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FORMULATION AND REFORMULATION OF VERBAL CONCEPTS

Thesis for the Degree of M. A.
MICHIGAN STATE UNIVERSITY

Eugene Richard Hall

1960

FORMULATION AND REFORMULATION OF VERBAL CONCEPTS

By

Eugene Richard Hall

A THESIS

Submitted to the College of Science and Arts
Michigan State University in partial fulfillment
of the requirements for the degree of

MASTER OF ARTS

Department of Psychology

1960

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AN ABSTRACT

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ABSTRACT

This thesis was concerned with the generality of a method of describing and quantifying reformulation behavior in problem solving. The method consisted essentially of dividing the problem solving episode into two phases, preparation and solution. During the preparation phase, the subject saw the part of a problem that allowed him to form a hypothesis about what the required solution of the problem would be. He then turned a toggle switch which illuminated a number of possible solutions. This action prevented him from seeing the preparation material again unless he turned the switch back. "Switching-back" was taken as the observable sign of reformulation.

A previous study using geometric figures about which concepts could be formed, did obtain differences in the switchback index of reformulation. The present study, designed to assess the generality of the method, employed verbal concepts. Subjects were given pretraining on either of two verbal concepts. This pretraining resulted in the establishment of effective sets but presenting problems for which the established set was inappropriate did not result in disproportionate returns to the preparation material; consequently, predicted differences in the switchback index of reformulation did not appear.

It was suggested that time score increases during the solution phase could be taken as a sign of reformulation. The increased

time may have allowed the subject to reformulate the problem by recalling the familiar verbal material of the preparation phase. If so, this would obviate the necessity of a manual return to preparation.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
History of Set	1
Current Conceptions of the Nature and Operation of Set	3
Advantages of Set	5
Disadvantages of Set	6
Reformulation	7
EXPERIMENT	11
Hypothesis	11
Design	11
Apparatus	12
Materials	13
Procedure	15
RESULTS	19
DISCUSSION	28
SUMMARY AND CONCLUSIONS	37
BIBLIOGRAPHY	38
APPENDIX	41

LIST OF TABLES AND FIGURES

TABLE Page

I Frequency Distribution of Sensory Choices by Type of Pretraining 19

II Errors, Switchbacks and Mean Times in Seconds Over Five Test Trials 20

III Time Increase (Log Units) Between Last Training Trial and First Test Trial 22

FIGURE

1. Floor plan of apparatus. 14

2. Preparation and Solution Time for Training and Test Trials--Group I. 23

3. Preparation and Solution Times for Training and Test Trials--Group II 24

4. Preparation and Solution Times for Training and Test Trials--Group III 25

5. Preparation and Solution Time for Training and Test Trials--Group IV 26

6. Training Trials Performance for 48 Subjects Having Each Concept. 27

INTRODUCTION

History of Set

Near the end of the nineteenth century, extensive investigations into the nature of thought were carried on at the German University of Würzburg (13, 28, 29). Several important interrelated contributions towards an understanding of the nature of thinking emerged from this early psychological laboratory. The Würzburg group demonstrated that factors other than simple associations of conscious ideas or sensations operated to influence the course of problem solving. These "other" factors appeared to function in such a way that the thinking processes could be characterized as being "directed" towards a definite end; namely, the solution of a given problem, and not merely random processes. In their attempts to account for the direction of thought the phenomenon of "set" became established (13).

The Würzburg group employed a method of study consistent with the then current concept of thought as the content of consciousness. The "thought experiment" devised by this group consisted of giving the subject a simple problem to solve and then asking him to describe his experience from the time when the problem was given until the solution was reached (28). This introspective method, however, did not adapt itself well to a systematic analysis of thought. It was soon discovered that thought could not always be characterized as having (conscious) content. Certain activities or processes exhibiting directedness and not open to introspective analysis appeared to be involved in problem solving. The thought processes themselves leading up to the solution of a problem appeared to be determined

by events other than those which could be reported on by the subject. One source of this determination was shown to be in the instructions given by the experimenter (8).

Once a subject had been given a task, he adopted a "task-attitude" or "set" for the duration of the task. This task attitude determined in large part the responses that the subject would make, the manner in which he would prepare for problem solution and the nature of the solution that he would give. Ach (as reviewed by Gibson, 8) early demonstrated this notion of task-attitude by presenting the numbers 6 and 2 to his subjects. This presentation yielded a reaction of 8, 4 or 12 depending on whether the task prescribed was adding, subtracting or multiplying. The aim, intention or set of the subject determined the reaction that he would give.

