > r > 0$, so that they believe in more repetition than the zero correlation case. Or they may belief in $-1 < r < 0$, which would generate higher probabilities of alternation between outcomes than an independent process. In general we will consider a person with more repetition bias someone who believes in high probability of repetition of outcomes (high or positive $r$) and a person with more alternation bias someone who believes in less repetition (low or negative $r$).

The interesting feature about this model is that the unconditional probabilities of outcomes 0 and 1 for each trial is constant and is not affected by $r$. Consequently, the value of $r$ will not change the expected number of 0s and 1s after a sequence of $n$ realizations. On the contrary, the repetition bias is going to affect the variability of the outcomes given by $n$ realizations. Specifically, the variance of the random variable *numbers of 1s* in a sequence of $n$ realizations increases with the repetition bias.

To see the consequences of varying beliefs for $r$ on the outcome distribution of $n$ realizations of a random variable we will consider a medical treatment that has equal probability of success/failure (1/0), i.e. $p = q = 1/2$. Imagine also that for each success

a patient will have some pain for 3 hours one day and in case of failure the pain will be for 8 hours. In Table 2 we show the distribution of the number of successes and accumulated hours of pain after 10 applications of this treatment. We show the distribution for different levels of repetition bias. Given that $p = q = 1/2$ the probability of repetition is the same for values 1 and 0, i.e. $\mathrm{P(Rep.)} = \mathrm{P}(X_i = 1|X_{i-1} = 1) = \mathrm{P}(X_i = 0|X_{i-1} = 0) = 1 - \mathrm{P(Alt.)}$. It can be seen that the distribution of number of successes (or accumulated pain hours) become more variable as we move from low to high probabilities of repetition, or alternatively, from negative to positive autocorrelations. Specifically the probabilities of the middle outcome *5 successes* (55 *pain hours*) is decreasing with the probability of repetition and the extreme situations *0 and 10 successes* (80 and 30 *pain hours*) become more likely. It can be said that those who believe in more repetition think of several applications of a medical treatment as a more risky health prospect. While those who believe in the alternation bias consider ten applications as a more certain intervention. Notice that the expected number of successes is 5 (55 *pain hours*) for any belief, this is easily seen in Table 2 given that all distributions are symmetric at that value. Eventually, this pattern will be applied no matter the unconditional probabilities considered ($p$ and $q$). In short, the repetition bias (high or positive r) will make *n* realizations of a medical treatment appear more risky while it will not have any effect on the expected number of successes.

In this section we are considering the theoretical effect of randomness beliefs on decisions over medical treatments. Will the belief in more repetition increase or decrease the willingness to accept a treatment? Given that the level of repetition bias affect the perceived risk of a repeated treatment we predict that the effect is going to be interacted with intrinsic risk preferences of decision makers. In particular, for those who are risk averse the repetition bias will have a negative effect. This is because the final aggregate health lottery is perceived as more risky for higher probabilities of repetition as illustrated in the example of Table 2. On the other hand, a symmetric reasoning allows us to predict that those who have a preference for risk will have a positive impact of the repetition bias. This is because risk prone individuals would perceive repeated medical treatments as more risky if they believe in high probability of repetition. Therefore we have the next prediction:

T1: *The effect of the repetition bias on the willingness to accept or recommend a repeated treatment is negative for risk averse individuals and positive for risk prone subjects*.

In order to respond to our research question we need to distinguish between single and multiple applications of a treatment. In the first case we will not expect any effect of the alternation/repetition bias since for one single realization it does not affect the probability of the final outcomes. On the contrary, the theoretical insights here exposed suggest that when the treatments are going to be repeated in several applications, individuals will have different health distributions in their minds according to their beliefs about conditional probabilities as shown in Table 2. Therefore, the second theoretical prediction about the effect of the repetition bias on medical treatments is:

T2: *The repetition/alternation bias could affect decisions over repeated treatments but not over single treatments*.[4]

Table 3 summarizes the two theoretical predictions, T1 and T2, that we will study empirically.

[4] There could be a case in which the repetition bias could affect single treatments under the present analysis. Imagine that individuals think of a single treatment as part of a sequence of several applications of the same that will happen in the future. For example, if the health consequences of a flu vaccine for one patient in a given year are seen as one of the many vaccinations that will follow in subsequent years. Nonetheless, previous decision making literature finds that individuals do not tend to show that kind of wide framing reasoning when considering single lotteries (see Redelmeier and Tversky, 1992; Kahneman and Lovallo, 1993; Benartzi and Thaler, 1995; Thaler et al., 1997; Benartzi and Thaler, 1999). In any case, we will predict that the effect of the repetition bias is inferior when individuals are deciding on single than on repeated treatments.

**Table 2. Probability distribution of a multiple-play treatment with varying repetition bias**

| Number of Successes | Pain hours | Belief on $r$ | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | -1 | -0.8 | -0.6 | -0.4 | -0.2 | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1 |
| | | P(Rep)=1- P(Alt) | | | | | | | | | | |
| | | 0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1 |
| 0 | 80 | 0 | <.0001 | <.0001 | <.0001 | .0001 | .0010 | .0050 | .0202 | .0671 | .1937 | .5 |
| 1 | 75 | 0 | <.0001 | <.0001 | .0005 | .0028 | .0098 | .0246 | .0469 | .0671 | .0622 | 0 |
| 2 | 70 | 0 | .0001 | .0016 | .0084 | .0229 | .0439 | .0664 | .0835 | .0873 | .0665 | 0 |
| 3 | 65 | 0 | .0063 | .0316 | .0662 | .0970 | .1172 | .1251 | .1208 | .1040 | .0697 | 0 |
| 4 | 60 | 0 | .168 | .2289 | .2391 | .2269 | .2051 | .1786 | .1489 | .1150 | .0717 | 0 |
| 5 | 55 | 1 | .6512 | .4756 | .3718 | .3007 | .2461 | .2005 | .1594 | .1189 | .0724 | 0 |
| 6 | 50 | 0 | .168 | .2289 | .2391 | .2269 | .2051 | .1786 | .1489 | .1150 | .0717 | 0 |
| 7 | 45 | 0 | .0063 | .0316 | .0662 | .0970 | .1172 | .1251 | .1208 | .1040 | .0697 | 0 |
| 8 | 40 | 0 | .0001 | .0016 | .0084 | .0229 | .0439 | .0664 | .0835 | .0873 | .0665 | 0 |
| 9 | 35 | 0 | <.0001 | <.0001 | .0005 | .0028 | .0098 | .0246 | .0469 | .0671 | .0622 | 0 |
| 10 | 30 | 0 | <.0001 | <.0001 | <.0001 | .0001 | .0010 | .0050 | .0202 | .0671 | .1937 | .5 |

Note: unconditional probabilities of success and failure is fixed at $p = q = 1/2$, the number of realizations is 10 times, and the health outcomes are 3 pain hours (if success) and 8 pain hours (if failure).

**Table 3. Theoretical effect of the repetition bias on preferences for medical treatments**

| | | Risk preferences | |
|---|---|---|---|
| | | Risk averse | Risk prone |
| Type of treatment | Single-play | *No effect* | *No effect* |
| | Multiple-play | *Negative effect* | *Positive Effect* |

## 3. The study

The experiment was administered to 1,056 subjects from the Spanish general population through an online survey. The socio-demographic characteristics of participants are shown in Table 4. The average respondent was equally likely male/female, about forty years old, mostly with tertiary education, employed and in good health condition. Participants were paid a fixed amount of bonuses, that they could exchange for gifts. At the beginning of the survey they were informed about the objective of the study carried out by the *Pablo de Olavide University* and *Glasgow Caledonian University*. We emphasized that they would faced hypothetical medical decisions and that their responses should be as close to a real situation as possible so that they should think of health consequences for themselves or other people. They were informed that anonymity was guaranteed and they could avoid responses or quit the survey at any moment if they needed to. Finally, we thanked them for their collaboration. The different parts of the survey are described below and were aimed at eliciting the level of repetition bias, decisions on health treatments and the level of risk aversion.

### 3.1. The repetition bias

Randomness beliefs of respondents was elicited through a production task and a perception exercise. In this sense, we were able to classify participants according to three measures of the repetition bias, the two elicited by each task separately and a third one being a combination of both. All the subjects were instructed to think of two outcomes with the same probability (50%) for each realization. Half of the sample was said that the two outcomes were *HEADS* and *TAILS* so that they had to think of several tosses of a fair coin. The other half was framed in an medical scenario so that they had to consider two outcomes of a medical treatment, *SUCCESS* and *FAILURE*. We also gave some participants additional information about the repetition bias and the independent nature of the random variables. In our analysis we control for those two experimental manipulations, specifically we use an indicator in our regressions for the random variable frame (*coin* vs. *medical*) and the information frame (*info* vs. *no info*).[5]

[5] Detailed results of the effect of those two experimental factors on production and perception of random variables will be shown elsewhere and available for the reader upon request. The focus in this study is to exploit between individual variation in the repetition bias to estimate the effect on medical treatment preferences.

**The production task**

In the production task each respondent was asked to generate a sequence of ten realizations of a random variable with two equally likely outcomes. In order to avoid ambiguity or vague instructions (Nickerson, 2002) we made the task very specific. Subjects were shown a pre-generated sequence and explained the number of times each outcome was generated (e.g. the number of heads and tails) and the number of times the outcome produced followed a realization of the same type (repetition probability). They were explained the specific realizations in which a repetition occurred with instructions like: *"As you may see a repetition happened in the second realization because heads appeared, as in the first realization".* A graphical explanation is shown in Figure A1 of the appendix. Several examples of sequences were presented to make sure that respondents understood the repetition concept. Eventually they were asked to generate a sequence as much representative as possible of ten realizations of a binary random variable with respect to the expected number of outcomes of each type and the number of repetitions expected. For each realization they had to select the outcome (e.g. heads or tails) and automatically the selected outcome appear in the screen for that realization. An example of a production exercise is shown in Figure A2. The respondent could see the outcomes she generated all the time, for example when selecting the seventh realization she could see clearly the six previous realizations.

