The Accuracy of Mathematical Models of Justice Evaluations*

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Word count: 4701

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* This research was partly funded by a grant from the Swedish Research Council. The author may be reached via kimmo.eriksson@mdh.se. Comments from an anonymous reviewer on a previous version of this manuscript were gratefully received.

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Abstract

Jasso (1978) proposed a Universal Law of Justice Evaluations describing a logarithmic relationship between the perceived injustice of a reward and the ratio between this reward and the just reward. In applications this model is treated as if it were exact, whereas analogous models in psychophysics have empirically established degrees of uncertainty. Here we make the first assessment of the magnitude of error in the logarithmic model of justice evaluations, using published data and a novel experiment. For the standard application of the model, where just rewards are inferred from justice evaluations, we find that the inherent inaccuracy leads to errors of about 15 percent on average. We also compared the logarithmic model to two non-logarithmic models. Almost 20 percent of our respondents made justice evaluations that were more consistent with one of the latter models, suggesting that no single model is really universal.

The Accuracy of Mathematical Models of Justice Evaluations

Injustice is one of the core concepts in sociology and political philosophy, studied in classic works by Marx, Durkheim and Rawls. A problem with the study of injustice is its subjective nature; indeed, conflicts often become difficult precisely because parties have different opinions about what resolution would be just. Hence, an important task for social science is to find ways of dealing scientifically with subjective notions of injustice. In the 1970s, Guillermina Jasso and Peter Rossi launched an influential quantitative research program in this vein, where they studied people's opinions of distributive justice through vignettes. In this paradigm, each vignette describes relevant details about a rewardee so that the respondent can form an opinion of what reward would be just. The respondent is then asked to judge the injustice in one or more hypothetical rewards to the rewardee described in the vignette. Analysis of such a data set from Jasso and Rossi (1977) led Jasso (1978) to propose what she called a "universal Law of Justice Evaluation about shares of all goods of social distribution" (p. 1417). This is a mathematical relationship proposed to hold between three entities: First, the *actual reward* (A), i.e., the hypothetical reward presented together with the vignette. Second, the *just reward* (C) for the vignette rewardee in the respondent's opinion. Third, the *justice evaluation* (J) expressed by the respondent. Jasso's Law of Justice Evaluation says that the relationship between the justice evaluation and the ratio between the actual and just rewards is logarithmic:

$$J = \theta \ln(A/C) \qquad (1)$$

The proportionality constant θ may vary between different respondents, but must be constant for any given respondent over a given rating task (otherwise, the law would be devoid of content). Observe that equation (1) does not contain any error-term. As Jasso (2006, p. 383) puts it: "The justice evaluation function posits an exact relation between the actual reward, the just reward, and the justice evaluation [...] Thus, the equation can be used to solve for any of the three variables, given the other two." In particular, the just reward can be expressed in terms of the other entities as follows (Jasso 2006, p. 385):

$$C = A \exp(-J/\theta) \qquad (2)$$

Indeed, in numerous studies where the Law of Justice Evaluation is applied it is used in this way as if it were an exact mathematical identity (e.g., Jasso and Webster 1997, 1999; Jasso and Wegener 1997; Jasso and Meyersson Milgrom 2008).

Of course, in reality the Law of Justice Evaluation cannot be an exact description of the relationship between rewards and respondents' justice evaluations. It may be a fairly good description, but certainly not exact – we are, after all, dealing with the workings of the human mind, which is a notoriously complex field. To illustrate this point, let us discuss another and more firmly established research area where people experience magnitudes: the psychophysics of hearing, a field of research with clear resemblance to justice evalutions as pointed out by Markovsky (1988). In the abstract of a classic paper by Stevens (1955), the relationship between subjective loudness and objective intensity of sound was summarized as follows: "The evidence suggests that for the typical listener the loudness *L* of a 1000-cycle tone can be approximated by a power function of the intensity *I*" (p. 815). Here we see that Stevens presented a mathematical model (a power function) for the relationship between the experience and the underlying entity (sound intensity) – but he also made clear that this relationship is only approximative and subject to individual variations. Stevens also included graphs showing how much subjects' judgments deviated from the proposed model. Even so, the scope of the model is still contested; e.g., different mathematical models seem to be appropriate depending on whether judgments are about the loudness of a single sound or the difference in loudness between two sounds (Marks, 1979).