The Würzburg investigators expanded this notion of task-attitude and introduced a terminology employing three principal concepts. The Einstellung (set) was produced by the conscious acceptance of the Aufgabe (instructions). The determindierende Tendenz (determining tendency) was a more specific selective agent opposable to associative tendencies. The Bewussteinslage (conscious attitude) was the imageless, undescribable experience accompanying a mental set or trend (8).

Subjective methods of studying problem solving gradually gave way to objective experimentation. Set now became a hypothetical construct rather than an introspective observation and the original precision of meaning for these terms was lost. Many terms now appear in the literature which all refer broadly to the general fact that directedness appears as a major characteristic of thinking and behavior. This directedness may come from specific instructions

as demonstrated by Ach and others (30), or it may arise from the subject's interpretation of the task properties (23, 18). In this paper, the term set will be used to refer to directedness in terms of readiness to make a particular response.

Current Conceptions of the Nature and Operation of Set

Problem solving in the laboratory is said to begin with a stimulus situation and instructions which establish sets and define the goals (7). Many investigators assume either implicitly or explicitly that set formation is the major portion of problem solving. The set steers the course of thinking towards a particular channel, colors the character of the thought processes and limits the ultimate possibilities of response (23).

The formation of a set occurs during the period when the subject is preparing to solve the problem (12, 30). The human perceptual system seen as having a limited capacity (3) requires that a selective operation be performed on all inputs into the system. This selective operation occurs during the preparation period when the individual assesses, categorizes, codes, groups or otherwise relates the various parts of the stimulus situation as to their relevancy or irrelevancy for the solution of the given problem.

The set operates by selecting in advance. It does not select from among several responses called up by the stimulus but rather it limits the field of response in advance of the stimulus so that only responses conforming to the task are ordinarily called up (30). Once the set has been thoroughly established it may function automatically with little awareness of its operation by the subject (28).

That sets can be established without the use of instructions and without the awareness of the subjects was demonstrated by Rees and

Israel (23) and later confirmed by Maltzman and Morrisett (18). Rees and Israel established sets for certain anagram solutions over other possible solutions by simply training their subjects on a particular method of solution. Subjects trained to make solutions falling into a conceptual category of, for example, nature-words continued to seek nature-word solutions even when it was possible to make alternate solutions. Similarly, subjects trained to solve anagrams by using a certain letter order continued to solve anagrams in this manner even when alternative solutions were possible.

The order set was said to be usually involuntary, unverbalized and unconscious. The category set was found to be either automatic or accompanied by verbal awareness and a conscious attitude of search. It was equally effective in either case. The occurrence of one kind of solution rather than an alternate solution in an ambiguous situation provided the means of testing the influence of the training series in establishing sets toward a certain type of solution word (category set) or toward a certain method of attack (order set). The effectiveness of the two kinds of set was measured in terms of the frequency and quickness of appropriate solutions, i.e. in terms of the selection and facilitation of solutions.

There seems to be little reason to believe that sets established by a training method operate any differently in terms of selectivity and facilitation from those established by instructions. It may be, however, that sets established by training are more enduring, more permanent (19, 26) and operate at a less conscious level (23) than the instruction set. The degree of awareness of the set may itself by a function of the nature of the task.

Set operates not only in problem solving but also in the related areas of perception and memory. Külpe (15) demonstrated the

effects of set on perception as early as 1904. He found that the tachistoscopic presentation of colored nonsense syllables resulted in perceptions in which the actual sensory qualities of the stimulus not relevant to the task-set were "to all intents and purposes not seen" (13, 28). Varying the instructions resulted in different sensory contents, thus, "the attentive set served to function as a selective agent." Various other experiments on the relation of set to perception have been reviewed by Gibson (8).

Chapman (4) repeated Külpe's experiment to determine if the irrelevant features were really absent from the perception or whether they were simply forgotten by the time the experimenter asked the subject to report something he had not been looking for. Chapman found that both factors were at work. He found that perceptions actually conformed to the instructions but that the process continued during primary memory with the irrelevant aspects of the stimulus fading in imagery. Hence, set operates on both perception and primary memory; it determines what will be remembered as well as what will be perceived.

