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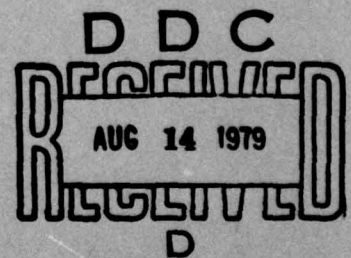
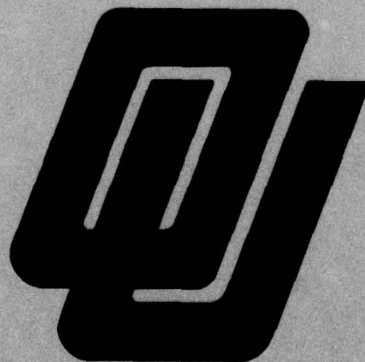
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Consistency Checking in Hypothesis Generation

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activated in memory in response to only part of the available data. This candidate hypothesis is then assumed to be checked for consistency against the remaining data. This latter process is called "consistency checking". Experiment 1 was performed to provide evidence that consistency checking occurs during hypothesis generation. Subjects who retrieved and checked hypotheses for consistency required more time to generate a hypothesis than subjects who just retrieved hypotheses. Experiment 2 indicated that subjects performed a task analogous to the consistency checking process faster than subjects who retrieved and checked hypotheses for consistency. Experiment 3 was performed to provide evidence that consistency checking is a self-terminating process. Subjects' latencies depended upon the position of a disconfirming datum within a data set, supporting this conjecture. Although some of the predictions in experiment 1 were not supported, the results generally confirm the existence of a high-speed verification process in hypothesis generation.

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Consistency checking and Hypothesis Generation

The term "hypothesis generation" refers to the generation of answers or possible explanations to account for a given set of information which will be referred to as "data". For example, a physician generates disease hypotheses in response to a patients symptoms and the results of diagnostic tests. Gettys and Fisher (in press) and Gettys, Fisher, and Mehle (1978) have developed a tentative model of the hypothesis generation process. According to this model, hypotheses are first retrieved or activated within a semantic memory network similar to that described by Collins and Loftus (1975). Any hypothesis so retrieved is assumed to be subject to some form of plausibility assessment which may range from simple semantic verification to complex processes involving probabilistic inference, depending upon task demands and the importance of the problem. The purpose of the present series of experiments is to provide evidence for the existence of a minimal form of plausibility assessment which is assumed to be intimately tied to the retrieval of hypotheses in multiple data problems.

Gettys, Fisher, and Mehle (1978) have described a study which estimated the number of activation tags a hypothesis node receives before it is retrieved as a possible hypothesis. For problems which involved three or six data, the hypotheses were estimated to be retrieved using only two or three data,

respectively. These estimates suggest that some mechanism or process must exist to insure that the retrieved hypothesis is consistent with all of the available data rather than just the data from which the hypothesis was retrieved. We have named this proposed process "consistency checking" and have made three predictions concerning its operation in the overall hypothesis generation process. First, when consistency checking occurs in hypothesis generation, this process should add time required to generate a consistent hypothesis beyond that required to retrieve a hypothesis from memory. Secondly, consistency checking is expected to be a more rapid process than hypothesis generation. Thirdly, it is expected that consistency checking is a self-terminating process.

According to our theoretical analysis, the generation of hypotheses which are consistent with a set of data involves the operation of independent retrieval and consistency checking processes. The retrieval process involves activation of potential hypotheses in response to only part of the total number of data presented in a decision problem. Any retrieved hypothesis is then assumed to be checked for consistency against the remaining data. If the retrieved hypothesis is found to be consistent with the remaining data, it will be emitted as a response. However, if any datum is found to be inconsistent with the retrieved hypothesis, the entire process will be repeated until a consistent hypothesis is found.

If the consistency checking process is independent from hypothesis retrieval, it should be possible to eliminate consistency checking from hypothesis generation by instructing subjects to respond with the first retrieved hypothesis suggested by a set of data irrespective of its consistency ("first

hypothesis retrieval condition"). Hypothesis generation data collected from subjects given such instructions could then be compared to data from subjects instructed to generate consistent hypotheses ("consistent hypothesis retrieval condition"). We predict that subjects instructed to generate consistent hypotheses will perform a hypothesis generation task slower than subjects instructed to respond with the first retrieved hypothesis. This time difference should be due to the occurrence of the additional retrievals and consistency checking required to generate a consistent hypothesis. In addition, it predicted that this time difference will increase as a function of the number of data presented in the decision problem (data set size). This is expected to occur for two reasons. First, as data set size increases the average number of data which are checked for consistency will increase. Thus, the amount of time used for consistency checking will increase with data set size, adding disproportionately to the time needed to retrieve a hypothesis from memory. Secondly, the generation of consistent hypotheses may require the retrieval of several hypotheses, some of which will be discarded as a result of consistency checking. Since we believe that hypothesis retrieval involves only part of the available data, it is expected that the probability of generating a consistent hypothesis on the first retrieval attempt will decrease as a function of data set size. As data set size increases more retrievals will be necessary to generate a consistent hypothesis and these will add disproportionately to the time needed to retrieve a hypothesis as set size increases. For this same reason we expect the number of errors to increase as a function of set size in the "first hypothesis" retrieval condition, but not in the "consistent hypothesis" condition. Thus, we expect an interaction between these