The more repetitions produced the higher the underlying probability of repetition. Table 4 shows the probability of repetition implicit for each number of repetitions and the distribution of the sequences generated by subjects. Most of the sequences presented less than 50% probability of repetition indicating a tendency to alternate more often than an independent process would entail. For example, 75% of subjects produced a sequence consistent with less than 0.5 repetition. Nonetheless, there was variability with many subjects producing very different rates of repetition. This pattern is consistent with other studies (Nickerson and Bluter, 2009; Falk, 1981; Budescu, 1987).

**The perception exercise**

For the perception task, individuals were shown six sequences on the computer screen simultaneously. They were instructed to evaluate, on a scale from 0 to 10, how likely it

was that each sequence was produced after ten realizations. They were explicitly said to consider the number of outcomes of each type and the number of repetitions. All the sequences had the same number of outcomes of each type (either 5 heads and 5 tails or 5 successes and 5 failures) so that they all were equally likely in this respect. However we changed the number of repetitions for each sequence. Three of them were presenting less repetition (1, 3 and 4 repetitions) than an independent process is expected to produce (i.e. presenting alternation bias). The other three had more repetition (5, 6 and 8 repetitions) than an independent process (i.e. presenting repetition bias). We randomly changed the order of the sequences in the screen to avoid order effects. See Figure A3 for an example of the computer screen for the perception exercise. In Table 4 it is shown the average score for each sequence, with those presenting less repetition obtaining higher likelihood. Again this result is consistent with a general belief in more alternation (Falk and Konold, 1997; Bar-Hillel and Wagenaar, 1987; Wageneaar, 1970).

**Repetition bias groups**

For the analysis we classify participants in two groups of approximately equal size according to the repetitions produced. We will referred to them as the ALT-BIAS group (with 3 or less repetitions) and the REP-BIAS group (with 4 or more repetitions).[6] In a similar way we separate subjects according to their repetition bias in the perception task. For each individual we compute the difference between the (average) score given to sequences with 5, 6 and 8 repetitions and the score for sequences 1, 3 and 4. Individuals were separated into two groups by the median of this perception index. Eventually, we compute the arithmetic average of the number of repetitions produced and the perception index to create a combined repetition bias indicator.[7] In this way we have two groups, ALT-BIAS and REP-BIAS, for each of three different criteria: production (Pr.); perception (Per.); and production and perception (Pr. & Per.). The three measures were significantly positively correlated (p-value<0.001). The spearman correlations between the Pr. & Per. groups and the Pr. and Per. ones were 0.6 and 0.53 respectively,

[6] Notice that the idea is to compare two groups with different degrees of repetition bias, one with a tendency for more repetition (REP-BIAS) and another with a tendency for less repetition (ALT-BIAS). Obtaining a similar size for the two groups requires including those subjects with 4 repetitions (i.e. P(R)=0.44) in the REP-BIAS category.

[7] We standardized the number of repetitions and the perception index from zero to one in order to compute the arithmetic average.

indicating that the combined measure is capturing variation from both type of cognitive tasks. The correlation between the production and perception categories was 0.12, indicating that the two tasks made a different classification of participants, although correlated.

**Table 4. Summary statistics**

| **Socio-demographics** | % /Mean | **Repetition bias** | | **Risk Aversion** | % /Mean |
|---|---|---|---|---|---|
| Gender (Female=1) | 49.5 | Repetitions produced: | % | Pain treatment: | |
| Age | 41.3 | 0 (P(R)=0) | 5.0 | Risk averse | 41.8 |
| Education: | | 1 (P(R)=.11) | 1.2 | Risk averse (SoP) | 0.44 |
| Primary | 5.6 | 2 (P(R)=.22) | 15.3 | | |
| Lower Secondary | 25.8 | 3 (P(R)=.33) | 20.5 | Life exp. treatment: | |
| Upper Secondary | 23.1 | 4 (P(R)=.44) | 33.5 | Risk averse | 49.2 |
| Tertiary | 45.5 | 5 (P(R)=.56) | 14.5 | Risk averse (SoP) | 0.49 |
| Occupation: | | 6 (P(R)=.67) | 6.4 | | |
| Employed | 52.5 | 7 (P(R)=.78) | 1.0 | | |
| Self-employed | 14.0 | 8 (P(R)=.89) | 1.6 | | |
| Unemployed | 17.5 | 9 (P(R)=.1) | 1.0 | | |
| Inactive | 16.0 | | | | |
| Self Reported Health: | | Repetitions perceived: | Mean | | |
| Excellent | 10.28 | 1 (P(R)=.11) | 6.41 | | |
| Very good | 33.59 | 3 (P(R)=.33) | 6.43 | | |
| Good | 43.77 | 4 (P(R)=.44) | 6.21 | | |
| Fair | 10.85 | 5 (P(R)=.56) | 5.05 | | |
| Poor | 1.52 | 6 (P(R)=.67) | 4.99 | | |
| | | 8 (P(R)=.89) | 3.29 | | |

Note: P(R) is the probability of repetition implicit for each number of repetitions in the series generated or perceived by subjects.

### 3.2. Treatment decisions

All subjects responded about their preferences for two different medical treatments. Half of the sample were in a single-play scenario and the other half in a multiple-play scenario. The first treatment was similar to one described in Redelmeier and Tversky (1992) and in DeKay (2011) and was designed for patients suffering a flare of a disease

that causes 6 hours of pain a day. The treatment would reduce the pain to 3 hours with 50% chance, or increase to 8 hours with 50% of probability each day. In the single-play scenario of this PAIN TREATMENT subjects were said that the flare is for only one day. In the multiple-play the flare extended over 10 days. Subjects were said to imagine themselves in that situations and respond whether they were willing to accept (WTA) the treatment. After that they were asked how sure they were about their responses, answering on a scale from 0 (not very sure) to 10 (very sure). This is what we call Strength of Preference (SoP) and allows us to have more individual variation in preferences. We construct a SoP variables standardized from 0 (very sure that she will not accept) to 1 (very sure that she will accept). In Figures A4 and A5 the computer screens for the single and the multiple-play frame scenarios are shown respectively.

The second treatment was analogous to one proposed in DeKay (2011) and DeKay and Kim (2005) and was designed for 65 years old patients having a life expectancy of five years more, this is they were expected to live up to age 70. Subjects were presented a treatment that will increase the life expectancy up to age 76, with a 40% probability, or decrease life years to age 68, with a 60% probability. They were explicitly said that on average the treatment will increase life expectancy (the mean increment is 1.2 years). In the single-play of the LIFE EXPECTANCY frame a physician had to decide whether to recommend or not this treatment for one patient. In the multiple-play group the treatment would be applied to 10 patients. Subjects were asked whether they think that the physician should recommend the treatment (WTP) and after that they expressed their Strength of Preference as in the PAIN TREATMENT. In Figures A6 and A7 we show the single and the multiple-play frame scenarios respectively.

There were several differences between the PAIN and LIFE EXPECTANCY treatment. First, the most obvious is the health outcome with the former affecting quality of life and the latter regarding quantity of life. Also the perspective is different, because in the PAIN treatment subjects had to consider that the treatment would be applied to themselves while in the LIFE EXPECTANCY frame subject evaluated the convenience of the medical intervention for other people. Finally, the probability of success is higher in the PAIN treatment (50%) than in the LIFE EXPECTANCY treatment (40%) even though both entail positive health gains. This design allows us to explore the empirical effect of the repetition bias for very different medical preferences. Specifically, DeKay (2005) finds evidence that people tend to consider health outcomes for different patients

to not be fungible so that the life years increment for one patient cannot be added to the life years reduction for other patient for computing net gains. Given that the theoretical effect of the repetition bias (see section 2.3) requires some aggregation the findings could be different for the LIFE EXPECTANCY treatment.

In Figure 1 we can see preferences for multiple and single applications of the treatments. More than 60% of subjects were willing to accept or recommend in both scenarios. This illustrate that subjects were prone to apply the risky treatment instead of choosing the more conservative no-treatment alternative. They could have seen the treatment highly appealing due to their expected health gains. A t-test confirms that there is no significant differences, in WTA (WTR) or SoP, between the multiple and single play versions of both treatments. This result is consistent with studies like DeKay (2005) and DeKay et al. (2006), with no high differences between single and repeated-play medical interventions, but contrast with DeKay (2011) and Redelmeier and Tversky (1992).

### 3.3. Risk aversion

Given that theoretical predictions for the effect of the repetition bias is interacted with risk preferences (see Table 3 and section 2.3) we separate risk averse individuals from those whose preferences are consistent with a risk seeking behavior. In order to do that we asked participants to choose between two medical options with the same expected health outcomes, i.e. on average the two alternatives gave the same number of pain hours or life expectancy. One of the alternative was certain and the other was risky. In the case of the pain outcomes the certain situation was 6 hours of pain and the risky choice was either 4 or 8 hours of pain with a 50/50 chance. In the case of the life years outcomes the certain situation gave 70 years of life expectancy and the risky choice gave either 73, with 40% chance, or 68, with 60% probability. Individuals responded their Strength of Preference as well, i.e. how sure they were about their decisions. This questions were administered after the PAIN TREATMENT decisions and the LIFE EXPECTANCY TREATMENT choices respectively. Similar visual aids to those questions were shown to participants to illustrate the certain and risky alternatives. In Table 4 it can be seen that about 41.8% subjects are risk averse with respect to pain hours and 49.2% with respect to life years. For the analysis we separate individuals as risk averse or risk seeking depending on whether they are above or below the median

SoP for the certain alternative, this way we have two groups with a similar number of participants.