Advantages of Set

The chief advantages of set lie in its facilitating and selecting effect on the problem situation (8, 11, 20, 23). The set operates to select the inputs into the perceptual system (3). Because of this selection the variety and kinds of responses that will be called up into the situation are limited (30). Perception of only relevant aspects of the stimulus situation makes for ready categorization of these aspects and accurate, rapid solutions of problems can follow. Set, in providing readily available responses to certain aspects of the environment, eliminates the need to find new responses to

recurring every day situations and "frees" the mind to let it deal more effectively with other more complicated tasks (16).

Disadvantages of Set

But the effects of set are not always beneficial to the subject. Certain dangers are inherent in set. The existing set may not be applicable to a given problem or it may lead to a solution inferior to one which could be obtained by using another strategy. Instead of being master of his habits, the individual may come to be mastered by them. Luchins has shown the blinding effects of too persistent a set (16). He demonstrated the effects of set in directing the method of solution of his now famous water jar problems. His subjects were trained on one method of solving the problems which required the manipulation of three jars in such a manner that a certain specified amount of water would be left in one of them. After having been trained to use a longer, more complex method of solution, his subjects were "blind" to a shorter more direct method of solving the problems.

Duncker (6) uses the term "functional fixity" to refer to a disadvantage of set which depends on learning or transfer. If an object has one customary use or function, it is not easily seen as suitable for a different function. In an experiment by Adamson (1) subjects found it difficult to conceive of boxes already serving one purpose, namely, that of containing material, to be used for another purpose. Similar experiments utilizing Maier's two-string problems also point to this phenomenon of functional fixity (2,18).

Interference in transfer experiments may be the result of conflicting sets. In certain situations, antagonistic or conflicting sets may result in delaying (5) or altogether preventing an appropriate

response (16). Rees and Israel (23) demonstrated the effects of interaction between two kinds of set on both selection of and speed of solutions. Using a category set (nature words) and an order-set, they found that when the two sets were congruent, the combination increased the number of set solutions. When the two sets were in opposition, the order set was more effective in determining solutions. Time scores remained relatively short in the critical series when the two sets were congruent but there was still some increase over the time scores of the training series. When the two sets were in opposition, time scores for the critical series were considerably lengthened. Rees and Israel concluded that the presence of the one set (nature set) tended to hinder the operation of the other (letter order set).

Failure in problem solution is seen as being frequently due to an inflexible direction which blocks the correct way of looking at the problem (8, 17). If set is assumed to be the primary portion of problem solving, then a correct solution to a problem depends upon the extent to which the subject has formed an appropriate set (as well as upon the nature of the problem) in his preparation. If the subject discovers that he is set wrong for the solution of a problem he must discard the inappropriate set, return to a new preparation for the problem and reformulate the problem in terms leading to a new more appropriate set.

Reformulation

One way of approaching the study of the inappropriate set is through a study of the reformulation process. What happens when the person finds that his set is wrong, that he is not prepared to solve a simple problem? What behaviors of the subject can be used to infer and describe the reformulation process?

Reformulation can be assessed subjectively by asking the subject when the experiment is over to comment on his "experience" at finding that he was not prepared to solve a simple problem. This method has among its disadvantages one of being temporally separated from the problem on which reformulation occurred or was made necessary. Consequently, the subject may not be able to recall his experience when asked. Introspective methods have also shown that the subject is frequently unable to verbalize or to describe his experience; hence, this method does not offer any objective evidence that reformulation really did occur or, if so, what the nature of the process was.

A more desirable technique of assessing reformulation is one employing an objective index that can be obtained from direct observation of the subjects' behavior at the point where reformulation is necessitated. Such a method involves the establishment of a task-induced set and the subsequent presenting of problems which cannot be solved by that set. If it is assumed that the subject's formulation of the problem determines what kind of solutions he will get set to look for, failure will lead to reformulation and a different set. Since formulation occurs during preparation, returning to preparation can be taken as a sign of reformulation.

Johnson has devised an apparatus which permits the separate exposure and timing of two parts of a problem, "preparation" and "solution." During the preparation period, the subject is given enough information to "collect his thoughts," that is, to form a set or a direction, towards the problem's solution. During the solution period, the subject is required to make a response which solves the problem. A toggle switch on the apparatus permits the subject

to see either side of the problem at will but not both. If the subject finds on switching to the solution side of a problem that he is not prepared to solve that problem (i.e. is set wrong) he can "switch back" to the preparation side and re-examine the preparatory parts of the problem. A "switchback" is taken as an index of reformulation.

