Examining Heuristic-System 1 and Analytic-System 2 Processing During Reasoning on the Syllogisms and the Modified Version of the Bat and Ball Problems: Response Time, Response Confidence, and Dual-Task Assessments

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Abstract

How are reasoning processes shaped by the heuristic system and analytic system? In the present study, we were focused on how heuristics and analytical thinking affect reasoning. According to dual-process theories, reasoning consists of two distinct modes of processing: System 1 and System 2. System 1 generates responses that are automatic, fast, and intuitive. This system does not need working memory resources. The other system is reflective. Characteristics of this system are deliberative, slow, and conscious. System 2 depends on working memory capacity. Therefore, system 2 needs working memory resources. In the present study, the experimental design was as follows: All participants performed randomly distributed modified version of the bat and ball problems and the syllogistic reasoning problems while they kept memory load in mind and had a time limit in the initial response stage. Then the questions were asked again without memory load and deadline. Both tasks consist of conflict (experiment questions) and no-conflict (control questions) questions. Whereas participants chose among four options in a modified version of the bat and ball problems, they chose between yes and no, considering two premises

and a conclusion in the syllogistic reasoning problems. A two-response paradigm was applied. The problems were asked twice. In the first presentation of the problems, we occupied the participant's working memory with a dual task procedure and time pressure. We replicated the common implication of system 1 with fast response and system 2 with slow thinking.

Keywords

Analytic system; conflict detection; dual process of thinking; heuristics & biases; reasoning; two response paradigm; working memory

INTRODUCTION

The brain can be thought as a device whose abilities including motor activities, perception, and memory have evolved to reinforce the decision that regulates actions (Gazzaniga et al., 2008). The first question is why and how do people make decisions? When a person comes across choices among possibilities, he or she selects an available course of action (Smith, E. E., & Kosslyn, S. M., 2007).

In daily events, many decisions are easy to make even it contains uncertainty since some factors might be very important for a decision maker who can choose fast in decision making. When one option is dominated by the other option, even if lots of possibilities he faces, the decision maker selects the option which is highly valuable for him (Hastie & Dawes, 2010). Indeed, many decisions are not taken that easily. When values and outcomes are undefined, it becomes more difficult to make a decision. Three elements, which constitute a decision, are alternatives, consequences, and beliefs (Smith, E. E., & Kosslyn, S. M., 2007). Alternatives include several strategies, options, and choices. These are available courses of action that reasoners can consider. The benefits and losses, which are consequences, follow the choice of a particular alternative.

There are three determiners, which are "outcomes, values, and utilities", which specify consequences. Whereas the outcome belongs to the result, the value is equal to its net worth, and the utilities are considered as the desirability of the value (Smith, E. E., & Kosslyn, S. M., 2007).

Kahneman and Tversky examined the role of intuitions in reasoning and decision-making. They found fallacies that were made by the reasoners. People's intuitions are shaped by past experiences and mental models including categories. The reason why categories and stereotypes, which are produced by culture, play a role in predictions is that they are formed over similarities and patterns (Tversky & Kahneman, 1983).

De Neys (2006a) presented four experiments with four different purposes. Experiment 1 was designed for a chronometric comparison between heuristic response and analytic response. Four tasks, which were presented respectively, are "Linda Problem, Bill Problem, Drinking Age Problem, Destination Problem". In experiment 2, the problems were presented with the executive finger tapping task that was used as attention demanding secondary task. Experiment 3 was planned Linda and job problems with spatial storage task that was used as working memory load. In experiment 4, the drinking age problem and card selection task were presented with a spatial storage task. The reason why De Neys (2006a) used secondary tasks to evaluate dual process predictions is that cognitive load affects system 1 and system 2 in different ways.

The results from the study of De Neys (2006a) follow:

- In experiment 1, conjunction fallacy and indicative selection tasks were asked to the participants. The idea behind the experiment was to observe a chronometric comparison of deliberative and heuristic responses. The fast answer was labeled as a heuristic response. Because the heuristic system needs less inference time than the analytic system. The results of experiment 1 support the time course assumption of dual-process theories. The correct responses require more

processing time than intuitive incorrect responses.