Our aim in this paper is to start putting the logarithmic model of justice evaluations on the same kind of empirical footing as Stevens' model for loudness judgments. First, we will assess the current empirical evidence. Second, we will report a new experiment designed specifically to investigate how individual respondents make justice evaluations based on ratios between actual and just rewards. Finally, we will discuss what conclusions to draw on the accuracy of the logarithmic model, whether other models may be more appropriate, and what might be the proper use of mathematical models of justice judgments.

Empirical Data on Justice Judgments

Let us first recall how Jasso (1978) came up with the logarithmic model of justice evaluations. First she made a theoretical assessment of a number of possible models derivable from previous literature, and indentified shortcomings. She then analyzed a large dataset from a previous vignette study (Jasso and Rossi, 1977). Each vignette described either an individual or a couple by specifying seven attributes: sex, marital status, number of children, years of formal education, occupation, earnings, and age. Each respondent was handed a set of vignettes to judge on a nine-point scale ranging from "-4 Extremely Underpaid," through "0 Fairly Paid," to "+4 Extremely Overpaid." From this set of justice evaluations of vignettes, Jasso (1978) derived the logarithmic model by looking at data plots:

> "Plots of both the mean justice evaluation for the natural logarithm of each value of earnings (for example, in the two-earner married-couple case, N = 51) and of the mean justice evaluation for the logarithm of earnings for each distinctly different vignette (e.g., in the same case, N = 281) indicate unmistakably that the justice evaluation is linearly related to the logarithm of earnings" (p. 1408).

Unfortunately, Jasso (1978) does not show these plots, nor is any other direct measure of the accuracy of the proposed linear relationship provided. The only quantitative results presented are the results of linear regressions of justice evaluations on all vignette attributes, with earnings represented by their logarithms. These regression models yield R^2 values of 0.71 or less, so the fit is very far from perfect. However, because of the multiple attributes, it is impossible to say how much of the errors that is due to inaccuracy of the logarithmic specification. Indeed, the entire issue of accuracy of the logarithmic model is not mentioned at all.

Soltan (1981) pointed out that the logarithmic law was obtained by a curve-fitting exercise that possibly relied on the particular nine-point scale used in the data-collection, and concluded that "empirical tests remain the final arbiter." In a direct reply, Jasso (1981) maintained that the logarithmic specification of the justice evaluation function was "provisionally tenable." Although this wording suggests that further empirical testing is necessary, only additional philosophical arguments for the logarithmic model were put forward by Jasso (1990) when she returned to this question.

The only attempt at an empirical validation of the logarithmic model seems to be an experimental paper by Markovsky (1985) who showed graphs of how well a logarithmic model fitted his data, aggregated over all participants. The graphs were non-linear and Markovsky pointed out that "these non-linearities fit well with the logarithmic model." (p. 835). However, Markovsky made no attempt to assess the degree of accuracy of the logarithmic model for individual participants. Nor has anyone else, although data exist that would allow such assessment. Jasso and Webster (1999) let each respondent make justice judgments about seven different rewards for the same vignette. Each such set of seven judgments thereby constitute a dataset that should conform to the logarithmic law. In order to infer which reward the respondent perceives as just for each vignette, Jasso and Webster fitted the logarithmic model to each seven-point dataset. From this exercise, they reported an average proportion of variance explained (R^2) of 0.83 (p. 373).

In social sciences we are used to thinking of an R^2 value of 0.83 as very high, because we are normally dealing with complex phenomena for which there are several underlying factors, some of which may be unknown. This is not the situation here, however. By the experimental design, there is just a single source of variation for the seven justice evaluations, namely the reward under evaluation, so if the logarithmic model were perfect there is no reason why the R^2 value should not be very close to 1. As an illustration, Figure 1 shows an example of seven fictitious justice evaluations and the curve obtained by fitting a logarithmic model to these data. This example is chosen so that the R^2 value is 0.83. Observe how far the the fictitious data are far from forming a logarithmic shape; indeed, their graph is convex, whereas a logarithmic graph is concave.