instruction conditions and data set size for both RT and error data. Regression analyses predicting hypothesis generation reaction time (RT) as a function of set size can be performed for both the "first hypothesis" and "consistent hypothesis" instruction conditions. The slopes of the best-fitting regression lines can then be compared. We predict that the slope of the "first hypothesis" retrieval instruction condition will be less than the slope of the "consistent hypothesis" retrieval instruction condition. The difference in the slopes of these lines will reflect how much time is required to perform the additional retrievals and consistency checking as set size increases and can be used as a crude estimation of the additional time required for these processes.

The second major consistency checking prediction is that it should be a more rapid process than hypothesis generation. In a semantic network model of memory (Collins and Loftus, 1975), concepts are represented as nodes interconnected by relational pathways. When a hypothesis is retrieved from such a network, activation is assumed to spread from both the nodes representing the general hypothesis category and from the data until several of these sources of activation meet at a hypothesis node. This activated node would then become a potential hypothesis. Thus, hypothesis retrieval may involve the activation of potential hypothesis nodes by relational paths leading from the data and general hypothesis category nodes. However, in consistency checking, the hypothesis is already available in memory and only the relation pathways leading to the data nodes must be activated. Thus, consistency checking is assumed to involve only the activation of relational information. From this it follows that consistency checking should occur at a faster rate than hypothesis

generation.

This prediction can be examined by a task manipulation in which the time to generate a consistent hypothesis (hypothesis generation task) can be compared to the time required to perform a task which is analogous to the consistency checking process (consistency checking task). This latter task involves the initial presentation of a hypothesis, followed by the presentation of a data set. The subject then must decide if the hypothesis is consistent with the data. This task can be considered analogous to consistency checking since it eliminates the hypothesis retrieval process and involves only the verification of relational information between the hypothesis and data. We expect that the consistency checking task will be performed faster than hypothesis generation, because the hypothesis generation task requires the additional retrieval process. In addition, it is expected that the time difference between these two tasks will increase as a function of data set size since the average number of retrievals involved in the generation of consistent hypotheses is thought to follow the same function. Thus, we predict a task by data set size interaction. Regression analyses predicting hypothesis generation and consistency checking RT as a function of set size can also be performed. It is expected that the slope of the best fitting regression line for the consistency checking task will considerably less than the slope of the hypothesis generation task. The difference between these slopes can also be used as a crude estimation of the additional time needed for retrieval of a consistent hypothesis since the hypothesis generation task involves hypothesis retrieval while the consistency checking task does not.

The final prediction about consistency checking is that it is a

self-terminating process. If a disconfirming relationship is found between a potential hypothesis and a single datum, the consistency checking process will stop. This prediction is based on the efficiency of this type of search. If a subject encounters a datum which is inconsistent with a hypothesis, the hypothesis is rendered implausible and it is useless to continue to verify it with the remaining data. This prediction can be examined using the same consistency checking task as was used to estimate the rate of hypothesis retrieval. If consistency checking terminates upon encountering a disconfirming hypothesis, then the latency to render a hypothesis implausible should increase as the ordinal position of the first disconfirming datum is increased in a set of data.

Three experiments were performed to verify these three major predictions. Experiment 1 involved an instructional manipulation where subjects either generated the first hypothesis suggested by a set of data or a hypothesis which was consistent with all of the same data. Experiment 2 involved a task manipulation in which subjects either generated hypotheses or checked them for consistency. Finally, Experiment 3 was designed to test the self-terminating assumption by manipulating the position of a disconfirming datum within a set of data.

Preliminary scaling study

An initial scaling study was performed to select a roughly homogeneous set of hypothesis generation problems to be used in experiments 1 and 2.

Method

Materials. A total of 100 animal hypothesis generation problems were used as materials. All problems consisted of characteristics normally associated with different animals. The data included such items as mode of locomotion, types of appendages, native continent, food sources, color, and size. Twenty-five problems were included in each set size (1, 2, 3, and 4 data). All the data were selected by the senior author to suggest a fairly large number of animals. Thus each problem could have several correct answers.

Subjects. Twenty-four University of Oklahoma introductory psychology students served as subjects for class credit and were run in two groups of 12 subjects.

Procedure. Subjects were presented the hypothesis generation problems one at a time by an overhead projector. The order of the problems was not randomized. The one datum problems were presented first, followed successively by the two, three, and four data problems. The problems were presented on a screen and subjects were given 60 seconds to write as many animals as they could which were consistent with all the data presented on that trial. After 60 seconds the experimenter stopped the group and moved to the next problem. Subjects were given a five minute break half way through the procedure.