- In experiment 2, conjunction fallacy and indicative selection tasks with the secondary finger tapping task were presented simultaneously. A dual task procedure was applied. The participants tapped on "B, M, N, V" while they were solving the problems. It is an attention-demanding secondary task. Therefore, the central executive component of the working memory was burdened. The results show that incorrect answers increased and correct responses decreased in the conjunction fallacy questions. The secondary task affected the accuracy of responses. It was considered that the heuristic responses were given more frequently. In the card selection task, the incorrect answer, which is the matching card selections, increased. The correct logical answer, which is P and not-Q selection, decreased. Both increases and decreases are significant. There is no significant difference among the other card selections.
- In the following experiments, the reasoning tasks were applied with the secondary working memory task. The dot memory task, which is a spatial storage task (Miyake et al., 2001), was used to load the working memory while participants were answering the questions. Participants attempted to remember presented dot patterns including three dots and four dots. The 3x3 matrix was used to fill. The results demonstrated that correct responses decreased under cognitive load in experiment 3. Dot memorization caused the analytic thinking to be repressed by heuristics. In experiment 4, the incorrect matching card selections increased under the executive burden. The correct answers decreased. Unlike the experiment 2 result, the secondary memory load does not affect the deontic card selection task.

All the results are consistent with the assumptions of dual process theories in the study of De Neys (2006a).

In the psychology of reasoning and decision making, three paradigms became dominant

(Evans, 2008). One of these paradigms is the "biases and heuristics" that include the judgment of probability (Gilovich et al., 2002; Kahneman & Tversky, 2013). The other research program focused on decision making under risk (Koehler & Harvey, 2008). The last paradigm is related to social judgment theory. Kahneman and Frederick (2005, 2012) focused on probability judgment. A dual process probability judgment was improved. It was found that heuristic responses lead to biases. When incorrect responses were studied, It was figured out that representativeness (Kahneman & Tversky, 1972) and availability (Tversky & Kahneman, 1973) as heuristics generate biases in probability judgment. Analytic reasoning, which might prevent these biases, is associated with System 2. Therefore, it seems that normatively correct responses differ from biased responses. Similar differentiation was observed in deductive reasoning (Evans, 2008)

Empirical findings supported the distinction between reasoning processes. Therefore, dual process theories signify two distinct cognitive processing underlying reasoning. The neutral terms, which are system 1 and system 2, were used in the literature (Evans, 2008; Kahneman & Frederick, 2012; K.E. Stanovich, 1999). Different researchers have offered various terms to name two types of thinking such as "input modules versus higher cognition" (Fodor, 2018), "adaptive unconscious versus conscious" (Wilson, 2022), and "impulsive versus reflective" (Strack & Deutsch, 2004), "stimulus bound versus higher order" (Toates, 2006), "system 1 versus system 2" (Evans, 2003; Kahneman & Frederick, 2012). Even though two distinct processing were labeled by the authors, there is not just a dual processing theory to explain thinking processing during reasoning. Some of the researchers in this field disagreed with the assumptions about "underlying cognitive systems; some propose parallel and some sequential relationships between the two processes, and so on"(Evans, 2008).

Dual process approach predicts that under memory load, reasoning performance regress

Analytic reasoning is highly demanding on working memory resources. Therefore, the working memory capacity of a participant affects the analytic reasoning process. Individual differences in WMC are interpreted through the dual task procedure. Reasoning with secondary working memory tasks creates a conflict in the participant's mind (Evans, 2003). It is assumed that System 1 produces the correct response when the problem does not contain conflict (Evans & Stanovich, 2013). Even though the cognitive load is presented, the performance of participants does not affect since system 1 is not associated with computational resources. System 2 relies on logical standards, which requires executive resources. Therefore, it is supposed that participants' reasoning performance decrease under the load condition (Evans, 2003).

