Familiarity-matching in decision making: Experimental studies on cognitive processes and analyses of its ecological rationality

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Abstract

Previous studies have shown that individuals often make inferences based on heuristics using recognition, fluency, or familiarity. In the present study, we propose a new heuristic called *familiarity-matching*, which predicts that when a decision maker is familiar (or unfamiliar) with an object in a question sentence, s/he will choose the more (or less) familiar object from the two alternatives. We examined inference processes and ecological rationality regarding familiarity-matching through three studies including behavioral experiments and ecological analyses. Results showed that participants often used familiarity-matching in solving difficult binary choice problems, and that familiarity-matching could be applied in an ecologically rational manner in real-world situations. A new perspective on human cognitive processes is discussed in this study.

Keywords: binary choice task; heuristic; familiarity; familiarity-matching; ecological rationality

Introduction

When making decisions, individuals often use simple inference strategies such as heuristics. In the field of heuristics research, many researchers initially focused on cognitive biases involved in heuristics (e.g., Tversky & Kahneman, 1973, 1974, 1983). In contrast, recent studies have discussed the adaptive aspect of heuristics (e.g., Gigerenzer & Goldstein, 1996; Gigerenzer & Todd, 1999; Goldstein & Gigerenzer, 2002). Some studies investigated human inference cues or inference strategies using binary choice tasks (e.g., Goldstein & Gigerenzer, 2002; Hertwig, Herzog, Schooler & Reimer, 2008; Honda, Abe, Matsuka & Yamagishi, 2011; Honda, Matsuka & Ueda, in press). These studies showed that subjective memory experiences, such as recognition, fluency, or familiarity of an object could be valid inference cues. For example, in the binary choice task, "Which city has a larger population, Tokyo or Chiba?" when a decision maker recognizes (or is more fluent or familiar with) Tokyo and does not recognize (or is less fluent or familiar with) Chiba, s/he tends to choose the recognized (or the more familiar or fluent) city –as the one with a larger population size. An interesting observation is that, in many cases, this simple inference can often lead to correct inferences. Thus, a simple heuristic using subjective memory experiences can be ecologically rational (e.g., Goldstein & Gigerenzer, 2002; Hertwig et al., 2008; Schooler & Hertwig, 2005; Honda et al., in press).

Choice of an object based on similarity of familiarity: Familiarity-matching

So far, previous studies have investigated the effects of subjective memory experience for finding correct alternatives in a binary choice task. However, if the familiarity of an object in alternatives can serve as a valid inference cue, it is possible that the same holds true for the familiarity of an object in a question sentence. For example, if we consider the binary choice task, "Which country is Hameln in, Germany or Liechtenstein?" A decision maker may infer it as "I have heard the name 'Hameln' and I am familiar with this city. Further, I am more familiar with Germany than Liechtenstein; therefore, Hameln should be in Germany!" In this case, the decision maker chose the more familiar alternative because the familiarity of the chosen alternative was similar to that of the object in the question sentence. Likewise, in the task, "Which country is Schellenberg in, Germany or Liechtenstein?" A decision maker may infer it as "I have never heard the name 'Schellenberg' and I am unfamiliar with the city. Further, I am less familiar with Liechtenstein than Germany; therefore, Schellenberg should be in Liechtenstein!" In this case, the decision maker chose the less familiar alternative because the two objects were similarly unfamiliar. A decision maker may thus use an inference strategy like "matching familiarity" between an object in the question sentence and another object in the alternatives. That is, a decision maker makes inferences based on similarity of familiarity between objects. Similarity judgments are closely connected to decision making and similarities between the familiarity of an object in a question sentence and that of an object in alternatives may become an important cue for making decisions. In fact, a recent study (Hiatt & Trafton, in press) has shown that familiarity can be one of the most important cues in similarity judgments.

Based on these considerations, we propose a new heuristic termed as *familiarity-matching*: If an object in a question sentence is familiar (or unfamiliar) for a decision maker, then s/he will choose the more (or less) familiar object from the two alternatives in a binary choice task. The goal of this study was to examine if cognitive processes in binary choice can be explained in terms of familiarity-matching and to investigate its ecological rationality. In the following sections, we shall report on three studies. In Study 1, we conducted a behavioral experiment and examined if familiarity-matching could adequately explain inference processes. In Study 2, we examined the ecological rationality of familiarity-matching. Finally, in Study 3, we analyzed the real-world environment in terms of familiarity.