Analysis. The total number of generated hypotheses, the total number of unique hypotheses, and the percentage of correct and incorrect hypotheses were tabulated for each of the 100 problems used in the study. These results were

used to select the problems for experiments 1 and 2.

Experiment 1

Experiment 1 was performed to provide evidence that consistency checking occurs in hypothesis generation. Experiment 1 employed an instructional manipulation designed to produce or eliminate consistency checking. In the "first hypothesis" instruction condition subjects were told to respond with the first hypothesis which was suggested by the data presented for a particular problem without concern for its plausibility. Hypotheses generated in response to these instructions should occur only as a result of the hypothesis retrieval process. This is because subjects were asked to respond with the first hypothesis which was activated by the data. Consistency checking should not have been involved since the generated hypotheses were not required to be consistent with all of the available data. In contrast, in the "consistent hypothesis" instruction condition subjects were asked to generate hypotheses which were consistent with all of the available data. This condition supposedly involves both the operation of hypothesis retrieval and consistency checking, since subjects would have to insure that any retrieved hypothesis was consistent with all of the available data. The additional time required to generate a consistent hypothesis over the amount of time required to retrieve a hypothesis can be attributed to the operation of consistency checking.

Method

Design: The basic design of experiment 1 was a two by four mixed factorial. Retrieval instructions were manipulated as a between-subjects variable with two

levels (first hypothesis vs. consistent hypothesis). Data set size was manipulated as a within-subjects variable with four levels (1, 2, 3, and 4 data) and problems were nested within each level of set size. Equal numbers of male and female subjects were included within each retrieval instruction condition. Thus, sex was treated as an additional blocking variable in the design. Performance was measured by reaction time (RT) and error rates. Reaction time was defined as the time required for a subject to generate a hypothesis following data onset. Errors were measured by the correctness of the generated hypotheses in light of the data for a particular problem.

Hypothesis generation problems. Forty-eight problems were used as stimuli for the generation of hypotheses. All problems consisted of characteristics normally associated with different animals. Twelve problems of each set size (1, 2, 3, and 4 data) were selected from those presented in the preliminary scaling study on the basis of the percentage of correct responses given for a particular problem. To minimize the number of incorrect hypotheses made in the present study, the problems with the twelve highest percentage of correct responses were chosen for each set size. Overall, the percentage of correct responses ranged from 100.0 to 85.7 percent.

In addition, there were four practice problems of each set size which consisted of products and industries for which different States are noted. The products and industries were selected to suggest the names of states which had a large variety of keyboard characters in their names to familiarize subjects with the location of as many letters on the keyboard as possible before the presentation of the experimental problems.

Instructions. Subjects' generated hypotheses under instructions to either respond with the first hypothesis which was suggested by a set of data or to respond with a hypothesis which was consistent with all of the data for a particular problem. In the "first hypothesis" retrieval condition, subjects were told to read all of the data presented on a given problem and then respond with the first hypothesis which occurred to them without regard for its correctness or plausibility. In contrast, subjects assigned to the "consistent hypothesis" retrieval condition were told to read the data presented on a given problem and then respond with a hypothesis which was consistent with all of the data. In the practice problems, a consistent hypothesis was defined as a state which was known for all of the product and industry data presented on a given trial. In the experimental problems, a consistent hypothesis was an animal name which had all of the animal characteristic data presented on a given problem. In addition, subjects in the consistent hypothesis condition were told to generate specific rather than general animal names. This was done because higher order animal classes (i.e. bird) were usually not consistent with all of the data in most of the problems.

In both instruction conditions, subjects' were told that they were being timed and were given accuracy instructions in regard to the speed-accuracy trade-off (Pachella, 1974). In the first hypothesis condition, accuracy was defined as responding with the first hypothesis which was suggested by the data, while in the consistent hypothesis condition, accuracy was defined as responding with a hypothesis which was consistent with all of the data.

Procedure. Upon entering the laboratory, subjects were seated at a CompuColor Model 8001 microcomputer which presented the entire experiment except for instructions and collected all responses. First, the appropriate retrieval instructions were given in the context of the State practice problems. Once the instructions were understood by the subject, the 16 practice problems were presented in the same order for all subjects. When these were completed, the instructions were repeated in the context of the experimental animal problems and these 48 problems were presented in a random order.

Both the practice and experimental problems were presented in a similar manner. First, the data was printed in the center of the computer screen so that it could be read from left to right. At this time a software clock started in the computer. Subjects were instructed to type their responses as soon as they thought of an appropriate hypothesis, and the first keystroke of their response stopped the clock and measured the latency of hypothesis generation. All subjects were forced to give an answer to all problems. Once the entire response had been typed and any spelling errors corrected, the subject pressed the "shift" key to advance the program to the next problem. This had the effect of erasing the screen and producing a 1.5 second delay before the next series of data was presented. At no time did subjects receive feedback concerning the correctness of their responses.

