The Conjunction Fallacy and Its Impacts in the User's Data Acquisition Process

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Abstract. There are moments within the process of creating an artifact, for instance at the initial requirements gathering or in the assessment phase, that users input data is collected. There may be an impact directly on the results of the analysis of this data if, for some reason, this data input is not accurate. This paper will focus on a specific phenomenon, known as the Conjunction Fallacy, which may lead users to commit errors of judgment that would impact directly in the accuracy of their evaluation of alternatives. In order to exemplify this issue, this paper presents experiments where, during the evaluation phase of the design of a product, it was verified the presence of the conjunction fallacy. It also presents a possible strategy to minimize the errors of judgment caused by the fallacy.

Keywords: evaluation of artifacts, conjunction fallacy, ergonomic assessment, usability evaluation.

1 Introduction

Collecting an accurate user´s input is an important issue in many areas such as Design, Ergonomics and Usability. Assessing the usability of an artifact, the perception of comfort in an ergonomic analysis, or the decision making process of launching a new product, are some examples, among the wide range of applications, where this issue is involved.

Even when the experiment conditions seem to be all controlled, with the sample correctly dimensioned, and questions clearly formulated, users may incur into mistakes [5]. This paper will focus on a specific phenomenon, known as the Conjunction Fallacy [6], which may lead users to commit errors of judgment.

According to a basic principle of mathematics, the "rule of conjunction", the probability that two events occur together cannot be higher than the smallest probability of each event happening isolated. For instance, considering two events "A" and "B", the probability of occurrence of a conjunctive event, the occurrence of "A" and "B" simultaneously, which we will denote as "A & B", can never be higher than the lowest probability of the event "A" or "B" isolated occurring.

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For example, imagine that we have two dice, one black dice and one white dice. Considering that the event "A" happens when we throw the black dice resulting in number “5”, and the event "B" happens when we throw the white dice and the result is number “3”. If we throw the black and the white dice at the same time, then the probability of the event “A” happening is of 1/6 (since the dice has 6 faces and only one is a number “3”). The same way, the probability of the event “B” happening is of 1/6. However, the probability of these two events occurring together, “A & B" is 1/36 (since there are 36 possible outcomes and only one of them is “black dice = 5 and white dice = 3”).

Thus, when there is a judgment or evaluation of conjunctive events, and the user assigns a higher probability of occurrence to a conjunctive event than to any of the isolated events, we say a "conjunction fallacy" had occurred.

The importance of discussing the conjunction fallacy permeates many areas of knowledge where there is a need for users to choose from alternatives, especially when the answers present conjunctive events [4]. In Design, these choices may happen at various points within the process of creating an artifact, either at the initial requirements gathering, in the assessment phase, or at any other moment [1]. An error of judgment arising from a possible conjunction fallacy would impact directly on the results of an analysis thus constituting itself as an important point to be studied [2].

In this sense, this paper presents, in Section 2, two experiments where, during the evaluation phase of the design of a product, it was verified the presence of the conjunction fallacy. One of the experiments used a digital data collection instrument, while the other did not. This procedure was adopted to avoid any influence in the results by the collection instrument. This paper also shows, in Section 3, another experiment where a strategy to minimize the errors of judgment caused by the fallacy was used. Finally, the conclusions and final considerations are shown in Section 4.

2 Case Studies Where the Fallacy Occurred

This section presents two case studies [3]. These case studies aimed to verify experimentally the occurrence of the conjunction fallacy. In both cases, the experiments consisted in exposing a problem to the user, followed by a set of isolated and conjunctive alternatives for the user to grade.

In order to isolate the data collection instrument variable, the first case study used a digital instrument, an online form, to collect the input data from the users, while the second case study used a paper version of a survey to collect the data.

For these experiments, there were chosen randomly 92 undergraduate students, from public and private universities in Brazil, and from different periods of design courses.

2.1 Case Study One

For the case study one, 50 of the 92 undergraduate students, which we will designate "Group 1", received a description of a problem followed by five possible alternative

Table 1. Questions and alternative answers for case study one

DINOTUNES is a website that sells music albums. This site received a bad user satisfaction review. The site users claim to find problems to buy the songs.
The website looks like a computer store
The website has usability problems
The website lacks presence in social networks
The website has too many buttons
The website lacks presence in social networks and has usability problems

solutions. They were asked to rank these alternatives from 1 to 5, in such way that the most likely alternative would receive the value of 1, the second most likely alternative would be assigned the value of 2, and so on. The table 1 bellow shows the question that was presented to the users followed by the 5 alternative answers:

The question was intentionally designed to represent a usability problem easily identifiable by designers. The answers were designed to represent four different alternatives for the users to chose, were each alternative represented an isolated event, and one alternative represented a conjunctive event. The table 2 bellow shows the events associated to each of the 5 alternative answers:

Table 2. Events and alternative answers for case study one

Event	Alternative answer
Isolated event A	The website looks like a computer store
Isolated event B	The website has usability problems
Isolated event C	The website lacks presence in social networks
Isolated event D	The website has too many buttons
Conjunctive event B&C	The website lacks presence in social networks and has usability problems

The respondents answered the survey on computers in the design lab of their college through the free software Survey Monkey [7]. The software was configured so that the user was only able to assign to each alternative a different value from 1 to 5. For example, it was not possible to have two or more alternatives with value 1.