Figure 1 about here

The point of Figure 1is to illustrate how large the deviations from a logarithmic model must be in a seven-point dataset in order for the R^2 value to be as low as 0.83. Because 0.83 was the average R^2 value in the study of Jasso and Webster, it seems that as a description of individual respondents' justice evaluations, the logarithmic model was typically as inaccurate as in the example in Figure 1. Without the raw data we cannot say anything more specific. However, even with the raw data we would not be able to make a perfect assessment of the logarithmic model, because the "just reward" is not known. Indeed, the law is used precisely in order to infer the just reward (Jasso and Webster, 1999). Next we report a new experimental study designed to circumvent this problem.

An Experimental Study

Ever since the paper of Jasso (1978), studies of justice evaluations of vignettes have had the purpose of determining the effects of various attributes on the just reward as inferred by the logarithmic law (e.g., Jasso and Webster 1997, 1999; Jasso and Wegener 1997; Jasso and Meyersson Milgrom 2008). In contrast, the purpose of the present study is to assess the logarithmic law itself. We are therefore not interested in the effects of vignette attributes. Instead of such attributes we present the just reward directly. This gives us perfect control of the just rewards, allowing us to determine the accuracy of the logarithmic law in inferring estimates of just pay. We can also test other model specifications to see whether the logarithmic model is the best for all individuals.

Method

A questionnaire presented 17 vignettes to be rated for injustice (Appendix). The instructions for ratings followed the usual format (cf. Jasso and Meyersson Milgrom 2008). However, instead of presenting a collection of attributes for a rewardee , each vignette presented only a just reward and an actual reward on the following format:

Person X is someone for whom you think 25 000 kr/month would be a just pay.

X's actual pay is 20 000 kr/month. RATE THE INJUSTICE:______

The first sixteen vignettes were created by combination of a just pay chosen from the set {15000 kr, 20000 kr, 45000 kr, 80000 kr} and an actual pay for which the difference to the just pay was chosen from the set {-50%, -26%, -17%, -10%, 11%, 20%, 35%, 100%}.[1] To test that all participants understood the task and took it seriously, the last vignette presented the same just pay and actual pay (30000 kr), for which the rating should always be zero in this task. Finally, participants were asked about what degree of confidence they had in their answers to the task. They gave their answer on a five-point scale from **Very unconfident** ("would probably give very different answers if I were to take the questionnaire at another occasion") to **Very confident** ("would probably give very similar answers if I were to take the questionnaire at another occasion"). As shown in the Appendix, the questionnaire also included one vignette on the standard format (taken from Jasso and Meyersson Milgrom 2008); this question is part of another study and not analyzed here.

The questionnaire was administered on paper to a sample of volunteers for experiments in the GameLab at Stockholm University in Sweden. Participants sat in cubicles separated by privacy screens and filled in the questionnaire individually. When they were done with this task, participants put the questionnaire in an envelope and proceeded with another unrelated study. At the end of the session, participants were given a movie pass as a show-up fee, debriefed and dismissed.

Analysis

For each respondent *r* we fit a logarithmic model to *r*'s responses to the sixteen vignettes (i = 1,...,16):

$$J_{ri} = \theta_r \ln(A_i/C_i) + e_{ri}$$

Here J_{ri} is the respondent's evaluation of vignette i, A_i and C_i are the actual resp. just pay in vignette i, θ_r is the respondent specific proportionality constant, and e_{ri} is the stochastic error term. We can compute the *relative error* in the logarithmic model's estimation of J_{ri} as $REJ_{ri} = |e_{ri}/\theta_r \ln(A_i/C_i)|$. To assess the goodness of the fit of the logarithmic model we compute both the proportion of the variance explained (R^2) and the mean relative error ($MREJ_r$) for each respondent.

[1] Each relative difference was meant to be used twice, but by mistake the relative difference 20% was used three times and -17% only once. This does not affect the point of the analysis, see note to Table 1.

We then follow Jasso (2006, p. 385) in inferring just rewards from the justice judgments by equation (2). For each respondent *r* we use the value of θ_r obtained from the model fitting. so that the equation for the inferred just reward for vignette *i* takes the form

$$C_{ir}' = A_i \exp(-J_{ri}/\theta_r) \quad (3)$$

The true just reward is

$$C_i = A_i \exp((e_{ri} - J_{ri})/\theta_r) \quad (4)$$

Therefore the *relative error in the inferred just reward* is

$$REC_{ri} = |(C_i - C_{ir}')/C_{ir}'| = |1\text{-}\exp(e_{ri}/\theta_r)| \quad (5)$$

and again we compute the mean relative error ($MREC_r$) for each respondent.