Johnson (14) obtained an objective index of reformulation using this procedure and apparatus. As the present study is modeled largely after Johnson's unpublished one, his experiment must be briefly summarized in order to adequately interpret the results of this study.

Johnson used a series of eight training cards to build up task-induced sets in his subjects. On each half of a card ten geometric figures were displayed in various spatial orientations. The subject's task was to decide what the ten figures on the preparation side had in common. He then turned the toggle switch to light up the solution side of the card on which ten more figures were displayed. Subjects solved the problems by choosing the one figure on the solution side that had the same characteristic as the figures on the preparation side.

For one series of cards, the common characteristic was the shape of the figures. For example, all of the figures on the preparation side were rectangles, or circles or triangles etc. For the other series, the common characteristic was the interior shading or texture of the figures. Each of the figures had, for example, vertical lines, horizontal lines, cross-hatched lines or the like.

The effectiveness of the training series in establishing sets was tested by presenting an "ambiguous" (cf. 23) situation to the subjects. The display of figures on the preparation side had both shape and

texture in common. The subject could solve these ambiguous problems by choosing either a shape or a texture response. The highly significant number of responses consistent with the training series showed that the materials had established highly effective sets. Hence the ambiguity of the situation was resolved by the set (cf. 31, p. 830).

The objective index of reformulation was obtained from a second group of subjects trained in the same manner. These subjects were given test problems for which the established set was inappropriate. The correct solution of their problems necessitated a "breaking" of the established set and the formation of the set different from the one on which they had been trained. The index of reformulation was obtained by counting the number of times it was necessary for the subject to return (i.e. turn the toggle switch back) to the preparation material before he could solve the problem.

The number of switchbacks made by this group was significantly higher than the number made by both a control group who solved problems consistent with their training sets and the ambiguous group. Significantly more individuals made switchbacks than in the other groups.

That the switchbacks did, in fact, constitute an index of reformulation was shown by the results obtained with a group trained and tested in the same manner but not allowed to switch back either during training or test trials. Significantly more errors were made by more individuals in this group than in any of the other groups.

EXPERIMENT

Hypothesis

Johnson's results showed that this method with its switch-back procedure could be used to separate formulation from solution and to obtain an objective index of reformulation without the uncertainties of subjective observation. An implied conclusion from his results is that an inappropriate set is one of the conditions leading to reformulation. A question arose as to the generality of the manual switchback as an indicator of reformulation in similar problems involving different kinds of materials. Specifically, could the switchback index of reformulation be obtained with problems employing verbal materials to induce sets rather than figures? The hypothesis tested in the present experiment was that this behavioral index of reformulation would be unaffected by the nature of the materials of the problem.

The present experiment, devised to test this hypothesis, made use of words grouped in such a way as to enable the subject to form concepts on the basis of the groupings. Two types of concepts were employed in a manner analogous to Johnson's figures. (A more complete discussion of the concepts is presented at a later point in the paper.)

Design

The subjects were ninety-six under graduate psychology students drawn from classes during the spring and summer terms of 1959. They were divided into four groups of 24 each. Group I, the ambiguous group, provided a test of the effectiveness of the materials in inducing

sets. Group II, the reformulation group, was to provide the switchback index. Groups III and IV were control groups. Group III controlled for the difficulty of the materials and was to provide evidence that factors other than the materials themselves were responsible for switchbacks. Group IV was also a reformulation group but they were not allowed to switch back. Greater errors in this group would show that the switchback did in fact lead to reformulation and subsequently to correct solutions. Each of the four groups was further divided into two subgroups according to the concept to which they were exposed during the training series.

Apparatus

The apparatus used in the experiment consists of a box divided into approximately equal halves and equipped with a holder at the back into which 5" by 8" index cards can be fitted manually by the experimenter. Each half can be lighted separately and timed separately by means of standard electric timers which are operated by each circuit. For this experiment the timers were equipped with specially constructed logarithmic dials so that time scores could be read directly in log units, thus precluding the necessity for later conversion.

The left side of the box presents that half of a card on which the parts of the problem essential to "preparation" are displayed. The right side presents that half containing the possible "solutions" to the problem. A one-way glass prevents the subject from seeing the materials before the light is turned on in that compartment. Stray light which would enable the subject to see through the glass is controlled by conducting the experiments in semi-darkness. A small

desk lamp sits under the apparatus and provides enough light to read the timers.