The result of the study by De Neys (2006b) showed that in the conflict problems incorrect heuristic responses increased. In the dual task, participants with high spans gave more correct responses than participants with low spans, when the conflict arises (De Neys, 2006b). In conflict items, the mean number of correct answers for all span groups decreased under complex dot pattern load. The concurrent memory load did not affect the performance in the reasoning task with no-conflict items. In the low span group, the load interfered with comprehension of the syllogisms in which the conclusions have a conflict between logic and belief.

System 2, which includes analytical thinking, demands executive resources along with working memory. In the designed experiment, a conflict occurs because both the working memory is loaded and the thinking for the correct answer takes place. Therefore, since more effortful thinking is inhibited by memory load, intuitive thinking, which is automatic, effortless, unconscious, associative, and does not require executive functions, plays a crucial role in producing the response (Bago & De Neys, 2017, 2019; De Neys, 2006b, 2006a; Kahneman, 2002).

This study was planned to examine reasoning from the dual process framework. The generic question is as follows: How does reasoning process when biased and genuine responses were given? This research was designed to observe both intuitive and analytical thinking processes. First, we aimed at the test time course assumption of the default-interventionist model. It is expected that the heuristic responses produced by system 1 are given faster, and the responses produced by system 2 are given slower. A two response paradigm (Thompson et al., 2011) was used to observe both intuitive and deliberative responses to the problems. This paradigm is based on asking questions twice. When the problems were asked the first time, time limit, countdown from 10 seconds, and memory load as dual task were applied. Cognitive load and time pressure cause the activation of system 2 to be inhibited. Therefore, the first responses were given as heuristics labeled by system 1. When the questions include conflict items, in order to give the correct response, it is necessary to develop conflict detection sensitivity. This is the property of system 2. When the system 2 activation is blocked in the first questions by cognitive load and time limit, it is hypothesized that incorrect responses are given to the first questions which include conflict items. The incorrect responses given to the first questions, which contain conflict items, may change when the question is asked for the second time. Because when the factors that prevent system 2 are removed, if the necessary cognitive effort is made, the conflict detection sensitivity develops. In this situation, the reaction times increase. Therefore, it was another expectation that the initial incorrect and final correct responses category in the experiment questions has the highest response time. The hypothesis is that participants spend more time to respond correctly than incorrectly to experiment problems. The questions, which include no conflict item, are asked as control. The expectation in these questions is that the first and final responses are correct.

In the confidence scale scores between P1 problems and P2 problems, it is the expectation that P1 confidence scale scores are significantly lower than P2 confidence scale scores. If the evaluation is made for the direction of change categories, “00” responses and “11” responses categories have higher confidence scale scores. When the first and second responses are within the same response category such as “00” responses, the confidence scale scores increase. Thompson et al. (2011) described this situation as the “feeling of rightness”.

The originality aspect of this study is that it was conducted with a population whose native language is Turkish. Therefore, the tasks, which are taken from the studies, were translated into Turkish. These tasks have not been applied to a Turkish speaker population until now. It is aimed to observe similar results in the different languages and therefore in the different cultures, as reasoning problems allow a language-based measurement.

Sixteen reasoning problems were randomly distributed to each participant. Therefore, there is no fixed order among the questions. This method was used to eliminate the effects of the fixed order of the questions. A trial follows that the problem was selected randomly from the set of 16 problems. This problem was asked with memory load and time limit. Then the same problem once again without memory load and time limit.

RESULTS

The questions which are presented with concurrent load and time pressure are named P1. The questions, which are presented without cognitive load and time pressure, are named P2. The results of this experiment have revealed that working memory load and time pressure caused the incorrect responses to increase. Because there is a significant difference between P1 accuracy scores and P2 accuracy scores. When memory load and time limit were removed, the correct responses increased in the second presentation of the problems (P2). Time limit and memory load made it difficult for system 2 to engage. Participants respond more correct answers to P2 questions

than to P1 questions. This result is consistent with the default interventionist model. Time limit and cognitive load caused to produce heuristic response generated by system 1.