Finally, we fit two competing models to the data of each respondent. The first model assumes justice evaluations to be directly proportional to the *ratio* between actual and just payoffs:

$$J_{ri} = \beta_r (A_i/C_i) + e_{ri} \quad (6)$$

The second model assumes that justice evaluations are proportional to the *difference* between actual and just payoffs:

$$J_{ri} = \gamma_r (A_i - C_i) + e_{ri} \quad (7)$$

Both these competing models are discussed by Jasso (1978) and dismissed on philosophical grounds. Here we assess empirically whether this dismissal was well-founded.

Results

61 respondents participated in the study, 32 females and 29 males ranging in age from 19 to 45 years. 57 respondents remained after exclusion of two females who did not rate the last vignette correctly and two men who rated all scenarios by zero.

Results of the analysis of fitting a logarithmic model to the data for each respondent are summarized in Table 1. As in Jasso and Webster (1999), the average value of R^2 was 0.83. The mean value of $MREJ_r$ was 0.64, which means that the estimations of the justice evaluation (J) obtained from the logarithmic model missed the mark by 64 percent on average. The mean value of $MREC_r$ was 0.14, which means that inferred just rewards were off the mark by 14 percent on average.

Table 1 about here

We also performed an analysis of the correlation between the respondents' expressed confidence in their evaluations and the goodness of fit (R^2) of their responses to the logarithmic model. No significant correlation was found (Pearson's R = –0.07, p = 0.57), suggesting that deviations from the logarithmic model are not driven by respondents' lack of certainty.

Finally, for each of the 57 respondents we compared the goodness of fit (R^2) for the three competing models. For the large majority (47 respondents, i.e., 82 percent) the best fit was obtained for the logarithmic model. For a notable minority (18 percent) one of the other models gave a better fit, either the ratio model (7 respondents) or the difference model (3 respondents).

Discussion and Conclusions

We have assessed the accuracy of the commonly used logarithmic model of judgments of injustice of rewards. This model has been proposed as a universal Law of Justice Evaluations (Jasso, 1978), or simply referred to as "the justice evaluation function" (Jasso, 2006). The logarithmic model has been found to capture the overall shape of aggregated data on justice evaluations (Markovsky, 1985), and may therefore be validly used in statistical models on aggregates of many individuals (cf. Shepelak and Alwin, 1986). However, it has not been known how accurately the model captures the justice evaluations of an individual respondent. This is an important question, as the typical application of the logarithmic model is to infer what reward an individual respondent perceives as just (Jasso, 2006).

First we observed that there exist earlier data on the goodness of fit of the logarithmic model for individuals (Jasso and Webster, 1999); the average value of R^2=0.83 suggested that the inaccuracy of the model may be substantial. In an experiment designed specifically to assess the accuracy of justice evaluation models, we replicated this average value of R^2. We found that behind this measure were relative errors in the justice evaluation estimates of more than 60 percent on average. When the logarithmic model was used to infer just rewards, the relative error was 14 percent on average. This rather large uncertainty has heretofore been neglected in studies using this method.

We also tested the fit of two other models that are not logarithmic. In these models the justice evaluations are assumed to be proportional to the ratio resp. difference between the actual and just rewards. The logarithmic model gave a better fit for most respondents. Nonetheless, each of the other two models gave a better fit for a few respondents, who together constituted almost twenty percent of our sample. In other words, we observed large variation between individuals in (expression of) perceptions of injustice. Given the limited data from each participant (16 evaluations) it is, of course, not possible to draw definite conclusions on whether this individual variation in which model fits best reflects systematic differences between individuals or if it simply reflects very large random errors. Regardless of which is the case, however, the same conclusion holds that no model can be expected to fit well to the responses of each individual.