Subjects. Forty-eight University of Oklahoma introductory psychology students served as subjects. Limited typing skills were required of all subjects who participated. Subjects were randomly assigned to one of the retrieval

conditions upon entering the laboratory. The data of an additional 17 subjects were discarded because of equipment failure, the inability to type, or because the subject was not a native speaker of English.

Results and Discussion

An ANOVA was performed on the trimmed means for each set size of a subjects latency data. Any individual RT was excluded from these means if it was above or below .75 standard deviations from the mean of all RTs within that set size. This cutoff criterion was chosen because it usually eliminated only extreme outlying latencies. This was necessary because subjects occasionally "drew a blank" and had latencies longer than two minutes. The analysis resulted in the expected main effects of instructions, $F(1,44) = 8.48$, $MSe = 10.38$, $p < .01$, and set size, $F(3,132) = 147.79$, $MSe = 10.38$, $p < .001$. However, the instructions by set size interaction was not significant. The means of both instruction conditions for each set size are presented in Table 1.

Insert Table 1 about here

Another ANOVA was performed on the means of the correctly answered problems of each set size. These means were used so the results of the present experiment could be compared to equivalent data obtained in experiment 2. Again, there were significant main effects of instructions, $F(1,44) = 4.95$, $MSe = 31.19$, $p < .05$, and set size, $F(3,132) = 47.94$, $MSe = 5.99$, $p < .001$, and the instruction by set size interaction was not significant. Regression analyses were performed

TABLE 1
TRIMMED MEAN REACTION TIME IN SECONDS AS A FUNCTION OF
INSTRUCTIONS AND SET SIZE IN EXPERIMENT 1

INSTRUCTIONS	SET SIZE			
	1	2	3	4
FIRST HYPOTHESIS	3.13	3.92	6.76	6.38
CONSISTENT HYPOTHESIS	4.08	5.43	8.97	8.26

on these means predicting RT as a function of set size. The resulting correlations were .905 and .861 for the first and consistent hypothesis conditions, respectively. The slopes obtained from these analyses were then used to estimate the extra time required by consistency checking. The slope obtained for the "first hypothesis" condition was 1.49 second/datum while the slope of the "consistent hypothesis" condition was 1.85 second/datum. The difference, .36 second/datum, is an estimate of the extra time which the consistency checking process requires. The means of the correctly answered problems for both instruction conditions and all set sizes are presented in Table 2.

Insert Table 2 about here

These means are also presented graphically along with the best-fitting regression lines in Figure 1a.

Insert Figure 1 about here

The significant set size effect is consistent with the results of Graesser and Mandler (1978) who found that the time required to generate the name of a dimension which is common to a set of words increases as a function of set