Reaction times' difference was also observed between P1 questions and P2 questions. When the time limit was removed, the reaction times of the P2 questions got longer. Also, P2 correct responses were higher than P1 correct responses. When the reaction times increased, the number of correct responses increased. In the P2 questions, participants have developed conflict detection sensitivity. Some of the biased reasoners changed their first responses, which were chosen in the P1 questions. It means that some of the participants became sensitive to conflict items in the second presentation of the problems. The increased response times also signified this conclusion. Mean reaction times difference across correct responses between P1 and P2 questions were also examined. A significant difference was observed. The mean value of correct responses' reaction times in P2 questions is significantly higher than the mean value of correct responses' reaction times in P1 questions. Correlation analysis was made to observe the relation between P1 correct responses and P1 reaction times. Significant and positive correlation were observed. When the correct responses increased, the reaction times got longer in P1 problems. The correlation between P2 correct responses and P2 reaction times was researched. The correlation was significant and positive. When the correct responses increased, the reaction times got longer in P2 problems. In the control syllogistic reasoning problems between P1 and P2, there is no significant difference. In most trials (72.4%), participants responded correctly to both the P1 control syllogisms and the P2 control syllogisms. In the bat and ball control questions, %94.5 (431) trials were responded correctly. The vast majority of the subjects respond correctly to both the P1 control bat and ball problems and the P2 control bat and ball problems.

A significant difference was shown in the result section between P1 experiment syllogisms and P2 experiment syllogisms. %9.6 (44) trials were observed as incorrect first response and correct final response. A significant difference was examined between the P1 experiment bat and ball problems and the P2 experiment bat and ball problems. %13.4 (61) trials were responded as first erroneous response and final correct response. Significant differences were observed in both experiment syllogisms and experiment bat and ball problems between P1 and P2. The reaction times results of the "01" responses category in the experiment problems had the highest values for bat and ball problems (30.36) and syllogisms (19.17). In the result section, a significant difference was observed between P1 confidence scale scores and P2 confidence scale scores. P2 confidence scale scores were significantly higher than P1 confidence scale scores.

DISCUSSION

The syllogistic reasoning task and the modified version of the bat and ball task were served in this research. There were experiment (conflict) and control (no conflict) questions in both tasks. The expectation was that in the control questions, both first and second responses are to be correct. DI theory supports that heuristic system 1 processing provides to generate correct responses on control (no conflict) problems in both P1 and P2 (Bago & De Neys, 2017). If the problem does not include conflict, the heuristic system produces the correct response quickly. In this case, the heuristic system likely guides the participant to select appropriate options. The guidance depends on prior semantic knowledge, which leads to "contextualizing" a problem. The knowledge as a prototype regulates the participant's judgment. Even though the predictor is not aware of what exactly he or she chooses, the heuristic system allows the participant to respond fast with less cognitive effort (De Neys, 2006b). Participants' accuracy scores were compared in the result section. There was a significant difference between the P1 control bat and ball problems and the

P2 control bat and ball problems. It was based on the sample size. Most of the trials were responded correctly, but the different results were limited. Therefore, it created a difference between P1 bat and ball control questions and P2 bat and ball control questions. The correct response scores (11, first and final correct responses) in both P1 and P2 decreased dramatically when the problems include conflict items for both syllogistic reasoning experiment questions and bat and ball experiment problems. Even though the both first and second correct responses decreased, the "11" responses frequency was still high. Whereas %34 (155) trials were responded as "11" responses in the experiment syllogisms, %25.7 (117) trials were responded as "11" responses in the experiment bat and ball problems. A major challenge for the Default interventionist model is the high frequency of "11" responses in the P1 and P2 experiment problems (Bago & De Neys, 2017, 2019; Raoelison et al., 2020; Šrol & De Neys, 2021). There can be several reasons for "11" responses in the experiment problems, which include conflict items. The first reason might be individual differences in the mental activities among participants. Challenging response deadline and secondary cognitive load may not make difficult to the tasks enough for some participants. Because working memory capacity of some participants might be higher than the other participants. If the working memory resources are not sufficiently occupied by the cognitive load, system 2 provides to access to the working memory resources and ensures that the correct response is produced in the P1 as well. Another reason for "11" responses in the experiment problems might be random guessing. A dual task as memory load and strict deadline during the first presentation of the problems made it difficult to respond. The tasks might be too challenging for some participants. Therefore, the first presentation of experiment questions may be responded as random guessing which might be correct. Because syllogistic reasoning problems include two options. Therefore, there is a ½ (%50) probability to respond correctly. Bat and ball questions involve four