In Table 3, there are the mean scores assigned by respondents for each alternative. The lower the value of the average, the higher the probability assigned by respondents, exactly as postulated by the Tversky & Kahneman procedure [6].

Table 3. Events, alternative answers and mean score

Type of event	Alternative answer	Mean score
Isolated event A	The website looks like a computer store	3.98
Isolated event B	The website has usability problems	1.92
Isolated event C	The website lacks presence in social networks	3.48
Isolated event D	The website has too many buttons	2.98
Conjunctive event B&C	The website lacks presence in social networks and has usability problems	2.64

It was expected the conjunctive event B&C to have less probability to occur than the isolated event B or the isolated event C . However, according to the data collected and presented on table 3, the conjunctive event B&C had a lower average value than the isolated event C, meaning for the users as a higher probability to happen, than the isolated event C.

2.2 Case Study Two

For the case study 2, in a posterior moment, another 42 of the 92 undergraduate students, which we will designate "Group 2", received a description of a new problem followed by another possible set of solution alternatives.

The same protocol was followed, however, this time a paper form (rather than an online form) was used to collect the user data. There were 6 alternatives instead of 5, as in case study one.

The users were asked to rank these alternatives from 1 to 6, in such way that the more likely alternative would receive the value of 1, the second most likely alternative would be assigned the value of 2, and so on (similar to case study one). The table 4 bellow shows the question that was presented to the users followed by the 6 alternative answers.

Table 4. Questions and alternative answers for case study two

Designers are designing the iCOPA, an application for smartphones that simultaneously presents relevant information about the World Cup. The prototype of the product has received many complaints from their appraisers such as getting lost in the interface.
The application presents a complex interface with many buttons
The application looks like a digital newspaper
The application lacks presence in social networks
The application does not provide a sports themed interface
The application lacks presence in social networks and presents a complex interface with many buttons
The application consists of an outdated technology

Again, the question was intentionally designed to represent a usability problem. The answers were designed to represent five different alternatives for the users to chose, where each alternative represented an isolated event, and one alternative represented a conjunctive event. The table 5 bellow shows the events associated to each of the 6 alternative answers.

Table 5. Events and alternative answers in case study two

Type of event	Alternative answer
Isolated event A	The application presents a complex interface with many buttons
Isolated event B	The application looks like a digital newspaper
Isolated event C	The application lacks presence in social networks
Isolated event D	The application does not provide a sports themed interface
Conjunctive event A&C	The presents a complex interface with many buttons application and it lacks presence in social networks
Isolated event E	The application consists of an outdated technology

The respondents answered the paper form survey, assigning to each alternative a different value from 1 to 6.

Table 6 shows the mean scores assigned by respondents for each alternative. Again, in this case study, the lower the value of the average, the higher the probability assigned by respondents.

Table 6. Events, alternative answers and mean score in case study two

Type of event	Alternative answer	Mean score
Isolated event A	The application presents a complex interface with many buttons	1.86
Isolated event B	The application looks like a digital newspaper	3.64
Isolated event C	The website lacks presence in social networks	3.90
Isolated event D	The application does not provide a sports themed interface	4.26
Conjunctive event A&C	The presents a complex interface with many buttons application and it lacks presence in social networks	2.48
Isolated event E	The application consists of an outdated technology	4.88

It was expected the conjunctive event A&C to have less probability to occur than the isolated event A or the isolated event C . However, according to the data collected and presented on table 6, the conjunctive event A&C had a lower average value, meaning for the users as a higher probability to happen, than the isolated event A.

3 Case Study 3: A Strategy to Minimize the Effect of the Conjunction Fallacy

The analysis of the results of case studies one and two, presented a possible solution to minimize error in judgment caused by the propensity to belief in conjunctive events. This solution was to reshape the procedure so that all alternatives were conjunctive. For instance, an alternative would be described as "A & B", while the following would be described "C & A", "B & C", and so on. In this experiment, the alternative "A & B" would represent an event more likely than any of the other events represented by the other alternatives "C & A", "B & C" etc.

3.1 Case Study Three

This section will present case study 3 [3] . This experiment shows a strategy to minimize the errors of judgment caused by the fallacy was used.