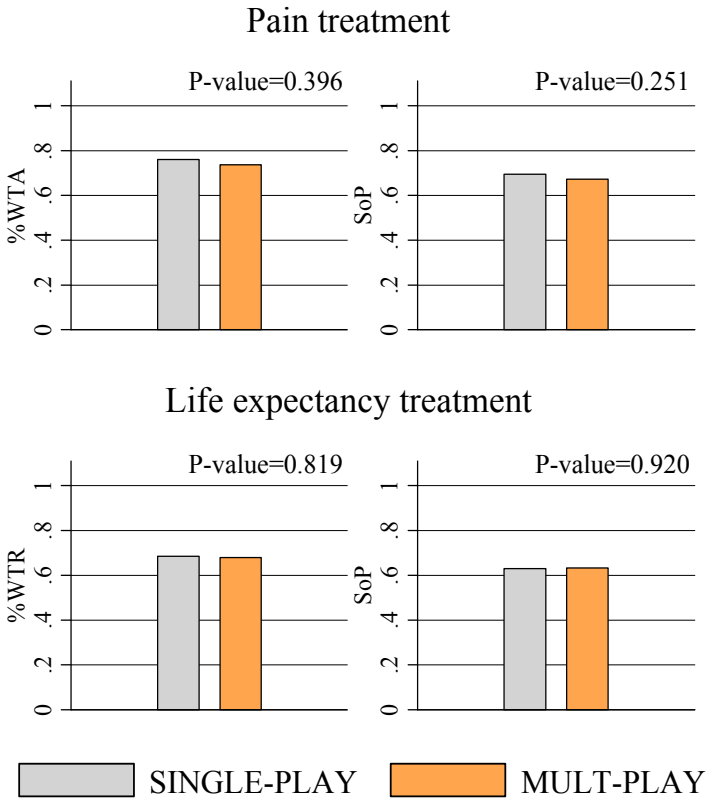


**Figure 1. Multiple vs. single-play treatments.** Willingness to Accept (WTA) or recommend (WTR) and Strength of Preference (SoP).

## 4. Results

The results for the relationship between the repetition bias and medical decisions are shown in Figures 2 to 6 and in Tables 5 and 6. In Figure 2 we compare WTA (or WTR) and SoP of those in the ALT-BIAS and REP-BIAS groups that responded in the multiple-play scenario and were classified as risk averse. In this case we expect a lower preference for the treatment in the REP-BIAS group (see Table 3). This is what we find for the pain treatment if we consider either WTA or SoP. Interestingly this pattern is found for all the repetition bias measures (Pr., Per. or Pr. & Per.). For example,

considering the Pr. & Per. categories 69% of those in the alternation bias group were willing to accept the pain treatment, while only 53% of the repetition bias group. This difference is also significant according to a t-test (p-value=0.009). We obtain higher statistical significance when considering the perception task or the combination of production and perception. On the other hand, no statistical differences is found for preferences on the life expectancy treatment ($p-value \geq 0.231$), although when focusing on the perception task we find the expected theoretical negative effect of the repetition bias.

In Figure 3 we analyze responses in the multiple-play scenario for those classified as risk seekers. The theoretical prediction in this case is a positive effect of the repetition bias, i.e. a higher WTA (or WTR) and SoP for those in the REP-BIAS group. We find this exact pattern for the life expectancy treatment. All repetition bias groups considered showed a higher preference (WTR and SoP) for the medical treatment than the corresponding alternation bias groups. This differences are also significant when considering the production exercise or the combination of the production and perception task ($p-value \leq 0.026$) but not for the perception task. On the contrary, we do not find any significant differences between the alternation groups and the repetition bias groups for the pain treatment.

The analysis in Figures 2 and 3 suggests that theoretical predictions of a negative effect for risk averse individuals is observed for the pain treatment but not for the life expectancy intervention. On the contrary prediction of a positive effect for risk prone subjects is only observed in the latter. Nonetheless the results are consistent with the idea that the effect of the repetition bias is interacted with risk preferences. Moreover, the interaction found is in the expected direction. This is, the effect of the repetition bias tend to be negative for the risk averse group, and tend to be positive for risk prone individuals. This pattern is found for both treatments: *pain* and *life expectancy*. We formally test for this interaction in Table 5 by estimating a logit regression equation in which the dependent variable is WTA (WTR) for the multiple-play treatments and the explanatory variables are the strength of preference for risk aversion (RA), a dummy variable indicating repetition bias (REP-BIAS) and the interaction between risk aversion and repetition bias ($RA \times REP\_BIAS$). We include the same independent variables in a linear regression for estimating the SoP. According to our theoretical

predictions the sign of the coefficient of RA × REP_BIAS should be negative, indicating that the effect of the repetition bias is lower (less positive or more negative) for those with more risk aversion. Interestingly this is what we find when considering the 12 regressions ( $2\text{treatments} \times 2\text{dependent variables} \times 3\text{REP\_BIAS tasks}$ ). The interaction is also significant (p-value<0.01) for most of the regressions (8 out of 12).

In Figures 4 and 5, and in Table 6 we analyze single-play lotteries. Looking at the comparisons between REP-BIAS and ALT-BIAS, in Figures 4 and 5, the most extended result is the absent of significant differences in preferences for single-play lotteries as suggested in our theoretical section (see Table 3). Also the estimated interaction between risk aversion and repetition bias is mostly insignificant, indicating that the effect of the repetition bias for single-play lotteries is not interacted with risk preferences. Only, in the case of the logit estimation of WTR the life expectancy treatment we find a slightly significant positive coefficient of $\text{RA} \times \text{REP\_BIAS}$ ($\text{p} - \text{value} \approx 0.01$). So, in general we do not find a significant effect of the repetition bias in the case of single-play treatments, even more in some cases the interaction between repetition bias and risk preferences is the opposite to the one expected for the multiple-play scenario, i.e. those risk averse have a more positive effect of the repetition bias.

Eventually, we study the relationship between single-play and multiple-play treatments in more detail. On the one hand, results above suggest that single-play treatments are mainly unaffected by the repetition bias. On the contrary, multiple-play treatments are affected differently depending on whether the individual is risk averse or risk seeking. This two results imply that differences between multiple-play and single-play treatments should be interacted with risk preferences (whether risk averse or not) and with the repetition bias. More specifically, given that the most extended randomness belief is alternation between random events, the multiple play treatments should be very appealing for risk averse subjects but not so for risk seekers. In consequence we should see higher preference for multiple-play, relative to single-play, in the risk averse group. In other words, the difference between WTA (WTR) for multiple-play and single-play should be higher for the risk averse group. In order to test for this prediction we estimate a logit regression including as independent variables: risk aversion (RA), a dummy for multiple-play interventions (MULT-PLAY), and the interaction term ($\text{RA} \times \text{MULT} - \text{PLAY}$). The results in Table 6 shows that the interaction term is positive

and statistically significant for both treatments. Moreover, when we estimate the same logit model for the group of subjects that showed more alternation bias (the ALT-BIAS group according to Pr. & Per.) the interaction become more important and more significant, indicating that preference for multiple-play, relative to single-play, is higher for risk averse individuals especially when the alternation bias belief is stronger. In fact when people tend to believe in more repetition, i.e. the REP-BIAS group, the estimation of the interaction $RA \times MULT - PLAY$ is less important and less significant or even turn to be negative (see this estimation in the same Table 6). This is consistent with the idea that when risk averse individuals believe in more repetition, the relative preference for multiple-play treatments decreases.

In order to illustrate results in Table 6 we can consider the WTA the pain treatment in both scenarios. For risk seekers the percentage of people accepting the single and multiple-play treatment was 94.6% and 84.6%, respectively. However the same figures for risk avoiders were 59.9% and 63.2% respectively. This is, the relative appealing of the multiple-play intervention was higher for the risk averse group. This pattern is even more striking when selecting those who believe in more alternation (the ALT-BIAS group according to Pr. & Per.) the treatment was accepted for the risk seekers by 93.5% and 85.9% in the single-play and multiple-play scenario. The same figures for risk averse subjects were 59.7% and 69.5% respectively. So again the multiple-play treatment was much more appealing, in relative terms, for risk averse individuals who believe is more alternation between random events.