Study 1: Examination of inference processes

The purpose of Study 1 was to investigate if individuals tend to rely on familiarity-matching in a binary choice task.

Method

Participants Japanese under graduate students (N = 31) participated in this study.

Tasks, materials, and procedure We conducted the binary choice task and the measurement of familiarity.

In the binary choice task, participants answered 100 binary choice questions. All question sentences had the following format: "X is a city in, country A1 or A2?" (e.g., "Sikasso is a city in, Mali or Switzerland?"). The order of the 100 questions was randomized (see Appendix for the procedure to generate the questions). For each question, participants were also asked to rate the difficulty level in answering the question using a visual analog scale (VAS). The scale consisted of a horizontal line labeled "very easy" on the left end and "very difficult" on the right end. Participants' responses were recorded over a range of 101-points (i.e., from 0 = "very easy" to 100 = "very difficult").

In the measurement of familiarity, participants were asked to indicate how familiar they were with each object presented in the binary choice task (i.e., 20 countries and 100 cities) using a VAS. Participants' responses were recorded over a range of 101-points (i.e., from 0 = "do not know at all" on the left end of the scale to 100 = "know much" on the right end of the scale).

We conducted the above two tasks using a questionnaire. Participants completed the binary choice task followed by the measurement of familiarity.

Results

Hereafter, the familiarity ratings for the object in the question sentence and for the two objects presented as alternatives are expressed as "Fam(Q)," "Fam(A1)," and "Fam(A2)," respectively. In the following analyses, we excluded the questions in which Fam(A1) was identical to Fam(A2).

Can familiarity-matching predict inference patterns? First, we analyzed the accordance rate of observed inferences with familiarity-matching for each participant. For example, when Fam(Q) = 45, Fam(A1) = 30, and Fam(A2) = 80, familiarity-matching predicts that the participant would choose A1. Figure 1 shows the accordance rate for each participant. In 29 out of the 31 participants, accordance rates were above chance level. The mean accordance rate was .88. These results indicate that the observed choices were predicted accurately by familiarity-matching.

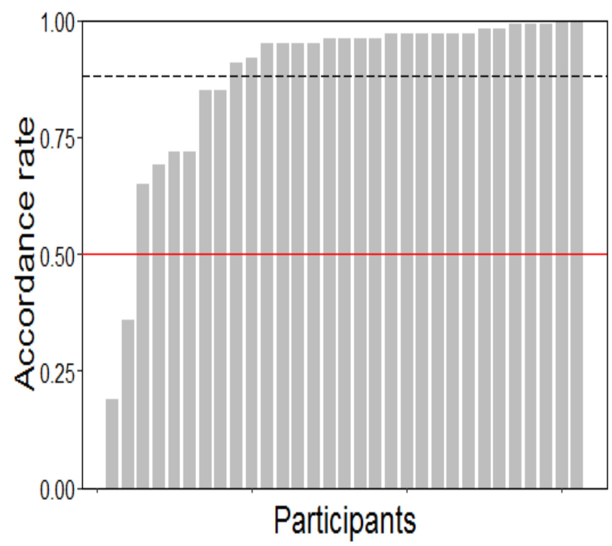

Figure 1: Accordance rate of observed inferences with familiarity-matching (individual data). The red line denotes chance level (.50) and the dotted line shows the mean accordance rate (.88).

Does the difficulty of a problem affect the use of familiarity-matching? Previous studies have shown that individuals do not always use heuristics but tend to rely on them for solving a difficult problem (e.g., Kahneman & Frederick, 2005; Honda et al., in press). Therefore, we examined if experiencing difficulty in a problem affected the use of familiarity-matching. We defined a dichotomized difficulty rating, high or low difficulty, based on the difficulty ratings being above or below the median for each participant. Hereafter, a problem assigned a rating above the median is expressed as "difficult problem" and a problem assigned a rating below the median as "easy problem". We examined the use of familiarity-matching for both types of problems.