In order to verify this approach, a group of 93 new students, that were not part of neither "Group 1" nor "Group 2", designated as "Group 3", received the same description of the problem as in the case study one, however followed by alternatives arranged according to the procedure described previously. The table 7 below presents the question and the alternatives presented to "Group 3":

Table 7. Questions and alternative answers for case study three

DINOTUNES is a website that sells music albums. This site received a bad satisfaction review. The site users claim to find problems to buy the songs.
The website looks like a computer store and presents usability problems
The website lacks presence in social networks and looks like a computer store
The website presents usability problems and has many buttons
The website has lots of buttons and lacks presence in social networks

Again, the question was intentionally designed to represent a usability problem. The answers were designed to represent different alternatives for the users to chose, however this time each alternative represented a conjunctive event. The Table 8 bellow shows the events associated to each of the 4 alternative answers:

Table 8. Events and alternative answers in case study three

Type of event	Alternative answer
Isolated event A1	The website presents usability problems
Isolated event A2	The website has lots of buttons
Isolated event B1	The website looks like a computer store
Isolated event B2	The website lacks presence in social networks
Conjunctive event A1&B1	The website looks like a computer store and presents usability problems
Conjunctive event B1 &B2	The website lacks presence in social networks and looks like a computer store
Conjunctive event A1 & A2	The website presents usability problems and has many buttons
Conjunctive event A2 & B2	The website has lots of buttons and lacks presence in social networks

Thus, it is expected that the conjunctive event combining "likely" alternatives, represented in this experiment as Conjunctive event A1 & A2, would be ranked by the respondents as the most probable one. Also, the events that intentionally combine

“likely” and “unlikely” alternatives ("A1 & B1" and "B2 & A2", not necessarily in that order) would receive lower probabilities. It would be also expected that the alternative combining the most improbable events “B1 & B2” be ranked as the least probable one (recalling that the events “B1” and “B2” are intentionally designed to be considered unlikely, as the events “A1 and “A2”).

The respondents answered the paper form survey, assigning to each alternative a different value from 1 to 4.

Table 8 shows the mean scores assigned by respondents for each alternative. Again, the lower the value of the average means that the higher the probability assigned by respondents.

Table 9. Events, alternative answers and mean score in case study three

Type of event	Alternative answer	Mean score
Conjunctive event A1 & B1	The website looks like a computer store and presents usability problems.	2.45
Conjunctive event B1 & B2	The website lacks presence in social networks and looks like a computer store.	3.07
Conjunctive event A1 & A2	The website presents usability problems and has many buttons.	1.61
Conjunctive event A2 & B2	The website has lots of buttons and lacks presence in social networks	2.88

As expected, the results presented that the conjunctive event combining “likely” alternatives, conjunctive event A1 & A2, highlighted in table 9, was ranked as the most probable one, with mean score of 1.61. Also, as anticipated, the events that combined “likely” and “unlikely” alternatives, conjunctive event "A1 & B1” and "A2 & B2", with mean scores of 2.45 and 2.88 respectively, received higher probabilities than the alternative combining the most improbable events, the conjunctive event B1 & B2, with mean score of 3.07.

In contrast with the previous case studies presented in Section 2 of this document, the users chose the erroneous answered in only 17.2% of the cases. In other words, the users rated correctly, in 77 of the 93 interviews (82.8%), the most likely event, “A1 & A2”, as more likely than the event “B1 & B2”.

In summary, compared to case study one, presented in Section 2.1 of this paper, the results decreased from an average of 80.4% of bad choices (caused by the conjunction fallacy) to only 17.2% of bad selections.

4 Conclusions and Final Considerations

The idea of this paper was not to present a statistically valid demonstration but to verify if the occurrence of the conjunction fallacy is easily observed, also indicating a possibility of a solution to it.

In fact, the results of the experiments of case studies one and two were analyzed separately to verify the internal consistency of the experiment, and in both cases it was possible to find out that the fallacy had occurred. This was verified since a percentage of conjunctive events were considered more likely to occur than isolated events. In the case of "Group 1", a total of 76% of respondents judged erroneously the conjunctive event as more likely to occur than some isolated event. In the "Group 2", the event conjunctive was chosen erroneously as more possible that some isolated event by 85.7% of the sample.

The results of "Group 3" were that only 17,2% of the respondents incurred in an error of judgment when ranking the alternatives. It seems that there was a reduction in the percentage of choices misjudged when comparing with the results obtained previously with the "Group 2", of 85.7%, and also when comparing with the results of "Group 1", of 76%.

In conclusion, although we may not assure that the solution proposed at case study 3 solves all the problems arisen by the conjunction fallacy, such knowledge contributes to the search for ways to minimize the error of probabilistic judgment arising out of such phenomenon and consequently to enhance the process of decision making.

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