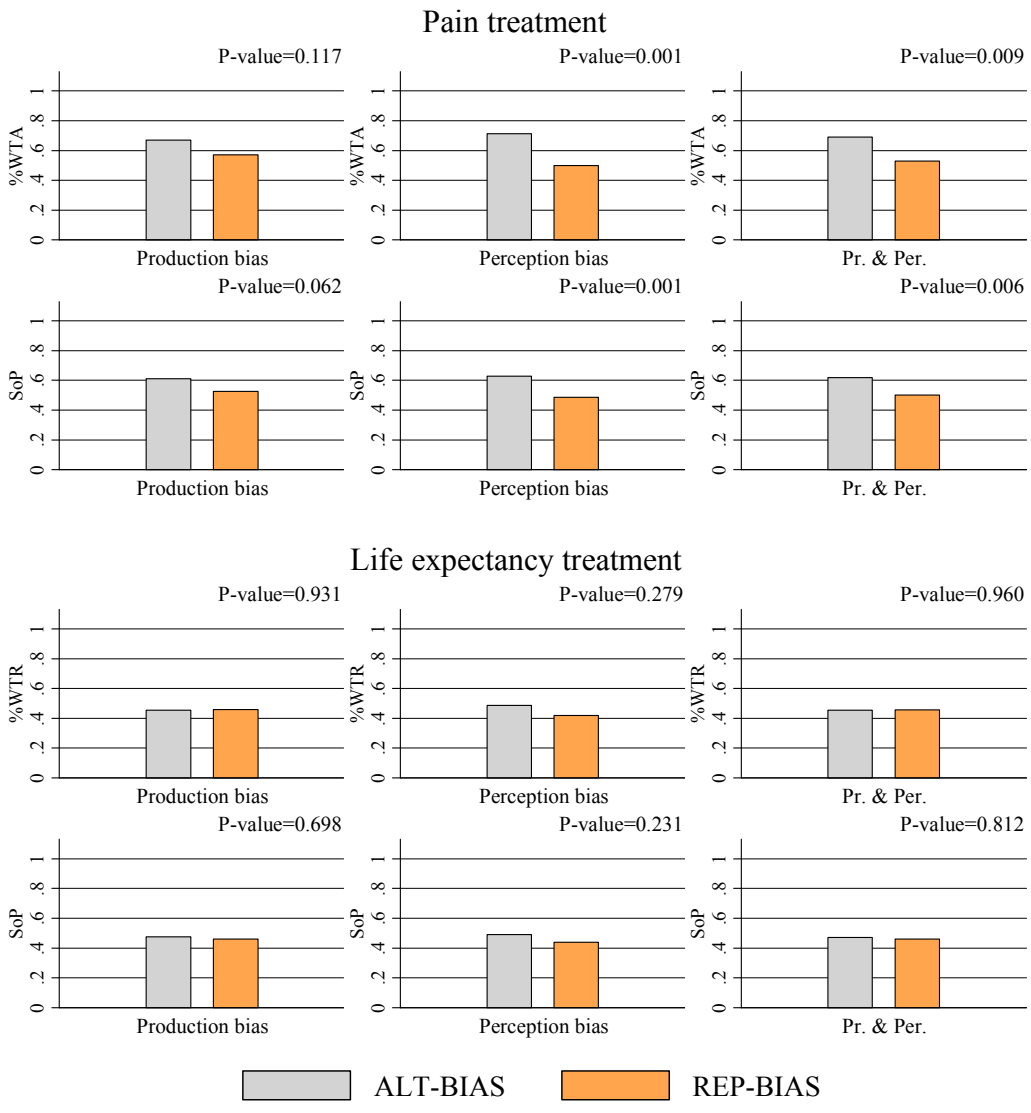


**Figure 2. Preferences for multiple-play treatments by repetition bias. Risk averse individuals.** Willingness to Accept (WTA) or Recommend (WTR) and Strength of Preference (SoP). T-test p-values shown above each graph

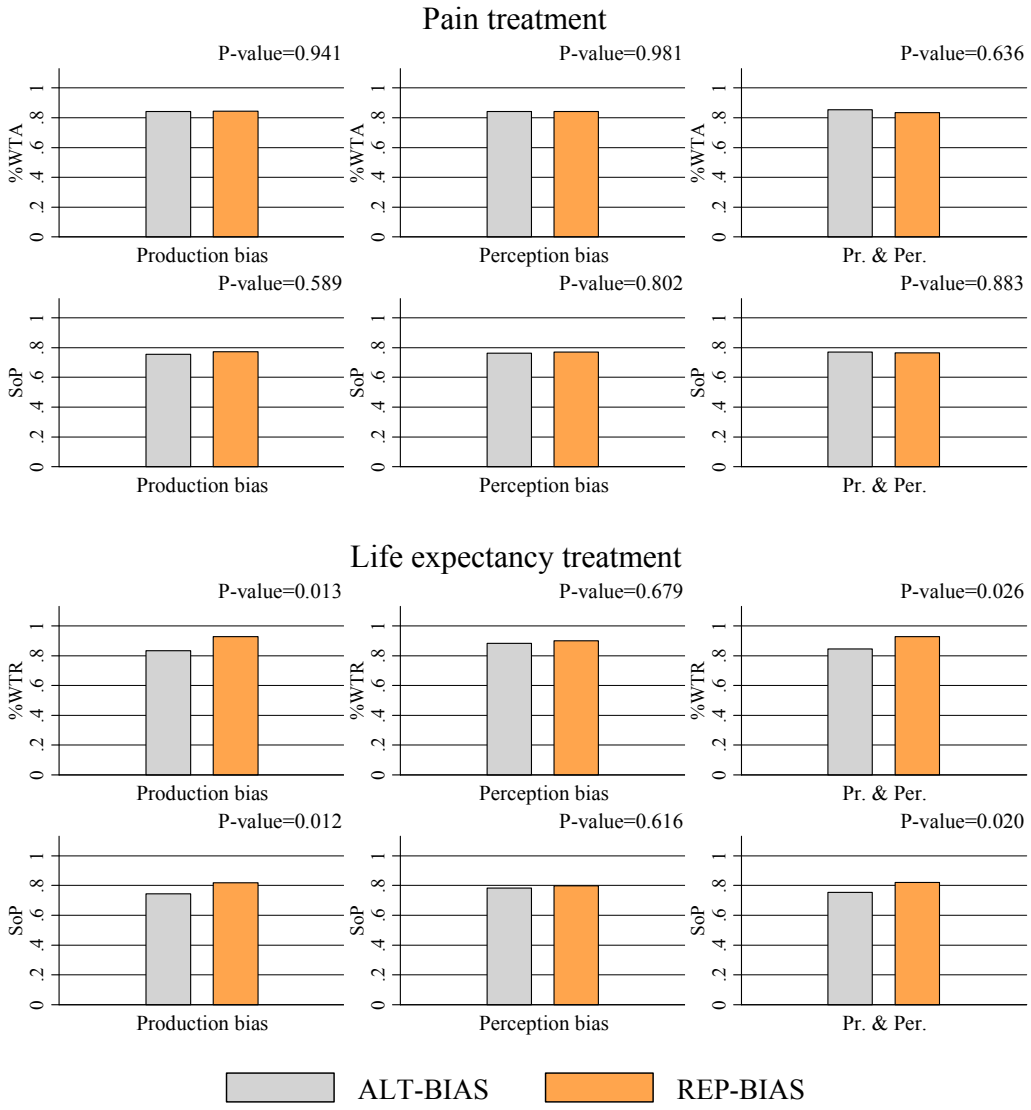


**Figure 3. Preferences for multiple-play treatments by repetition bias. Risk prone individuals.** Willingness to Accept (WTA) or Recommend (WTR) and Strength of Preference (SoP). T-test p-values shown above each graph

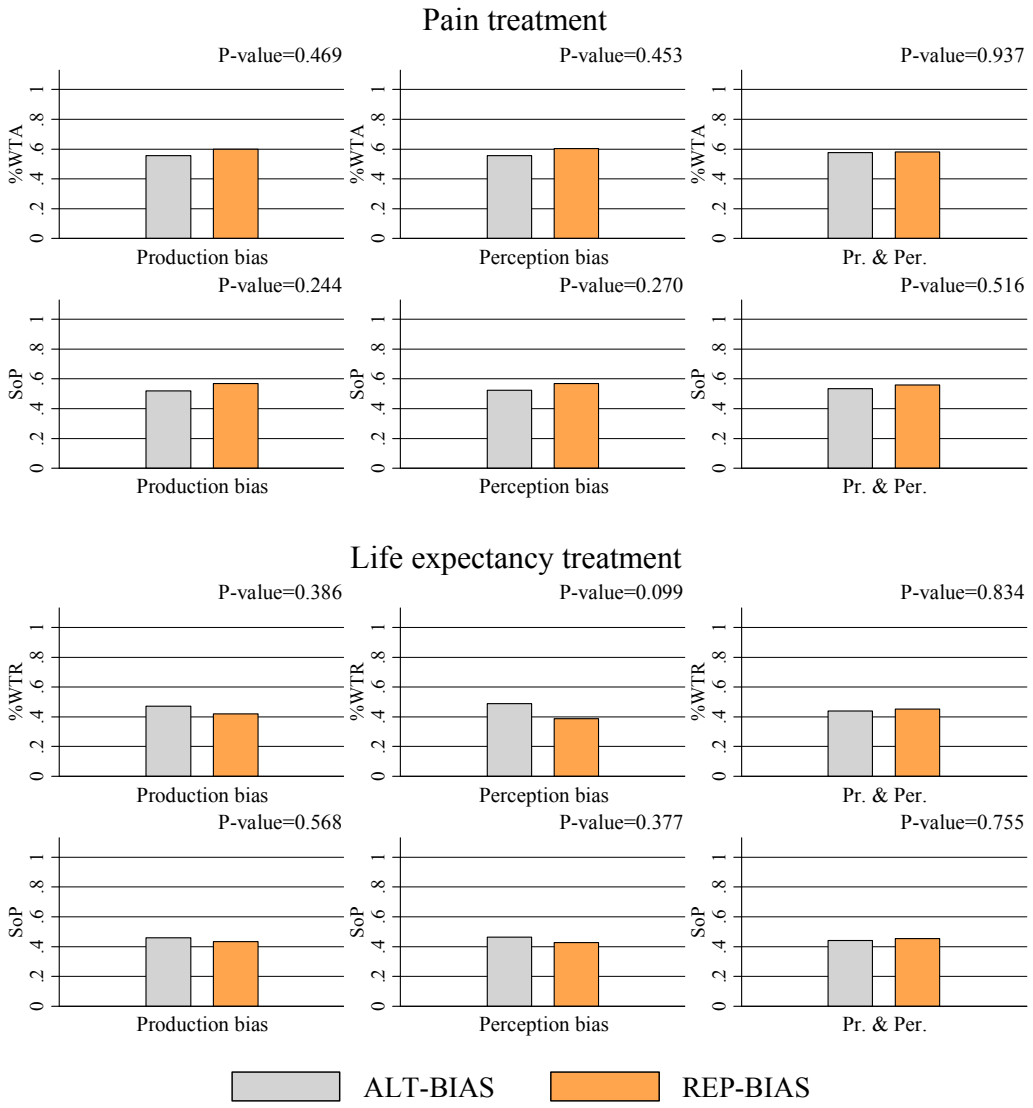


**Figure 4. Preferences for single-play treatments by repetition bias. Risk averse individuals.** Willingness to Accept (WTA) or Recommend (WTR) and Strength of Preference (SoP). T-test p-values shown above each graph