Some researchers have debated that accordance rates are not always a good indicator for examining if individuals "truly" use heuristics (e.g., Hilbig & Richter, 2011). Thus, we used Discrimination Index (DI) (Hilbig & Pohl, 2008) as an indicator of the blind usage of familiarity-matching by the participants. DI was calculated using the following equation:

$$DI = (Hit) - (False\ Alarm)$$

where (Hit) and (False Alarm) denote the proportion in which the accordance of a heuristic results in a correct or false inference, respectively. Since DI is defined as the difference between (Hit) and (False Alarm), DI ranges from –1 to +1. It is assumed that when a decision maker always follows a heuristic (i.e., s/he blindly uses a heuristic), DI should reach zero, as s/he uses the heuristic irrespective of its correctness, suggesting that s/he does not take advantage of specific knowledge relevant to the inference problem.

For each participant, we calculated DI for the two problem types. Figure 2 shows the distributions of DI for the two cases. We found that DI for the difficult problem was generally lower than DI for the easy problem. We also found that the mean DI for the difficult problem was not significantly deviated from zero (Mean = .07, $t(30) = 1.23$, $p = .23$, Median = .06), while the mean DI for the easy problem was significantly deviated from zero (Mean = .41, $t(30) = 6.47$, $p < .001$, Median = .39). These results implied that individuals used memory-based simple heuristics when they experienced difficulty in solving inference problems, which was consistent with the previous finding in Honda et al. (in press).

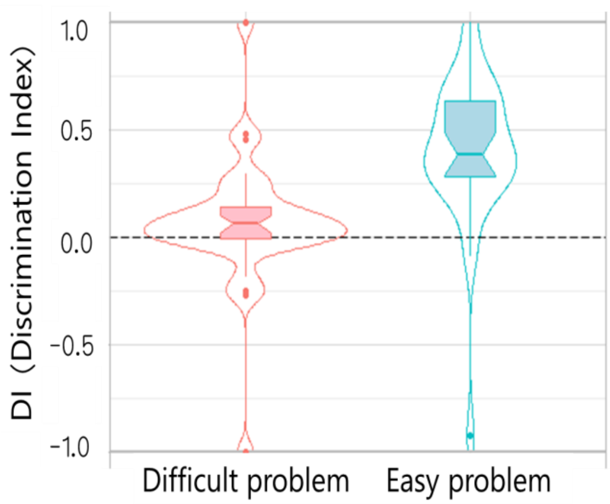

Figure 2: DI (Discrimination Index) for the difficult problem (left) and for the easy problem (right).

Discussion

In this behavioral experiment, the accordance rate of the prediction by familiarity-matching was sufficiently high (mean accordance rate = .88), showing that familiarity-matching predicted inference patterns effectively. Furthermore, our findings implied that participants used familiarity-matching when they experienced difficulty in problems. These results suggest that individuals take advantage of the familiarity of objects in both question sentences and alternatives as a cue when making inferences.

In the behavioral experiment, the materials used were selected by experimenters to serve as stimuli for the binary choice task. Therefore, the question of using familiarity-matching in a binary choice task as a valid inference strategy remains open for evaluation. Thus, we examined the ecological rationality of familiarity-matching.

Study 2: Analysis of ecological rationality

The purpose of Study 2 was to examine if familiarity-matching could serve as an ecologically rational strategy. In this study, we measured individuals' familiarity of objects and then examined whether familiarity-matching was generally a valid inference strategy in a binary choice task.

Method

Participants Japanese under graduate students (N = 39) participated in the task. None of them had participated in Study 1.

Materials, tasks, and procedure We used the 50 countries with the highest population in the world and their 50 capitals as materials. We investigated the participants' familiarity with each of the 100 objects (i.e., 50 cities and 50 countries). We conducted the measurement of familiarity which was similar to the method used in Study 1.

Analysis of the validity of familiarity-matching Familiarity ratings in Study 2 were converted into z-scores for each participant and the following analyses were conducted.