TABLE 2
MEAN REACTION TIME IN SECONDS OF CORRECT HYPOTHESES
AS A FUNCTION OF INSTRUCTIONS AND SET SIZE IN EXPERIMENT 1

INSTRUCTIONS	SET SIZE			
	1	2	3	4
FIRST HYPOTHESIS	3.42	4.41	7.75	7.28
CONSISTENT HYPOTHESIS	4.74	5.57	10.42	9.30

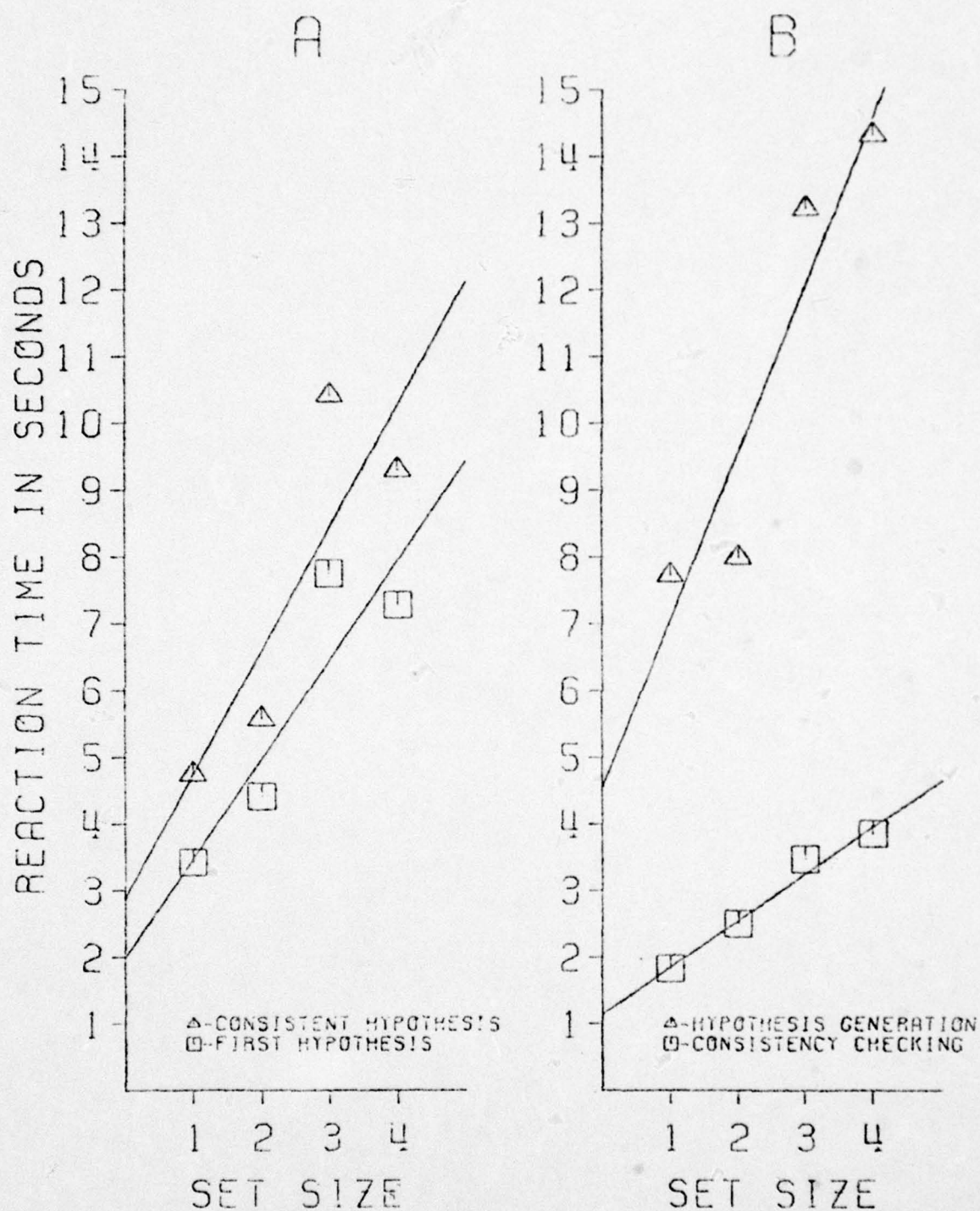


Figure 1. Mean reaction time of correctly answered problems. A) Experiment 1 for the "first" and "consistent" instruction conditions, and B) Experiment 2 for the hypothesis generation and consistency checking tasks. Also shown are the best-fitting regression lines for both instruction and task conditions.

size. However, the present results show that RT does not increase monotonically with set size since the mean of set size four is actually lower than that of set size three for both instruction conditions. This was probably due to the specific three-data problems used in the experiment. Our conjecture about this finding is that the three-data problems were generally more difficult for our subjects than the four-data problems. This was an unfortunate result of not being able to use randomly selected data for each subject. Fixed data sets were used to avoid the possibility that the same data would be presented to the same subject twice and also because some random selections of animal characteristics would have no correct answers (i.e. has wings, has four legs), or have correct answers which a typical subject would not know.

The significant instruction effect supports the prediction that consistency checking occurs during the hypothesis retrieval process. However, the failure to find a significant instructions by set size interaction is not consistent with the prediction that disproportionately more retrievals and thus more consistency checking will occur as set size increases. However, another result was obtained which is consistent with our prediction; the analysis performed on the number of errors made within each set size condition per subject resulted in a significant set size effect, $F(3,132) = 8.15$, $MSe = 1.06$, $p < .001$. The mean number of errors for set sizes 1 through 4 were 1.25, 1.75, 1.79, and 2.29, respectively. However, the instructions by set size interaction was not significant.

This result is consistent with the idea that hypotheses are retrieved using only part of the data. If hypothesis retrieval is based upon all of the data, irregardless of set size, then a constant error rate would be expected across

all set sizes. However, if retrieval is based on only part of the data then it would be expected that errors should increase as a function of set size. Gettys, Fisher, and Mehle (1978) estimated that the number of data from which a hypothesis is retrieved increases disproportionately slower than data set size. This means that the probability of a retrieved hypothesis being consistent with all of the data will become smaller as data set size increases. Since the probability of an error is a positive function of the retrieved hypothesis being inconsistent with part of the data, the number of errors should increase with set size.

In addition, more errors were made by the first hypothesis condition (1.99) than by the consistent hypothesis condition (1.55), but this difference did not attain traditional levels of significance, $F(1,44) = 2.96$, $MSe = 3.07$, $p < .10$. This trend in the means also is consistent with our prediction; subjects who do not consistency check should generate more hypotheses which are inconsistent with all of the data. The error data is consistent with the prediction that "first hypothesis" condition subjects would have more errors as set size increased, but is not consistent with the prediction that "consistent hypothesis" subjects would have a constant number of errors across set size. Evidently, subjects in the "consistent hypothesis" condition did not always check their answers for consistency, or did not have enough knowledge to generate consistent hypotheses.