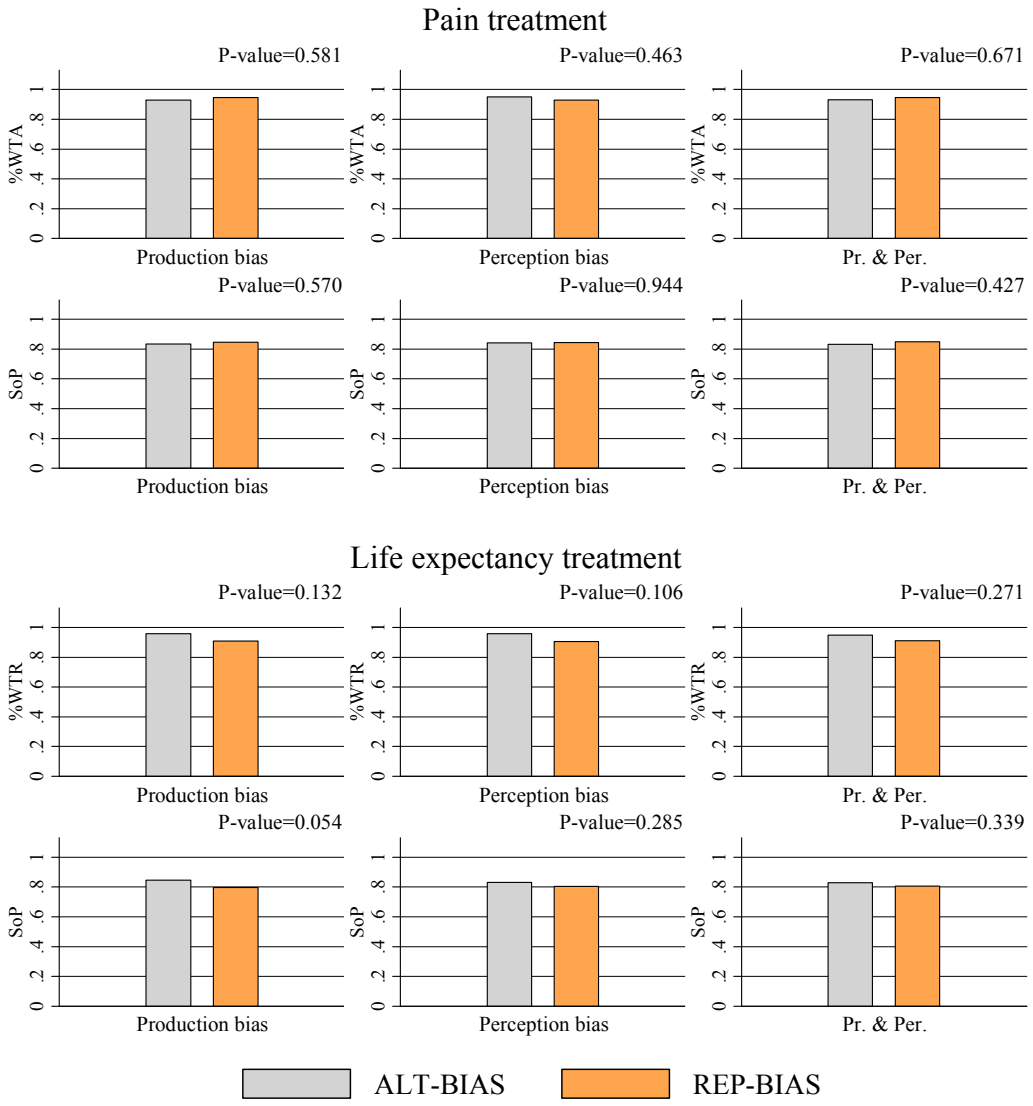


**Figure 5. Preferences for single-play treatments by repetition bias. Risk prone individuals.** Willingness to Accept (WTA) or Recommend (WTR) and Strength of Preference (SoP). T-test p-values shown above each graph

**Table 5. Interaction between repetition bias and risk preferences. Multiple-play treatments**

| | PAIN TREATMENT | | | | | | LIFE EXPECTANCY TREATMENT | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WTA (logit) | | | SoP (linear regression) | | | WTR (logit) | | | SoP (linear regression) | | |
| VARIABLES | Pr. | Per. | Pr. & Per. | Pr. | Per. | Pr. & Per. | Pr. | Per. | Pr. & Per. | Pr. | Per. | Pr. & Per. |
| RA | -1.69*** | -1.29*** | -1.66*** | -0.25*** | -0.21*** | -0.25*** | -2.64*** | -3.20*** | -2.83*** | -0.41*** | -0.47*** | -0.44*** |
| | (0.46) | (0.43) | (0.44) | (0.06) | (0.05) | (0.05) | (0.48) | (0.48) | (0.46) | (0.06) | (0.05) | (0.05) |
| REP_BIAS | 0.04 | 0.23 | -0.10 | 0.03 | 0.04 | 0.01 | 1.36*** | 0.25 | 1.27** | 0.10** | 0.02 | 0.09** |
| | (0.39) | (0.39) | (0.39) | (0.04) | (0.04) | (0.04) | (0.50) | (0.49) | (0.52) | (0.04) | (0.04) | (0.04) |
| RA × REP_BIAS | -0.58 | -1.51** | -0.71 | -0.14* | -0.24*** | -0.15** | -1.69** | -0.69 | -1.46** | -0.17** | -0.08 | -0.12* |
| | (0.60) | (0.61) | (0.59) | (0.07) | (0.07) | (0.07) | (0.72) | (0.70) | (0.74) | (0.07) | (0.07) | (0.07) |
| Cons. | 2.38*** | 2.28*** | 2.49*** | 1.45*** | 1.48*** | 1.47*** | 2.04*** | 2.69*** | 2.05*** | 0.86*** | 0.94*** | 0.86*** |
| | (0.68) | (0.69) | (0.68) | (0.32) | (0.31) | (0.32) | (0.72) | (0.74) | (0.73) | (0.30) | (0.30) | (0.30) |
| Obs. | 523 | 523 | 523 | 529 | 529 | 529 | 528 | 528 | 528 | 529 | 529 | 529 |
| (pseudo)$R^2$ | 0.11 | 0.13 | 0.12 | 0.18 | 0.20 | 0.19 | 0.23 | 0.22 | 0.23 | 0.33 | 0.32 | 0.32 |

Note 1. We report coefficients and standard errors (in brackets, below the coefficient). Note 2. ***, **, and * mean coefficient is significant at 1%, 5% and 10% of error respectively. Note 3. These estimations are also controlling for other experimental variables (*random variable*, *information frame* and *perception task order*) and for socio-demographics (*gender*, *age*, *education*, *occupation* and *health*). Note 4. Risk aversion (RA) included as a continuous variable ranging from 0 to 1. Note 5. For each treatment willingness to accept (WTA) or to recommend (WTR) and Strength of Preference (SoP) are estimated according to the production bias (Pr.), perception (Per.) and a combination of both (Pr. & Per.).

**Table 6. Interaction between repetition bias and risk preferences. Single-play treatments**

| | PAIN TREATMENT | | | | | | LIFE EXPECTANCY TREATMENT | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WTA (logit) | | | SoP (linear regression) | | | WTR (logit) | | | SoP (linear regression) | | |
| VARIABLES | Pr. | Per. | Pr. & Per. | Pr. | Per. | Pr. & Per. | Pr. | Per. | Pr. & Per. | Pr. | Per. | Pr. & Per. |
| RA | -3.54*** | -3.88*** | -3.78*** | -0.47*** | -0.46*** | -0.46*** | -6.32*** | -6.19*** | -5.97*** | -0.66*** | -0.64*** | -0.66*** |
| | (0.60) | (0.57) | (0.57) | (0.05) | (0.05) | (0.05) | (0.91) | (0.88) | (0.77) | (0.05) | (0.05) | (0.05) |
| REP_BIAS | 0.24 | -0.31 | -0.18 | 0.00 | -0.01 | -0.00 | -1.69** | -1.73** | -1.28* | -0.08* | -0.06 | -0.06 |
| | (0.57) | (0.57) | (0.57) | (0.04) | (0.04) | (0.04) | (0.79) | (0.78) | (0.69) | (0.04) | (0.04) | (0.04) |
| RA × REP_BIAS | -0.37 | 0.17 | -0.02 | 0.03 | 0.01 | 0.01 | 1.86* | 1.65 | 1.65* | 0.07 | 0.04 | 0.09 |
| | (0.80) | (0.79) | (0.79) | (0.07) | (0.07) | (0.07) | (1.02) | (1.01) | (0.92) | (0.07) | (0.07) | (0.07) |
| Cons. | 2.67*** | 3.00*** | 2.95*** | 0.84*** | 0.84*** | 0.83*** | 5.00*** | 5.04*** | 4.63*** | 0.76*** | 0.79*** | 0.77*** |
| | (0.78) | (0.79) | (0.79) | (0.26) | (0.26) | (0.26) | (1.00) | (0.99) | (0.92) | (0.27) | (0.27) | (0.27) |
| Obs. | 519 | 519 | 519 | 520 | 520 | 520 | 515 | 515 | 515 | 520 | 520 | 520 |
| (pseudo)$R^2$ | 0.26 | 0.26 | 0.26 | 0.32 | 0.32 | 0.32 | 0.33 | 0.34 | 0.33 | 0.41 | 0.41 | 0.41 |

Note 1. We report coefficients and standard errors (in brackets, below the coefficient). Note 2. ***, **, and * mean coefficient is significant at 1%, 5% and 10% of error respectively. Note 3. These estimations are also controlling for other experimental variables (*random variable*, *information frame* and *perception task order*) and for socio-demographics (*gender*, *age*, *education*, *occupation* and *health*). Note 4. Risk aversion (RA) included as a continuous variable ranging from 0 to 1. Note 5. For each treatment willingness to accept (WTA) or to recommend (WTR) and Strength of Preference (SoP) are estimated according to the production bias (Pr.), perception (Per.) and a combination of both (Pr. & Per.).