We analyzed the validity of familiarity-matching in the binary choice task using the familiarity ratings for the 50 countries and their capitals collected from participants. Specifically, we calculated the accuracy rate (i.e., validity) of familiarity-matching using the following procedure:

1. A hypothetical binary choice task such as "X is a city in, A1 or A2?" was conducted and each problem "was inferred" based on Fam(Q), Fam(A1) and Fam(A2).
2. For each question, if the absolute difference between Fam(Q) and Fam(A1) was less than that between Fam(Q) and Fam(A2), then A1 was selected, and vice versa (i.e., in the same manner as the prediction by familiarity-matching in Study 1).
3. We applied the above two steps to all possible combinations (50 cities * 49 alternative pairs) using the familiarity ratings provided by each participant, and then calculated his/her accuracy rate.

Results and discussion

Figure 3 shows participant accuracy rates calculated as described above (N = 39). The horizontal and vertical axes shows the participants (individual data) and the accuracy rate, respectively, while the red line in the graph indicates chance level (.50). Participant accuracy rates (Mean = .67) exceeded the chance level for all participants. Therefore, it is suggested that participants can accurately "make correct inferences” by matching more familiar objects in the binary choice task, even in the real-world environment.

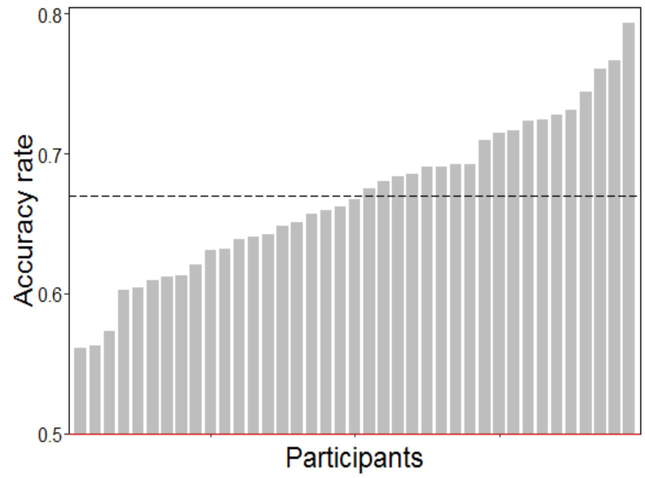

Figure 3: Accuracy rate of familiarity-matching by individual familiarity ratings. The red line denotes chance level (.50) and the dotted line shows the mean accuracy rate (.67).

Study 3: Analysis of the real world

According to previous studies (e.g., Goldstein & Gigerenzer, 2002; Honda et al., in press), if a city or country appears more frequently in the real-world environment (e.g., mentioned in media), then individuals will be more familiar with it because they are more likely to see or hear the name. Therefore, it can be estimated that familiarity-matching can be applied effectively in the binary choice task when the frequency of appearance of the name of a city is correlated with that of the name of a country in the real-world environment.

In this section, we investigated this issue using the following procedure. As an index of the frequency of appearance in the real-world environment, we used the log-transformation of the mean number of hits for each object in two online databases of Japanese newspapers[1]. When we searched for objects in both databases, we traced back from the oldest to latest date as possible (see footnote) on national news. We converted the log-transformed index into z-scores, which were used in this analysis.

First, we calculated the correlation coefficient between the number of hits for the 50 cities and that for the 50 countries using z-scores. This correlation coefficient was .86 (p < .001; 95% CI: .77 ~ .92; Figure 4). Therefore, it was found that the frequency of appearance of a city name in the media was highly correlated with that of the country name that corresponded to the city.

[1] The two databases were “Kikuzo II Visual” (online database of Asahi Shimbun; date range: January 1, 1984 to May 23, 2016) and “Yomidasu Rekishikan” (online database of Yomiuri Shimbun; date range: January 1, 1986 to May 23, 2016).