choices. Hence, there is a ¼ (%25) probability to give a correct answer. Briefly, initial responses could be randomly selected.

In the "01" responses category, the first heuristic incorrect response was given by biased reasoners. After the first quick response, the reasoners developed a sensitivity to conflict items. Hence, the first heuristic incorrect answer produced by system 1 was changed throughout the final answer which is the correct logical response produced by system 2. The default interventionist model predicts that the first heuristic response is incorrect and after additional consideration, incorrect responses might be corrected when the problems include a conflict item. When the initial responses were changed during the final response in the experiment problems, the reaction times were dramatically increased. According to the default interventionist model, when the initial incorrect heuristic response produced by system 1 is changed to a correct response during the final response, the reaction time gets longer because the system 2 thinking needs time to generate the correct response (Kahneman, 2011). This result is consistent with Bago & De Neys (2017, 2019) and Thompson et al., (2011). DI model prediction in this situation indicated that the incorrect response is corrected during the final response, and the reaction times increase because system 2 thinking is time consuming. Therefore, the result for "01" responses category reaction times in the experiment problems fit in the prediction of the DI model. The mean values of confidence scale scores were calculated within the direction of change categories for experiment and control questions. When the responses were not changed including "00" responses and "11" responses, the mean of confidence scale scores have higher values compared to the response categories which changed their initial response during the final response. It was revealed that when the initial response and final responses were matched, participants had high confidence. These results are consistent with Bago & De Neys (2017).

CONCLUSION

In this study, we aimed to observe how system 1 and system 2 affect the performance in the reasoning tasks including conflict and no-conflict items for both with constraints and without constraints. The syllogistic reasoning task and the modified version of the bat and ball problems, which involved experiment and control questions, were applied. Firstly, assessments were made on accuracy scores, response time scores, and confidence scale scores between initial and final responses. It was observed that the final response scores including accuracy scores, response time scores, and confidence scale scores are higher than the initial response scores. Positive correlations between accuracy scores and reaction time scores for both the initial response stage and final response stage were observed. Then, the reaction times of the correct responses were selected. It was shown that there is also a positive correlation between the number of correct responses and the reaction times of the correct responses for both the initial and final responses stages. Therefore, these result supports the DI model assumption.

In both the syllogisms control problems and the bat and ball control questions, the predominant category is first correct and final correct responses. Thus, our hypothesis for control questions was supported.

On the other hand, it was observed that the number of correct responses decreased significantly in the both syllogisms experiment questions and bat and ball experiment questions. In the experiment problems, the main response category was the initial incorrect response and the final incorrect response (“00” responses). These results are consistent with DI dual process predictions. The biased reasoners do not detect conflicts. Therefore, the responses, which were produced by system 1, were given. In addition, these biased reasoners, who gave incorrect answers

to both of the experiment questions, had higher confidence scale scores. The biased reasoners do not doubt their answers since they are not aware of the conflict.

When reaction times were observed, the results revealed that the participants, who developed sensitivity to conflict items in the experiment problems, had higher response times. If the problem contains conflict, analytic thinking gets involved where the correct answer is given (De Neys, 2006b). The conflict detection sensitivity was the characteristic of system 2. Hence, the result validates that system 2 based thinking is time consuming.

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