**Table 7. Estimation of Multiple-play treatment effect interacted with risk profile and repetition bias.**

| | PAIN TREATMENT WTA (logit) | | | LIFE EXPECTANCY TREATMENT WTR (logit) | | |
|---|---|---|---|---|---|---|
| VARIABLES | ALL | Pr. & Per. | | ALL | Pr. & Per. | |
| | | ALT-BIAS | REP-BIAS | | ALT-BIAS | REP-BIAS |
| RA | -3.59*** | -3.72*** | -3.69*** | -4.60*** | -5.49*** | -4.07*** |
| | (0.38) | (0.56) | (0.54) | (0.42) | (0.73) | (0.55) |
| MULT_PLAY | -1.12*** | -1.15** | -1.11** | -0.81** | -2.16*** | 0.32 |
| | (0.33) | (0.51) | (0.45) | (0.39) | (0.65) | (0.56) |
| RA × MULT_PLAY | 1.65*** | 2.00*** | 1.38** | 1.03* | 2.62*** | -0.43 |
| | (0.47) | (0.71) | (0.67) | (0.54) | (0.86) | (0.79) |
| Cons. | 3.08*** | 2.78*** | 3.35*** | 2.53 | 3.72*** | 3.61*** |
| | (0.51) | (0.76) | (0.72) | (1.56) | (0.85) | (0.77) |
| Obs. | 1,047 | 517 | 524 | 1,049 | 517 | 530 |
| (pseudo)$R^2$ | 0.164 | 0.163 | 0.192 | 0.255 | 0.246 | 0.29 |

Note 1. We report coefficients and standard errors (in brackets, below the coefficient). Note 2. ***, **, and * mean coefficient is significant at 1%, 5% and 10% of error respectively. Note 3. These estimations are also controlling for other experimental variables (*random variable*, *information frame* and *perception task order*) and for socio-demographics (*gender*, *age*, *education*, *occupation* and *health*). Note 4. Risk aversion (RA) included as a continuous variable ranging from 0 to 1. Note 5. We show WTA and WTR models, Strength of Preference (SoP) estimations give the same qualitative results. Note 6. We classify individuals according to the combined Pr. & Per. index, nonetheless the use of production and perception bias separately implies the same qualitative results.

## 5. Discussion

A rational decision making process requires that people have correct beliefs about choice alternatives. For example, if someone is buying a car she should have correct beliefs about different characteristics like the power of the engine, the speed, safety and fuel consumption per mile/kilometer. In a similar way physicians and patients from the general public deciding over health alternatives should know different characteristics of the medical treatments. The results shown here suggest that individuals should have correct information about the sequential dependence between health outcomes of treatments that are going to be applied several times. When informed about the unconditional probabilities of success of a medical treatment individuals could have subjective beliefs about the sequential performance (i.e. conditional probabilities) of multiple-plays of the medical intervention. This could lead to poor decisions to the extent that the true underlying medical random process is very different to the patient's beliefs, even causing welfare losses (choosing the alternative that is actually not the most preferred). For example, when deciding about getting a flu shot, risk averse people could be very much willing to accept this medical intervention if they think that after the fail of one year vaccination the next shot will be a success. However, that may not be the optimal decision in case that the effect of vaccinations are actually positively correlated.

From an academic perspective the analysis shown here is interesting because it tries to contribute to a research line studying medical treatments in different perspectives. The single and multiple-play perspectives have been considered distinct decisions approaches (DeKay, 2011; DeKay et al., 2006; DeKay and Kim, 2005; Redelmeier and Tversky, 1992; Redelmeier and Tversky, 1990). Here we propose a new argument that allows us to differentiate the underlying decision making for a medical treatment that is applied just once from the multiple applications of the same medical procedure. Given the nature of single-applications, there seems to be no room for an effect of conditional probabilities of health outcomes. On the contrary, multiple-play treatments are very different depending on the level of repetition or autocorrelation between health outcomes as shown in Table 2. The evidence presented here provide support for this idea, given that we find no systematic effect of the repetition bias on preferences for single-play treatments. On the contrary, the effect estimated on preferences for multiple-play treatments turns to be more statistically significant and quantitatively important.

Three further connections can be discussed between the analysis shown here and previous studies about multiple-pay lotteries. First in previous studies the subjective fungibility of health outcomes have been considered a key variable to improve the attractiveness of multiple-play treatments with positive expected health gains (DeKay, 2011; Dekay, 2005). Those who considered health outcomes as fungible were more willing to accept (recommend) repeated-play medical treatments. Also, fungibility seems to differ among groups of respondents, being higher for voters than for physicians (DeKay, 2011). Given that the theoretical effect of the repetition bias requires some kind of aggregation as shown in Table 2, the impact of the repetition bias could be moderated by the extent to which people think that health outcomes are fungible. The extension of the analysis shown here to groups of people with lower subjective fungibility, like physicians, could give different results.

The second link between the present analysis and previous relevant literature is the effect of the frequency vs. probability frame. In the frequency frame individuals seems to be more prone to accept medical treatments that are going to be repeated for different patients (DeKay, 2006). This can be attributed to the different connotations derived from the probability and frequency representation of a medical treatment. When individuals are said that the probability of success is 50% the intuitive understanding could be very different to when they are said that 5 patients are expected to be benefited out of 10 patients. In the frequency case, people could interpret that the treatment would succeed for 5 patients if 10 patients are treated. A similar cognitive process could be happening when a person believes in alternation between events. In the extreme case, with probability of alternation being P(Alt.)=1 the application of a treatment to 10 patients, or 10 times to a patient, would be a certain health prospect giving 5 successes for sure (see Table 2). As a consequence, risk averse individuals are likely to accept a treatment in this case.

Eventually, the third link with previous literature can be made about the varying willingness to accept single vs. multiple-play treatments. The most extending finding is that positive expected gains treatments are relatively more preferred when they are repeated (DeKay, 2011; Redelmeier and Tversky, 1992) at least when the frequency of success is shown (DeKay et al., 2006). However, we find no significant differences between the two perspectives (see Figure 1). Only when we separate individuals according to their risk aversion we find an effect. Specifically, the multiple-play

perspective seems to be relatively more appealing for more risk averse individuals, especially if they believe in the alternation bias. We think that this pattern is consistent with previous evidence. In those studies where the multiple-play treatment is more attractive than the single-play tend to have a high risk aversion profile. For example, in Redelmeier and Tversky (1992) only 15% of physicians recommended the single treatment, in spite of the higher expected gains. Also, in DeKay (2011) less than 50% of participants (either voters, physicians or medical administrators) recommended the single-treatment. Also, Sun et al. (2014) finds that the varying preference for single and multiple-play scenario was more important when outcomes were framed in a gain scenario, i.e where people tend to shown more risk aversion, with 46.6% and 81% choosing the higher expected value option in the single and multiple-play perspectives respectively (see Sun et al.'s Figure 1B). However, in a loss frame, i.e. where people tend to shown more risk seeking behavior, the differences were much less important, 66.1% vs 73.2% rate of acceptance for the single and multiple-play scenario.

In conclusion, we have carried out a survey where preferences for multiple-play medical treatments change with the level of repetition bias and underlying risk preferences of people. Consequences for individual decision making are considered given the evidence of people having beliefs that deviates from the actual characteristics of random events. The links between this study and previous literature on single vs. multiple-play decisions are considered and could provide us with ideas for future research.

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## Appendix

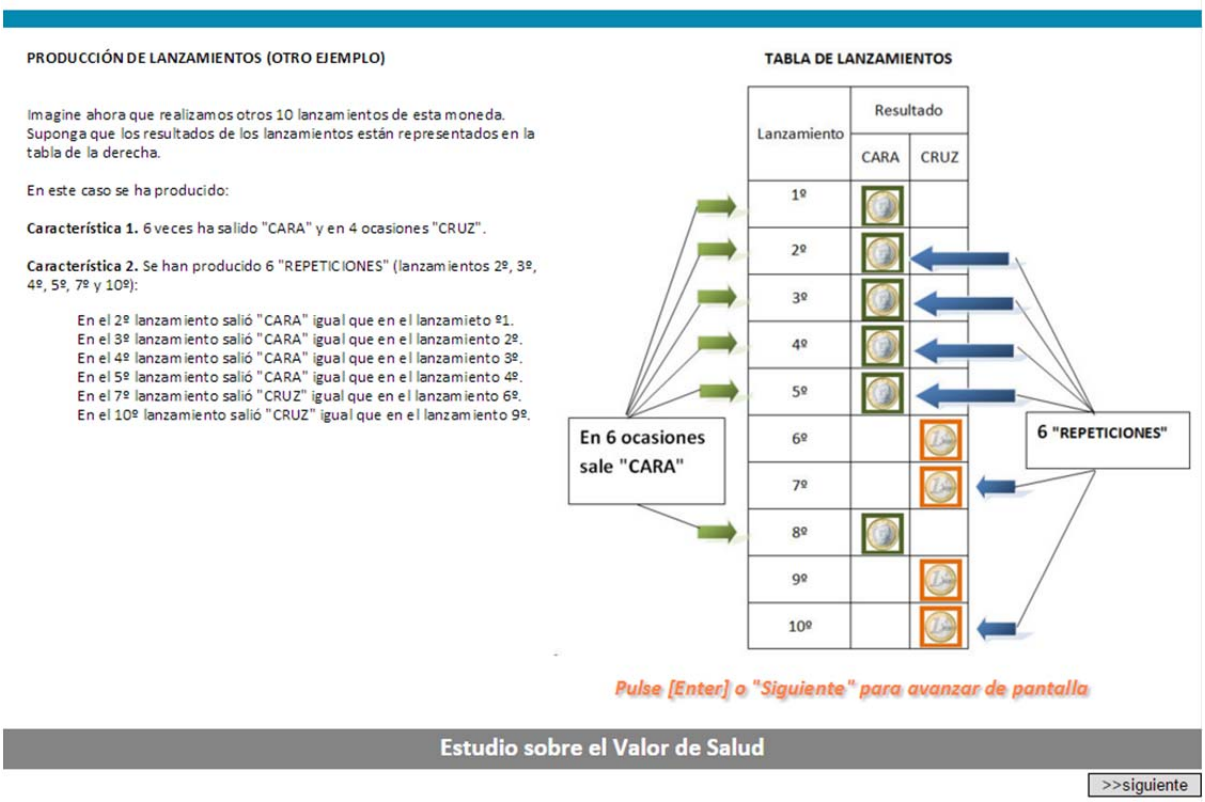


**Figure A1. Explanation of outcome and repetition probability.** In this example, the screen showed text and a graphic for a ten realizations (*LANZAMIENTOS*) sequence with 6 heads (*CARAS*), 4 tails (*CRUZ*) and 6 repetitions (*REPETICIONES*). Spanish in brackets