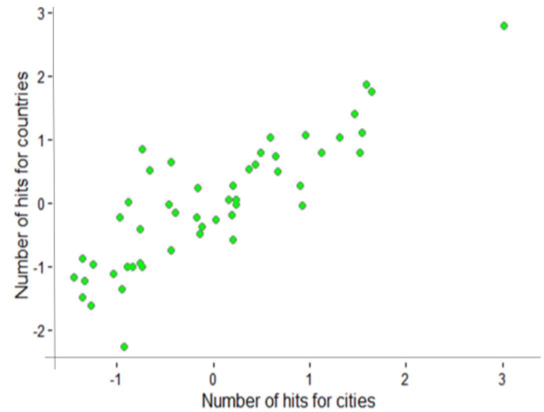

Figure 4: Correlation between the number of hits for cities and that for countries (log-transformed z-scores).

Although the correlation between participants’ familiarity with an object and the number of appearances in the media has already been reported in previous studies (e.g., Goldstein & Gigerenzer, 2002; Schooler & Hertwig, 2005), we confirmed that we could replicate such a correlation in the present study. Subsequently, using z-scores, we calculated the correlation coefficient between participants’ familiarity with each object (z-scores of the mean familiarity ratings for 39 participants in Study 2) and the number of hits for each object. This correlation coefficient was .88 (p < .001; 95% CI: .84 ~ .92; Figure 5). Therefore, it was found that the more often an object appeared in the media, the more familiar with the object individuals were, which was consistent with previous studies.

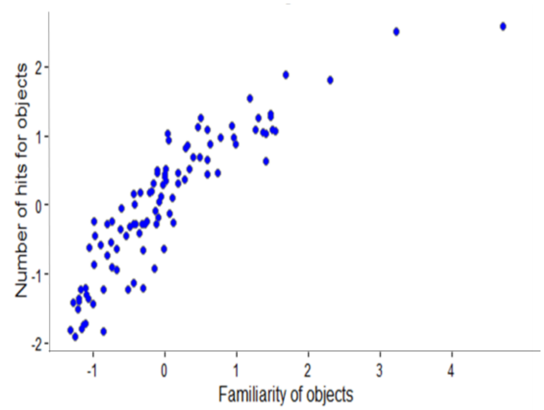

Figure 5: Correlation between familiarity of objects (z-scores) and the number of hits for these objects (log-transformed z-scores).

The combined results of Study 2 and Study 3 suggest that familiarity-matching can be valid even in the real-world environment, as the frequency of appearance of a city name in the media is highly correlated with that of the corresponding country name, and individuals’ familiarity with an object is also highly correlated with its frequency of appearance in the media. In other words, since a more frequently appearing object in the environment is likely to be more familiar for individuals, inferences based on similarity of familiarity can be valid in a binary choice task. Therefore, familiarity-matching can be applied as an ecologically rational strategy.

General discussion

In the present study, we proposed a new heuristic, *familiarity-matching*, which predicts that if an object presented in a question sentence is familiar for a decision maker, then s/he is likely to choose the more familiar object presented as alternatives in a binary choice task. The results of Study 1 showed that familiarity-matching could predict individuals' inference patterns effectively. In particular, the results implied that individuals used familiarity-matching when they experienced difficulty in inference problems. In addition, the results of Study 2 and Study 3 showed that familiarity-matching could be an ecologically valid strategy in the binary choice task, because of the high correlations between the frequency of appearance of a city name and that of a country name, and between the frequency of appearance of an object and individuals' familiarity with it.

So far, only the use of "familiarity" in making inferences has been primarily examined. Generally, in a binary choice task, "familiarity" of an object can be an informative cue (e.g., Honda et al., 2011, in press). In a binary choice task, "unfamiliarity," contrary to "familiarity," is often considered uninformative in making inferences. The present findings, however, indicate that individuals can also use "unfamiliarity" as an informative inference cue. Familiarity-matching can be applied for both, a familiar object and an unfamiliar object, in a question sentence. According to familiarity-matching, when presented with an unfamiliar object, a decision maker will infer the following: "The correct answer will also be the unfamiliar object." In this situation, the "unfamiliarity" can become an informative cue. Perhaps, in cases where a decision maker uses "unfamiliarity" as an inference cue, the cognitive processes may differ from those involved in a situation where s/he uses "familiarity" as an inference cue. The present study did not examine this issue, which, therefore, should be investigated in the future.