E manipulates a master switch which simultaneously turns on the light on the preparation side and activates an electric timer. The subject studies the left side of the card as long as he wishes and turns the toggle switch. This action darkens the preparation side and stops that timer while simultaneously illuminating the solution side and activating this timer. The subject indicates his solutions by pressing a numbered button on a bank in front of him thereby darkening the solution light and stopping the timer that measures solution time. The floor plan of the apparatus showing the lighting and timers is shown in Figure 1.

Materials

All instructions and words used in the experiment were typewritten in lower case pica type on plain white index cards. Five words, approximately centered and double-spaced, were typed on each side of an index card in the following manner:

dandelion	1.	sugar
butter	2.	yellow
gold	3.	throb
mustard	4.	brown
canary	5.	scooter

The words on the preparation side were such as to enable the subject to form a concept which solved the problem (in this example, yellow). The remaining words were made to be as neutral as possible.

Two types of concepts were used in the experiment. One type was based on the sensory impressions (cf 24, 25) made by objects

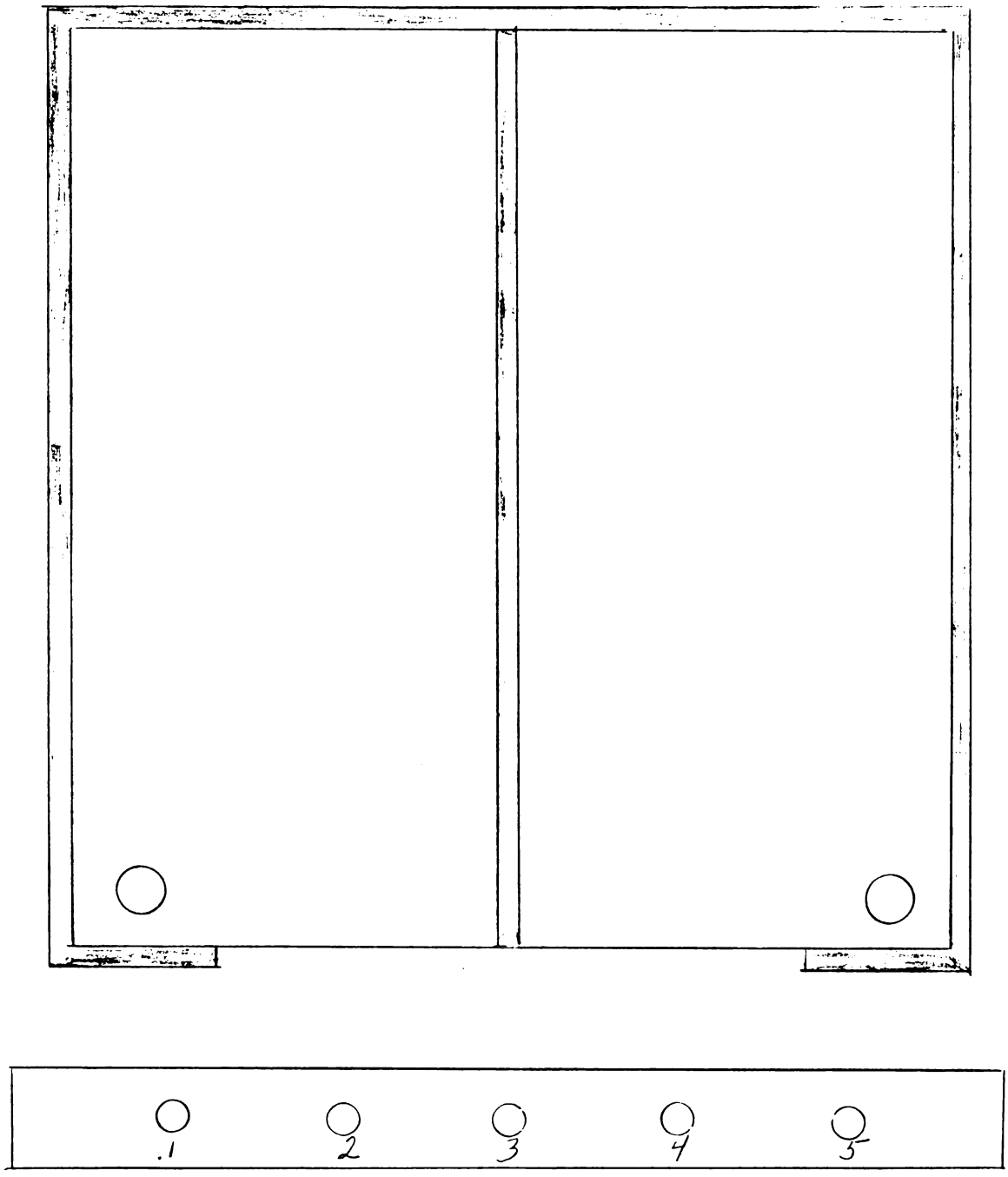


Figure 1. Floor plan of apparatus.

represented by words. An example of this concept appears above. A preliminary study indicated that the practice of naming the concept (yellow) led to the establishment of more effective sets than did choosing another example of the concept (for example, corn). Most of the words used for the sensory concept were taken from Underwood and Richardson's list of high response categories of sensory impression (24).

The other type of concept was based on more abstract characteristics. The words used for this concept could be subsumed under such concepts as bodies of water, articles of furniture, fish, etc.

Procedure

All subjects read a short paragraph identifying the experiment as one in "forming concepts on the basis of common characteristics shared by the objects represented by words." Subjects read that it would help them if they tried to "form a global impression of how the objects taken as a group would appear together." This statement was intended to preclude attempts by the subjects to analyze all of the properties of any one object thereby ignoring communality with the other objects.

Further instructions regarding the task and the apparatus were presented in the box. On the left (preparation) side, subjects read that they would next see a group of words which were all similar in some way. They were to decide what these words had in common and to remember the common element as they would have to find another example on the other (i.e. solution) side of the card. Subjects read that they could turn the switch whenever they felt that they knew what the common element was. They were warned that the left side would become dark and they would see only the right side

of the card. The last line of instructions, "You may switch back if necessary," was deleted from the instructions for Group IV (See Appendix).

Subjects then turned the toggle switch lighting up the solution side of the box where they read that they would next see five numbered alternatives. They were to pick the one that was another example of the other side and indicate their choice by pressing the corresponding button on the board in front of them.