To conclude, the situation for the logarithmic model of justice evaluations is in some respects reminiscent of the status of the power law model of perceived loudness. According to the standard textbook on the psychology of hearing,

> "The power law relationship between intensity and loudness has been confirmed in a large number of experiments using a variety of techniques. However, there have also been criticisms of loudness scaling. The techniques used seem very susceptible to bias effects [...] Very large individual differences are observed, and consistent results are only obtained by averaging many judgments of a large number of subjects." (Moore 2003, pp. 132-133).

Bias effects in justice evaluations were studied by Markovsky (1988). Here we have studied individual differences in the relationship between rewards and justice evaluations. However, it is worth noting that the method we have discussed and used in this paper departs in important ways from the standard approach in psychophysical scaling. Psychophysical judgments are typically provided with respect to a meaningful reference point or “modulus.” So in an audio volume judgment task, the number “50” may be deemed to represent the subjective loudness of a reference tone that happens to be 60 db. The subject then is instructed to judge the volume of a stimulus sound relative to the volume of the audio modulus. So if the stimulus sound seems as though it is 1.5 times the volume of the reference sound, then the response should be "75," or 1.5 times the value associated with the numerical modulus. Proper data collection using psychophysical scaling requires a bit of training so that subjects can practice the unfamiliar act of giving responses proportional to a modulus. A fuller psychophysical scaling treatment should be a priority for future research.

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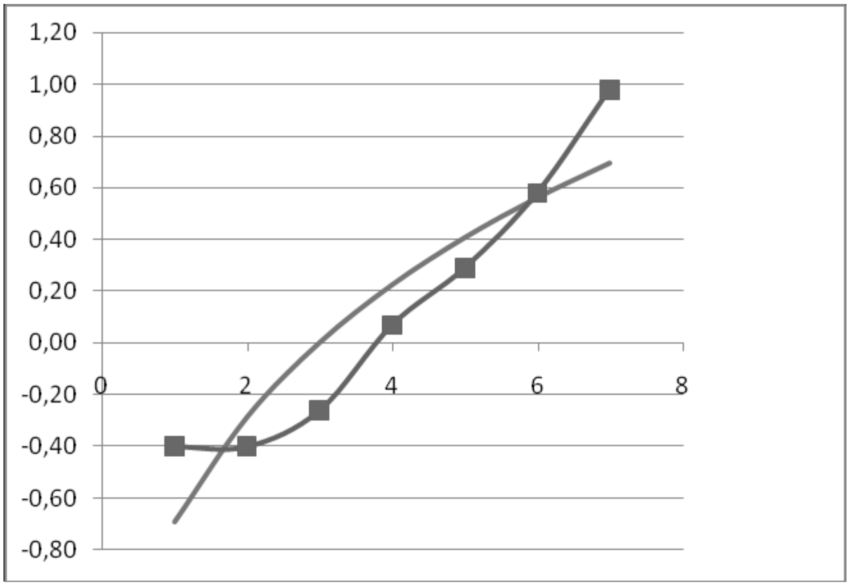
Table 1: Summary of Results of Analysis of Logarithmic Models Fitted to Experimental Data By OLS

Measure	**Mean value**	**Min value**	**Max value**	**Standard deviation**
R^2	0.83	0.49	0.98	0.12
$MREJ_r$	0.64	0.15	1.95	0.36
$MREC_r$	0.14	0.05	0.31	0.07

Note: $N = 57$. If instead we estimate the model from the average observation for each A/C ratio (to compensate for the fact that the number of observations per A/C ratio varied between 1 and 3), all values reported in the table stay unchanged with exception for the max value of MREJ which changes from 1.95 to 1.97.

Figure 1: The squares are seven fictitious justice evaluations of a reward ranging from 1 to 7. The curve is the result of fitting a logarithmic model to these data ($R^2 = 0.83$).



Appendix: The questionnaire

In this study you will evaluate the justice of a number of scenarios where persons are paid certain salaries. You will receive seventeen questions as in the following examples.

Person X is someone for whom you think 25 000 kr/month would be a just pay.
X's actual pay is 20 000 kr/month. RATE THE INJUSTICE:______ (e.g. –15)

Person Y is someone for whom you think 41 000 kr/month would be a just pay.
Y's actual pay is 67 000 kr/month. RATE THE INJUSTICE:______ (e.g. 25)

You are asked to rate each scenario by a number that represents your evaluation of the injustice in the pay.