The overall low error rate between the "first" and "consistent" instruction conditions also indicates that subjects in the "first hypothesis" condition probably engaged in some plausibility assessment before emitting their

responses. Thus, the instruction manipulation was not completely successful in either producing or eliminating the consistency checking process. The failure to find a significant interaction between instructions and set size with the RT data was also probably the result of the weakness of the instruction manipulation.

Examination of possible artifacts. Another possible explanation of the instruction effect is that subjects in the "first hypothesis" condition tended to repeat answers more often than in the "consistent hypothesis" condition. Collins and Loftus (1975) predict that a previously activated concept will be relatively easier to reactivate than a non-activated concept. This would lead to the prediction that a previously generated hypothesis would require less time to generate than a hypothesis which has been retrieved for the first time. Loftus and Loftus (1974) and Loftus (1973) have found that repeated retrievals from the a category result in faster latencies than the first retrieval from the same category. To test this prediction, the number of repeated hypotheses were found for each subject and entered into an ANOVA. The results showed that females (13.37) made significantly more repetitions than males (10.54), $F(1,44) = 5.01$, $MSe = 19.2$, $p < .05$, but the instruction effect was not significant, suggesting that response repetition does not account for the observed instructions effect.

Another possible explanation for the instruction effect is that the instructions given to the "consistent hypothesis" subjects asked for specific animal names rather than general categories of animals while no such restriction was imposed on the "first hypothesis" subjects. The retrieval of specific animal names may involve a more extensive memory search than the

retrieval of general categories of animal (e.g. bird, fish, snake, etc.). If this is true then it would be expected that the "consistent hypothesis" condition would be slower than the "first hypothesis" condition. First, the number of general animal names given by each subject in both instruction conditions were counted. An ANOVA performed on these data resulted in a significant effect of instructions, $F(1,44) = 10.64$, $MSe = 9.05$, $p < .01$. The mean number of general category names for the "first and "consistent" hypothesis conditions were 8.25 and 5.42, respectively. In addition, males (5.58) produced significantly fewer general names than females (8.08), $F(1,44) = 8.28$, $MSe = 9.05$, $p < .01$. If the instruction effect on RT was due to this difference in the number of general names, then it would be expected that there would be a high correlation between the number of general names emitted and the mean RT for each subject. However, the correlation between these measures was $-.210$ which is not convincing evidence for this argument.

Therefore, the instruction effect can tentatively be explained by the operation of consistency checking process, although the failure to find a significant instructions by set size interaction was disquieting. As previously mentioned this was probably due to the weak effect of instructions. In addition, there may have not been large enough data set sizes in the present experiment for the interaction to be manifest. In spite of this failure, the instruction manipulation did produce results predicted by the operation of consistency checking in hypothesis generation.

Experiment 2

Experiment 2 was designed to demonstrate that consistency checking is a more rapid process than hypothesis generation. This was done by comparing a hypothesis generation task to a consistency checking task. The hypothesis generation task was identical to the "consistent hypothesis" instruction condition in experiment 1. Again it was assumed that this condition involved the operation of both hypothesis retrieval and consistency checking as discussed previously. The consistency checking task involved presenting a hypothesis followed by the presentation of data. The presentation of a hypothesis prior to the data eliminated the hypothesis retrieval process from this task. After the data was presented the subject checked the data and hypothesis for consistency and then made either a "yes" or "no" response depending upon whether the all of the data was consistent with the hypothesis. This "consistency checking" task is analogous to the proposed consistency checking process for two reasons. First, the presentation of the hypothesis eliminates the hypothesis retrieval process, thus simulating the situation where a hypothesis has been activated by other data. Secondly, the task involves only the semantic verification of semantic relationships between the hypothesis and data.

Method

Design. Experiment 2 was a two by four mixed factorial design in which task (hypothesis generation vs. consistency checking) was a between-subjects variable and data set size (1, 2, 3, or 4 data) was a within-subjects variable.

This design was a "group-yoked" design. This design was termed "group-yoked" because the hypotheses generated by the subjects in the hypothesis generation task were presented to subjects in the consistency checking task. Thus the subjects in the consistency checking task were yoked to the correct responses given by subjects in the hypothesis generation task. This yoking could not be done at the individual level because a typical hypothesis generation subject does not always give correct answers to the problems. To eliminate this problem, all of the correct answers for a particular hypothesis generation problem were pooled and presented to consistency checking subjects in the same proportions as they were originally generated. Equal numbers of male and female subjects were included in both task conditions and served as an additional blocking variable in the design. Performance was measured by the latency to either generate a hypothesis or check a hypothesis against a set of data in the hypothesis generation and consistency checking tasks, respectively.

Subjects. Forty-eight University of Oklahoma introductory psychology students served as subjects for class credit. The data of an additional 20 subjects were discarded because of equipment failure, poor typing skills, or because the subject was not a native speaker of English.