All subjects were then shown three practice cards to acquaint them with their task. One of the sample cards, for example, had the words, republic, representatives, congress, legislate and elect typed on the preparation side. Subjects should have prepared to solve this problem by determining that all of these words were "political terms" (21). Consequently, on turning to the solution side and seeing the words: 1. imagination, 2. amendments, 3. portrait, 4. conclusion, and 5. helicopter, subjects should have been "set" to pick the word "amendments," another political term, as the correct solution.

After the three practice cards, subjects went directly into the body of the experiment. Subjects were run individually in a fixed order so that any population changes would be reflected in all groups. No two consecutive subjects were given the same concept. Ten training cards and five test cards were shown to each subject. Partial randomization of the order of presentation was accomplished by a shuffling procedure.

The training of Groups I, II and III was identical. Verbal reinforcement was used to enhance the establishment of set and switchbacks were permitted at any time. Group IV was trained in

essentially the same manner except that this group was never allowed to switch back. It was expected that the standardized pretraining would provide uniform sets. Consequently, different "test conditions" afforded the test of the hypothesis.

Group I was tested on five "ambiguous" problems which could have been solved by either concept. For example, one of the ambiguous cards contained the names of five "green vegetables" on the preparation side. On the solution side a subject set for sensory dimensions would find the word "green," while a subject set for abstract concepts would find the word "tomato." It was expected that solutions would be made on the basis of the respective training concepts if the words in the training series had been effective in establishing sets.

Group II, the reformulation group, was tested on problems for which the training set was inappropriate. Subjects who were trained to use abstract concepts now had to reformulate the problem in terms of sensory concepts in order to solve the problem. For the green vegetable card, this group could now solve the problem only on the basis of the concept "green." The abstract-concept group were similarly required to formulate the other concept to solve their problems. The number of times subjects in Group II switched back to the preparation side before they solved the test problems is the objective index of reformulation.

The test cards for Group III were the same cards that were used to assess reformulation in Group II. The cards were used differently however in that the problems were consistent with the subjects' pretraining. Since the established set would be appropriate, it was expected that both errors and switchbacks would be minimal for this group. If the number of switchbacks were significantly

smaller than for the reformulation group, evidence would be obtained to support a conclusion that an inappropriate set is one of the conditions necessitating reformulation and that the switchback is an index of this reformulation.