- Zero means "no injustice".
- The larger the injustice, the larger rating you give.
- A **negative** rating means that the person receives ***too little***, and a **positive** rating means that the person receives ***too much.***
- There is no limit to how large numbers you can use. You could use a scale from–100 to +100, or use a smaller or large range.

Responses as in the examples above would mean that one perceives the injustice to be *larger in the second scenario*, because 25 is meant to signify a larger injustice than does 15. In the first scenario the rating must be *negative*, e.g. –15, because person X receives less than the just pay.

Your answers are completely anonymous. Thanks for participating!

I am □ Female □ Male

1. **Person A is someone for whom you think 15 000 kr/month would be a just pay. A's actual pay is 13 500 kr/month. RATE THE INJUSTICE:______**
2. **Person B is someone for whom you think 20 000 kr/month would be a just pay. B's actual pay is 24 000 kr/month. RATE THE INJUSTICE:______**
3. **Person C is someone for whom you think 80 000 kr/month would be a just pay. C's actual pay is 40 000 kr/month. RATE THE INJUSTICE:______**
4. **Person D is someone for whom you think 45 000 kr/month would be a just pay. D's actual pay is 50 000 kr/month. RATE THE INJUSTICE:______**
5. **Person E is someone for whom you think 15 000 kr/month would be a just pay. E's actual pay is 20 250 kr/month. RATE THE INJUSTICE:______**
6. **Person F is someone for whom you think 20 000 kr/month would be a just pay. F's actual pay is 14 800 kr/month. RATE THE INJUSTICE:______**
7. **Person G is someone for whom you think 80 000 kr/month would be a just pay. G's actual pay is 72 000 kr/month. RATE THE INJUSTICE:______**
8. **Person H is someone for whom you think 45 000 kr/month would be a just pay. H's actual pay is 54 000 kr/month. RATE THE INJUSTICE:______**

9. **Person I is someone for whom you think 20 000 kr/month would be a just pay. I's actual pay is 10 000 kr/month. RATE THE INJUSTICE:______**
10. **Person J is someone for whom you think 80 000 kr/month would be a just pay. J's actual pay is 96 000 kr/month. RATE THE INJUSTICE:______**
11. **Person K is someone for whom you think 15 000 kr/month would be a just pay. K's actual pay is 30 000 kr/month. RATE THE INJUSTICE:______**
12. **Person L is someone for whom you think 45 000 kr/month would be a just pay. L's actual pay is 33 300 kr/month. RATE THE INJUSTICE:______**
13. **Person M is someone for whom you think 20 000 kr/month would be a just pay. M's actual pay is 22 200 kr/month. RATE THE INJUSTICE:______**
14. **Person N is someone for whom you think 15 000 kr/month would be a just pay. N's actual pay is 12 500 kr/month. RATE THE INJUSTICE:______**
15. **Person O is someone for whom you think 80 000 kr/month would be a just pay. O's actual pay is 108 000 kr/month. RATE THE INJUSTICE:______**
16. **Person P is someone for whom you think 45 000 kr/month would be a just pay. P's actual pay is 90 000 kr/month. RATE THE INJUSTICE:______**
17. **Person Q is someone for whom you think 30 000 kr/month would be a just pay. Q's actual pay is 30 000 kr/month. RATE THE INJUSTICE:______**

Now we would like to judge the following scenario in the same way.

A certain CEO is 36 years old. He has 5 years college education and 5 years previous experience as a CEO. He is recruited to an international corporation with a total stock value of 1000 billions kronor (i.e., about six times as large as Volvo). [**High treatment:** A hypothetical salary to this CEO is 50 000 000 (fifty millions) kr/month. **Low treatment:** A hypothetical salary to this CEO is 50 000(fifty thousand) kr/month. **Control treatment** gave no hypothetical salary.]

RATE THE JUSTICE OF THE HYPOTHETICAL SALARY:___________

A JUST PAY TO THIS CEO WOULD BE: _________________________ kr/month.

Finally, tell us how confident you were in general in your responses above. Tick one box.

Very unconfident (=would probably give very different answers if I were to take the questionnaire at another occasion)	**Somewhat unconfident**	**Neither confident nor unconfident**	**Somewhat confident**	**Very confident**(=would probably give very similar answers if I were to take the questionnaire at another occasion)