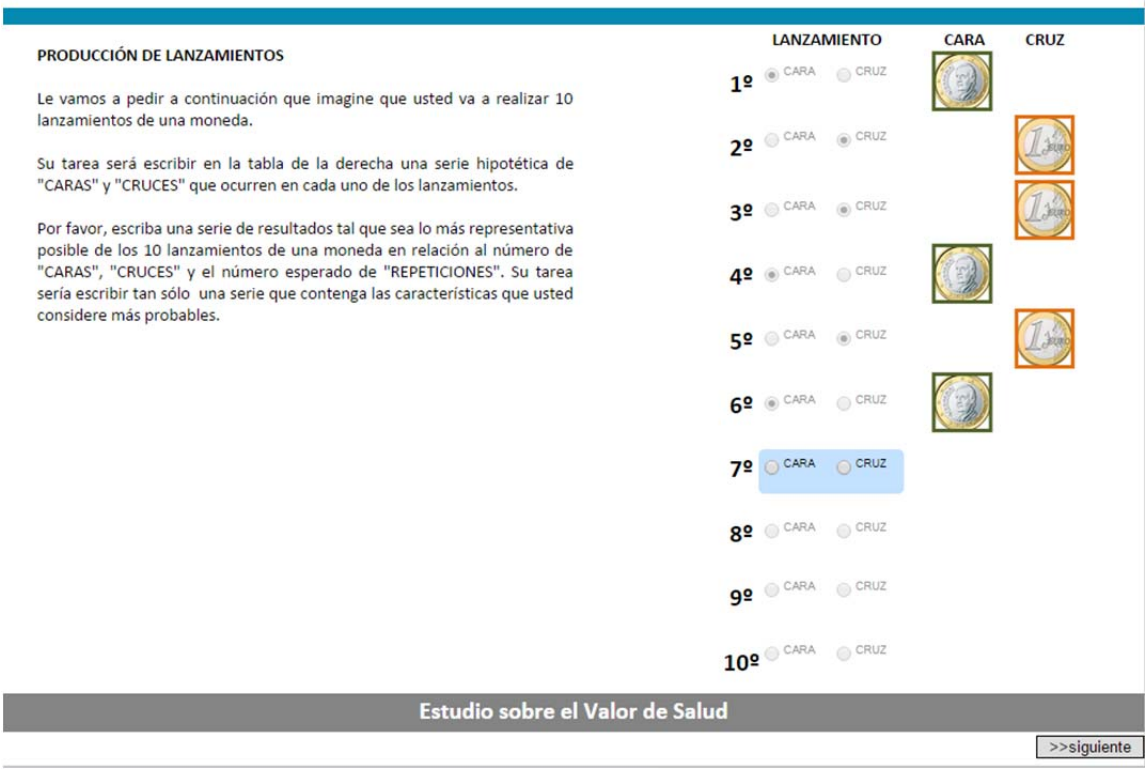


**Figure A2. Generation of a sequence.** In this example, the subject is generating the seventh realization (LANZAMIENTO). Spanish in brackets

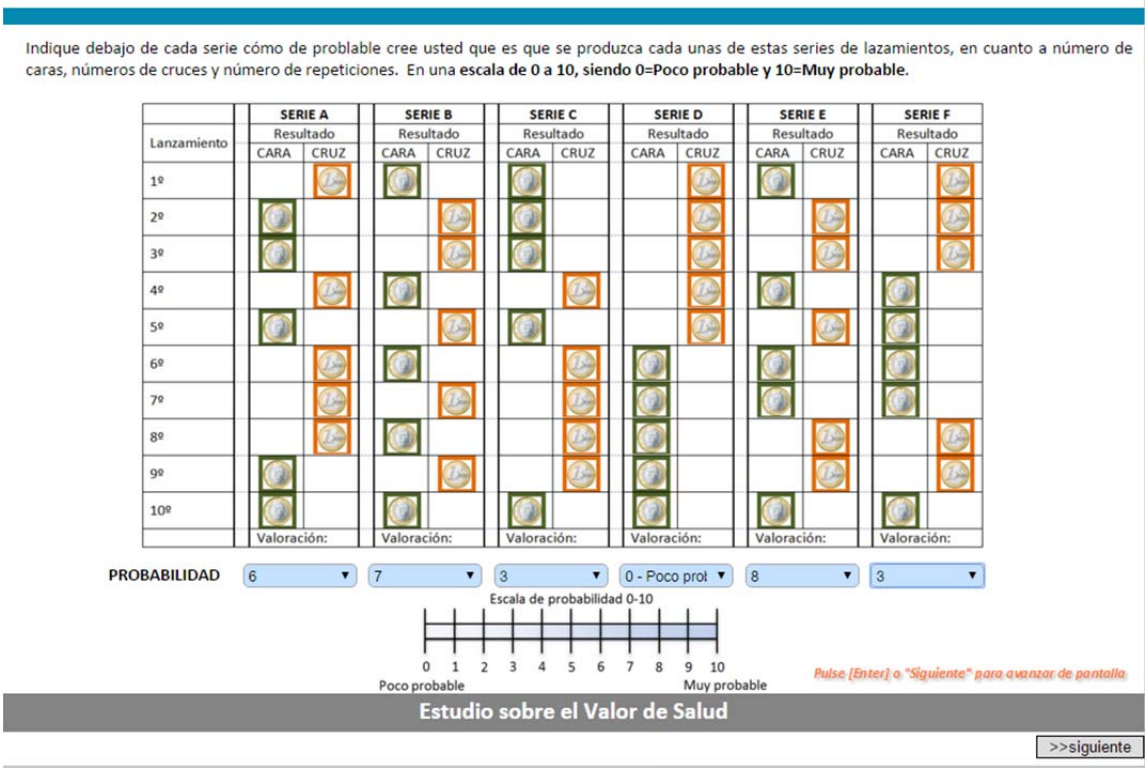


**Figure A3. Perception exercise.** Each sequence (*SERIE A-F*) is evaluated according to the likelihood (*PROBABILIDAD*) in a scale from 0 to 10. Spanish in brackets

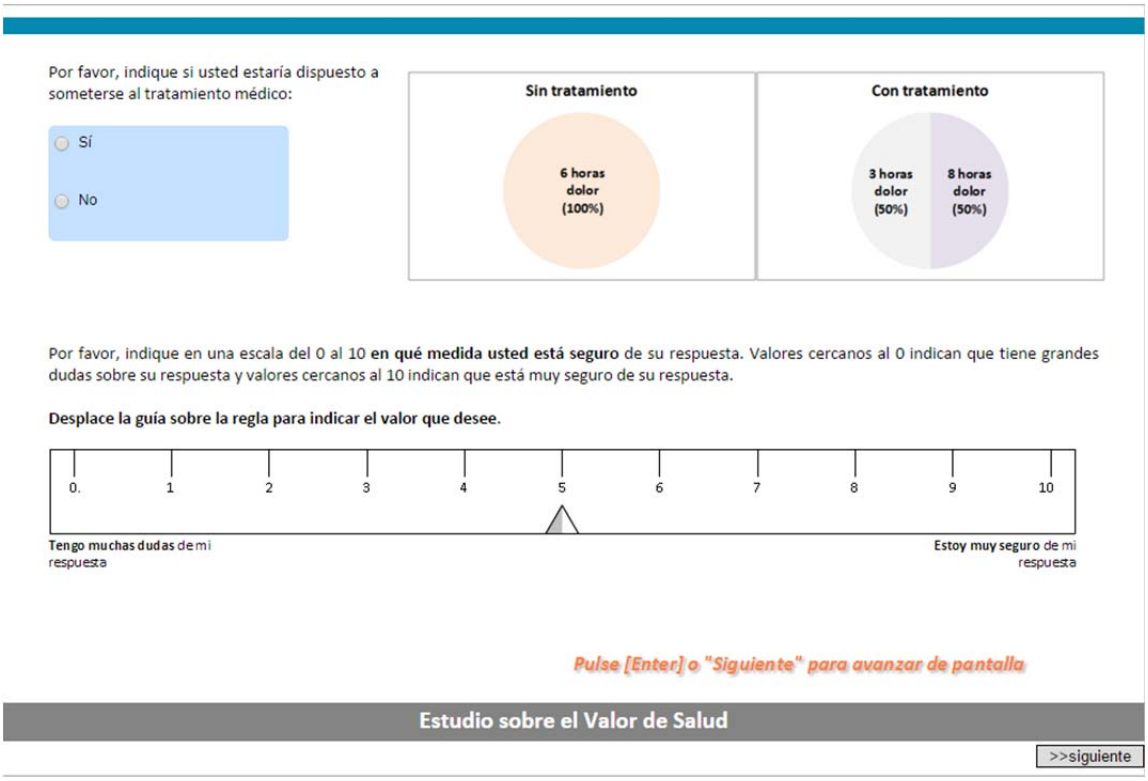


**Figure A4. PAIN TREATMENT single-play decisions.** People decided between a treatment (*con tratamiento*) with a 50/50 chance of 3/8 hours of pain (*horas de dolor*) and a sure situation with 6 hours of pain (6 *horas de dolor*). Spanish in brackets