However, familiarity-matching still has some limitations in the practical aspect. The definition of the familiarity-matching is limited to a binary choice task. We think that familiarity-matching can be applied to a multiple-choice task, because a decision maker has only to "match" familiarity of an object in a question sentence with that of an object in alternatives, no matter how many alternatives the task contains. However, it is not clear how familiarity-matching can be extended to other more complex tasks, so we may also need to investigate this issue.

To the best of our knowledge, the present study was the first study to examine the effect of familiarity of objects in a question sentence. We believe that focusing on the relationship between objects presented as both, a main theme ("question sentence," in this study) and a supplement ("alternatives," in this study), has revealed a new perspective on human inferences.

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Appendix. Binary choice task

The binary choice task (Study 1) was generated by following the four steps listed as under:

1. For "objects presented as alternatives," we selected 20 countries (more than 2 countries from 5 regions: Asia, Europe, Africa, North America, and South America) and randomly assigned these 20 countries to 2 groups: "Alternative A1" and "Alternative A2" (each group consisted of different 10 countries).

Alternative A1	**Alternative A2**
America	Canada
Sweden	Bolivia
Mexico	Italia
Columbia	Ukraine
Holland	Switzerland
Egypt	Iran
Turkey	Spain
Saudi Arabia	Kazakhstan
Australia	New Zealand
Mali	Morocco

2. Using the groups, "Alternative A1" and "Alternative A2" described above, we created 10*10 = 100 pairs as alternatives for the binary choice task.

	Alternative A1	**Alternative A2**
1	Holland	Iran
2	Australia	Bolivia
3	Columbia	Kazakhstan
4	Saudi Arabia	Morocco
	…	
98	Turkey	New Zealand
99	Mexico	Switzerland
100	America	Ukraine

3. From each country ("objects presented as alternatives"), we selected 5 cities (total of 20*5 = 100 cities) using the following criteria:
 (I) Out of the 5 cities, we selected the 2 cities with the largest population size in the country.
 (II) For the remaining 3 cities, we selected cities which satisfied following one (or more) of the following criteria: "is the high population size", "its name is included in that of a historical treaty, conference, or a similar historical event," "has a world heritage site," or "has hosted the Olympic or the Paralympic Games."

Cities	Countries
New York	America
Washington D.C.	America
Portsmouth	America
San Francisco	America
Bretton Woods	America
Rapallo	Italia
Trent	Italia
Roma	Italia
Milano	Italia
Genova	Italia
Teheran	Iran
…	
Sikasso	Mali
Puebla	Mexico
Tlatelolco	Mexico
Guadalajara	Mexico
Monterrey	Mexico
Villahermosa	Mexico
Rabat	Morocco
Marrakesh	Morocco
Tangier	Morocco
Fes	Morocco
Casablanca	Morocco

Note: We provided criterion (II) for two reasons: First, if all alternatives consisted of top cities in terms of population, participants might be more likely to know the answer (i.e., to use knowledge-based inference cues instead of heuristics), as it seemed that larger cities were comparatively more famous. Second, we wanted to create objects presented as question sentences (i.e., cities) that would be the only familiar element for participants (i.e., when participants are only familiar with a city, they often do not know the country it belongs to). However, even if a city satisfied criterion (I) or (II), we excluded cities whose names included the name of the country (e.g., Mexico City) or were located in several countries (e.g., Melbourne is located not only in Australia but also in America).

4. In order to make one of the two alternatives (from step 2) a correct answer, we placed a city (from step 3) in "X" in each question sentence ("X is a city in,").

	Alternative A1	Alternative A2
1. **Ramsar** is a city in,	Holland	Iran
2. **La Paz** is a city in,	Australia	Bolivia
3. **Bogota** is a city in,	Columbia	Kazakhstan
4. **Rabat** is a city in,	Saudi Arabia	Morocco
…		
98. **Ankara** is a city in,	Turkey	New Zealand
99. **Villahermosa** is a city in,	Mexico	Switzerland
100. **Bretton Woods** is a city in,	America	Ukraine

Note: Sentences in the actual questionnaire were written in Japanese.