Materials. The same 48 hypothesis generation problems used in experiment 1 were also used in the present experiment. In the consistency checking task there were 48 "true" and 48 "false" problems. The same animal characteristic data used in experiment 1 were also used in the "true" consistency checking problems. The hypotheses presented in the "true" consistency checking problems were the correct hypotheses generated by subjects who completed the hypothesis

generation task using the same data. Different correct hypotheses generated by the hypothesis generation subjects were presented to consistency checking subjects in approximately the same proportions as they had been emitted in the hypothesis generation task.

An additional 48 "false" consistency checking problems were constructed to make 'yes' and 'no' responses equally probable in the consistency checking task. Both the data and hypotheses used in these "false" problems were selected by the experimenter. Twelve "false" problems were used for each data set size and one datum was chosen to be inconsistent with the hypothesis used in each problem. In the case of multiple data problems the position of the disconfirming datum was counterbalanced across different problems.

Procedure. Since the hypotheses which were checked for consistency were generated by subjects in the hypothesis generation task, it was necessary to run the hypothesis generation task before the consistency checking task. The procedure used in the hypothesis generation task was identical to that used in the consistent hypothesis retrieval condition in experiment 1.

Subjects in the consistency checking task were seated at a CompuColor model 8001 microcomputer which presented the entire experiment except for instructions and also recorded all responses. Then 16 practice problems were presented which involved the same data as used in experiment 1, followed by the 96 experimental animal problems. In both the practice experimental problems, subjects were told to make a 'yes' response if the presented hypothesis was consistent with all the data or a 'no' response if any one datum was

inconsistent with the hypothesis.

A consistency checking trial began with the presentation of a hypothesis which was a State name in the practice problems and an animal name in the experimental problems. This hypothesis remained on the screen until the subject pressed the 'space bar' on the computer keyboard. At that time the hypothesis was erased, followed by a 1.5 second delay and the presentation of the data. The subject then pressed either the "Z" or "/" key to indicate either a "yes" or "no" response and the position of the "yes" and "no" keys were counterbalanced across subjects. These keys were located on the bottom row of the computer keyboard and were chosen as response keys because they were widely separated and subjects could easily keep their fingers poised above these two buttons. When a response was made, the software clock stopped, and the response was printed on the screen beneath the data and remained there for a 1 second interval. Finally, the screen was cleared and the next hypothesis was presented. This procedure was repeated until all of the problems had been presented.

Results and Discussion

An ANOVA was performed using the mean latencies of the correctly answered hypothesis generation and "true" consistency checking problems. Both main effects of task, $F(1,44) = 169.61$, $MSe = 17.64$, $p < .0001$, and set size, $F(1,132) = 64.84$, $MSe = 3.47$, $p < .0001$, were significant. In addition, the task by set size interaction was significant, $F(3,132) = 22.81$, $MSe = 3.47$, $p < .0001$. Regression analyses performed on the two task conditions predicting RT

as a function of set size produced correlations of .938 and .988 for the hypothesis generation and consistency checking tasks, respectively. The slopes of the best-fitting lines obtained from these analyses were 2.499 and .703 for the hypothesis generation and consistency checking tasks, respectively. The difference between these two slopes was 1.796. The mean RT's for both task conditions across set size are presented in Table 3.

Insert Table 3 about here

The same mean RT's along with their respective best-fitting regression lines are presented in Figure 1b.

By comparing Figures 1a and 1b, it can be seen that the y-intercept is noticeably greater for the hypothesis generation task obtained in experiment 2 than for the identical "consistent hypothesis" condition in experiment 1. This difference may have been due to a difference in typing skills between the subjects in the two experiments. Subjects were allowed to sign up for experiment 2 without having typing skills and only those subjects which had a great difficulty in finding key locations were discarded. However, in experiment 1, subjects were not allowed to sign up unless they were familiar with a typewriter keyboard.

The significant task effect demonstrates that a consistency checking task is performed more rapidly than a hypothesis generation task. The large difference

TABLE 3
MEAN REACTION TIME IN SECONDS OF CORRECT HYPOTHESES
AS A FUNCTION OF TASK AND SET SIZE IN EXPERIMENT 2

TASK	SET SIZE			
	1	2	3	4
CONSISTENCY CHECKING	1.83	2.50	3.47	3.85
HYPOTHESIS GENERATION	7.72	7.99	13.21	14.31

in the y-intercepts between the tasks is due to the different responses made by the two groups. The hypothesis generation task involved many different keys on the keyboard, while the consistency checking task involved only two. Despite this difference in y-intercepts, it can be seen that the slope of the best fitting regression line of the consistency checking task is considerably lower than that of the hypothesis generation task. This indicates that the amount of time needed to process one additional datum was considerably greater for the hypothesis generation task than the consistency checking task. This result provides support for the prediction that consistency checking is a more rapid process than hypothesis generation. In addition, the crude estimate of the additional time required for consistency checking obtained in experiment 1 (.361 second/datum) is also considerably less than the estimate of the additional time required for hypothesis retrieval obtained in the present experiment (1.798 second/datum). This difference in estimates is also consistent with the prediction that consistency checking is a high-speed verification process rather than a memory search process.