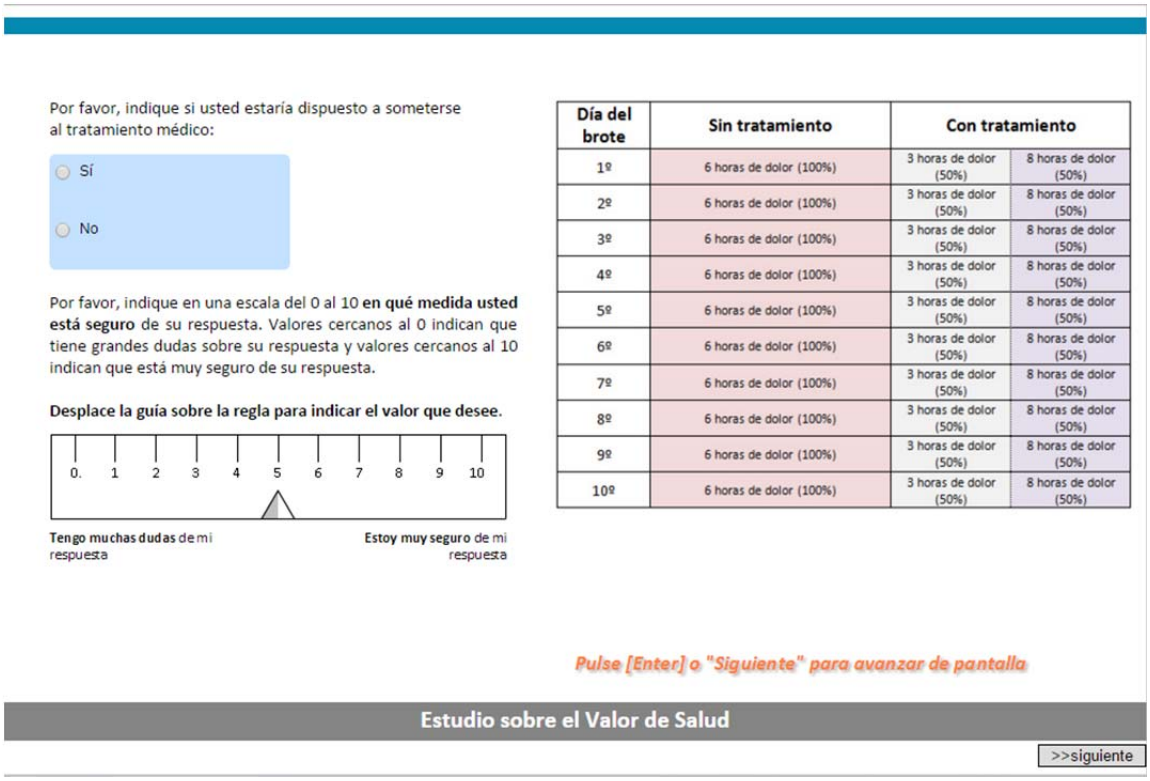


**Figure A5. PAIN TREATMENT multiple-play decisions.** People decided between a treatment with a 50/50 chance of 3/8 hours of pain (*horas de dolor*) each of the ten days a sure situation with 6 hours of pain each day. Spanish in brackets

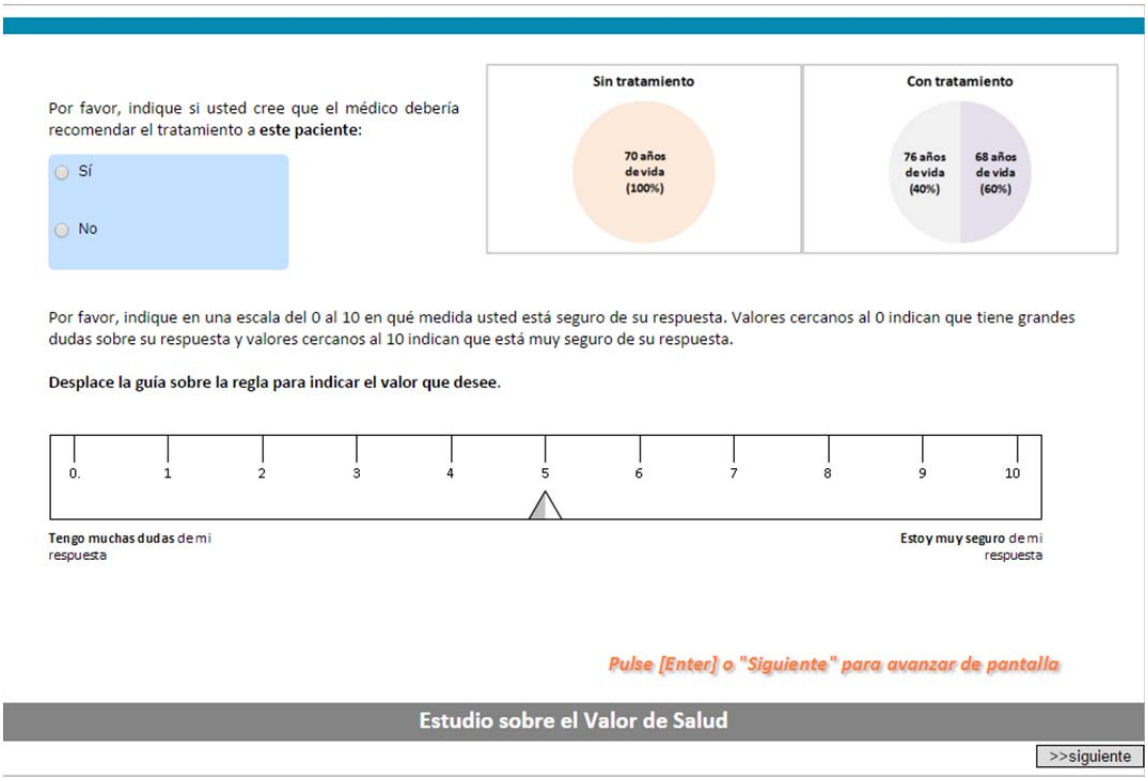


**Figure A6. LIFE EXPECTANCY TREATMENT single-play decisions.** People decided between a treatment (*con tratamiento*) with a 40/60 chance of 76/68 years of life (*años de vida*) and a sure situation (*sin tratamiento*) with 70 years of life (70 *años de vida*). Spanish in brackets

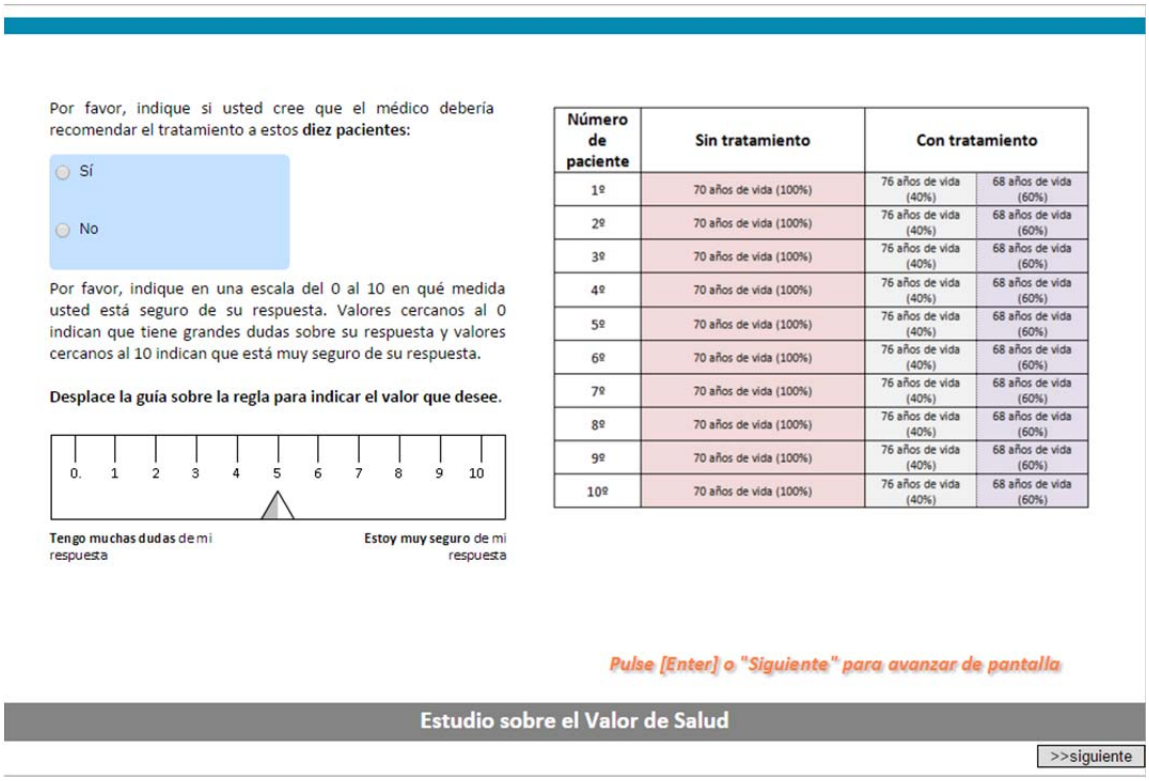


**Figure A7. LIFE EXPECTANCY TREATMENT multiple-play decisions.** People decided between a treatment (*con tratamiento*) with a 40/60 chance of 76/68 years of life (*años de vida*) for each of the ten patients (*pacientes*) and a sure situation (*sin tratamiento*) with 70 years of life (70 *años de vida*) for each patient. Spanish in brackets