Experiment 3

Experiment 3 was performed to test the prediction that consistency checking is a self-terminating process. This was done by varying the position of a disconfirming datum within three data consistency checking problems similar to those used in experiment 2.

Method

Design. Experiment 3 was a within-subjects design where the independent

variable was the ordinal position of a disconfirming datum within a series of three data (position 1, 2, 3 or no disconfirming datum). Performance was measured by the latency to determine whether a hypothesis was consistent or inconsistent with all of the available data. Sex and "yes-no" key positions were also included in the design as a blocking and counterbalancing variables, respectively. In addition the position of the disconfirming datum was counterbalanced for a given problem across subjects.

Subjects. Twenty-four University of Oklahoma introductory psychology students served as subjects for class credit. All were randomly assigned to the counterbalancing conditions.

Materials. Eighteen practice and sixty experimental consistency checking problems served as materials. All consisted of a hypothesis and three data. The practice problems involved checking countries against products and industries, occupations against tools, and animals against characteristics. The experimental problems only involved checking occupations against tools and animals against characteristics. Within each problem type there were 15 problems in which the hypothesis was consistent with all the data and 15 problems where one datum was inconsistent with the hypothesis. Within these disconfirming problems, there were five problems with the disconfirming datum in the first, second, and third positions.

Procedure. Upon entering the laboratory, subjects were seated at a Compucolor model 8001 microcomputer which presented the entire experiment and recorded all responses. First, instructions were given about the nature of the consistency checking problems and the the practice problems were presented. Then the

instructions were repeated and followed by the experimental problems. Both the practice and experimental problems were presented in the same order for all subjects. The procedure and instructions used in experiment 3 were similar to those used in the consistency checking task used in experiment 2. First, a hypothesis was presented on the screen and remained there until the subject pressed the "space bar". This erased the hypothesis and following a 1 second delay the three data were presented in a vertical list so that they could be read from top to bottom. The data remained on the screen until the subject pressed either the "Z" or "/" key on the keyboard, depending upon whether their response was "yes" or "no" and which of these two keys represented these responses. Then the response was printed on the screen and remained there for 1 second, after which, the screen was cleared and the next hypothesis was presented.

Results and Discussion

A within-subjects ANOVA was performed on the trimmed means obtained for each type of disconfirming datum problem and the confirming problems for each subject. Any individual RT was discarded if it was above or below .75 standard deviations from the mean of the distribution of all the RT's for a particular problem. The results of this analysis indicated a significant effect of the position of the disconfirming datum, $F(3,60) = 10.91$, $MSe = 1948.13$, $p < .001$. The means of the first, second and third disconfirming datum positions were 2.78, 3.23, and 3.49 seconds, respectively, while the mean of the confirming or true problems was 3.14 seconds. Tukey pairwise comparisons indicated that position 2 and 3 problems were disconfirmed significantly slower than position

1 problems, $t(1,60) = 3.53$ and 5.57 , respectively, error term = 12.71 , $p < .05$, but position 2 problems were not disconfirmed significantly faster than position 3 problems. Thus, as predicted, RT increased as a function of the position of the disconfirming datum. This result is consistent with the prediction that consistency checking is self-terminating. If consistency checking were an exhaustive process then subjects should continue checking a hypothesis after encountering a disconfirming datum. However, the present results suggest that subjects stop consistency checking when a disconfirming relationship is found between a datum and a hypothesis. The nonsignificant difference between the position 2 and 3 problems, however, suggest that some subjects did tend to read the last datum, but evidently most subjects stopped reading if the disconfirming datum was in the first position. Also of interest was a regression analysis performed predicting RT as a function of the position of the disconfirming datum. The slope of the best fitting line was $.35$ second/datum which is remarkably close to the $.36$ second/datum estimate of the additional time required for consistency checking obtained in experiment 1. This result provides converging evidence that consistency checking is a more rapid process than hypothesis retrieval.

Summary

In summary, the results of experiment 1 demonstrated that subjects who retrieved and checked hypotheses for consistency required more time to generate hypotheses than subjects who just retrieved hypotheses. This finding provides evidence that consistency checking occurs in the hypothesis generation process.

However, the predicted interaction between instructions and set size was not found. We believe this failure was the result of an ineffective instructional

manipulation. Evidently, subjects in the "first hypothesis" condition inadvertently checked their responses for consistency since they did not make significantly more errors than subjects in the "consistent hypothesis" condition. In addition, subjects in the "consistent hypothesis" condition did not always produce consistent hypotheses, especially in the larger set sizes. However, a similar interaction was found in experiment 2 which involved a task manipulation. This interaction demonstrated that consistency checking is performed much more rapidly than hypothesis generation. Finally, experiment 3 provided evidence that consistency checking is a self-terminating process.

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