Group IV subjects were treated in the same manner as Group II subjects in that the established set was inappropriate for solving the test problems. It was assumed that if they could not reformulate they would make errors.

RESULTS

The effectiveness of the training series in establishing sets was determined by comparing the number of sensory choices made in the ambiguous situation by each of the subgroups of Group I. As the two subgroups had had different pretraining, a significantly different number of sensory choices by the subgroups could be attributed to the type of pretraining that they had; in other words, it would afford evidence that the pretraining had resulted in set establishment. The frequency distribution of sensory choices according to type of pretraining is given in Table I.

TABLE I

FREQUENCY DISTRIBUTION OF SENSORY CHOICES BY TYPE OF PRETRAINING

Pretraining	Frequency of Sensory Choices						
	0	1	2	3	4	5	$\bar{X}$
Sensory (n = 12)			1	4	3	4	3.83
Abstract (n = 12)	4	3	2	2	1		1.42

$t = 4.82$; $P < .001$.

Inspection shows that the subgroup trained on the sensory concept made a far greater number of sensory choices than did the one trained on the abstract concept. The probability of such an occurrence is less than .001. Scoring responses on the basis of the number of abstract choices yields complementary results. Hence, it can be concluded that sets, or predispositions to make

responses consistent with those required in the training series, were established by the training materials.

Since the pretraining did result in sets, it was expected that giving a problem for which the established set was inappropriate would lead to more returns (i.e. switchbacks) to the preparation material. Consequently, Group II was expected to make significantly more switchbacks than any of the other groups. This hypothesis was not confirmed. The total number of switchbacks over the five test trials were 17, 19 and 15 for Groups I, II and III respectively (Table II). These values did not differ significantly.

TABLE II

ERRORS, SWITCHBACKS AND MEAN TIMES IN SECONDS OVER FIVE TEST TRIALS

Group	Switchbacks	Errors	Preparation Time	Solution Time
I	17	3	4.31	4.44
II	19	9	4.12	4.89
III	15	3	3.55	3.64
IV	-	10	4.89	5.75

Group IV, which brought an inappropriate set into a problem situation which did not allow for any (apparent) reformulation or restructuring of the situation, was expected to make more errors than the other groups. However, this group made errors equivalent to the number made by Group II who were allowed to reformulate by switching back. The total number of errors made by each of the

groups is presented in Table II. It should be added that choices by Group I were not considered errors if they were consistent with either dimension of classification, abstract or sensory. No correlation between errors and time scores were found. Average preparation and solution times over the five test trials are also given in Table II.

Number of appropriate solutions is but one way of assessing the effectiveness of set (23). A second way is in terms of the amount of time spent on a problem as an index of the efficiency of the set. It follows that if a set is highly effective, the choice of a response in a problem situation for which the set is appropriate will be in accordance with the set and will be made quickly. However, if conflicting sets, or determining tendencies of some kind, are operating, changes in time scores reflect this conflict and consequently bear on set efficiency.

As switchbacks did not provide an index of reformulation, differences in time scores between the training and test series were analyzed not only to provide an alternate means of assessing the effectiveness of the training sets but also in an attempt to determine the implications of these time score changes for the reformulation process. The method used involved calculation of the differences in time scores, expressed in logarithmic units, between the last training trial and the first test trial for each group. For example, Group I subjects spent 630 log units in preparation on the last training trial and 639 log units in preparation on the first test trial. These figures represent a net gain of plus 9 units for the group, an increase which is not significant. These time score changes are presented numerically in TableIII and graphically in Figures 2, 3, 4, and 5. Only the scores on the first test card were used as it

was assumed that the greatest impact of a set change would be reflected here. This assumption was borne out by the performance curves. Only the last training trial scores were used because of the belief that the single last trial scores fairly well represented asymptotic values (Figure 6).

TABLE III

TIME INCREASE (LOG UNITS) BETWEEN LAST TRAINING TRIAL AND FIRST TEST TRIAL

Group	Increase		t	
	Preparation	Solution	Preparation	Solution
I	9	24	1.37	2.42*
II	32	67	2.37*	5.11*
III	-11	2	-1.02	.13
IV	12	59	1.63	4.13*

*Significant at or beyond .05 level.

10 log (100 x time in seconds).

Figure 2. Preparation and Solution Time for Training and Test Trials--Group I

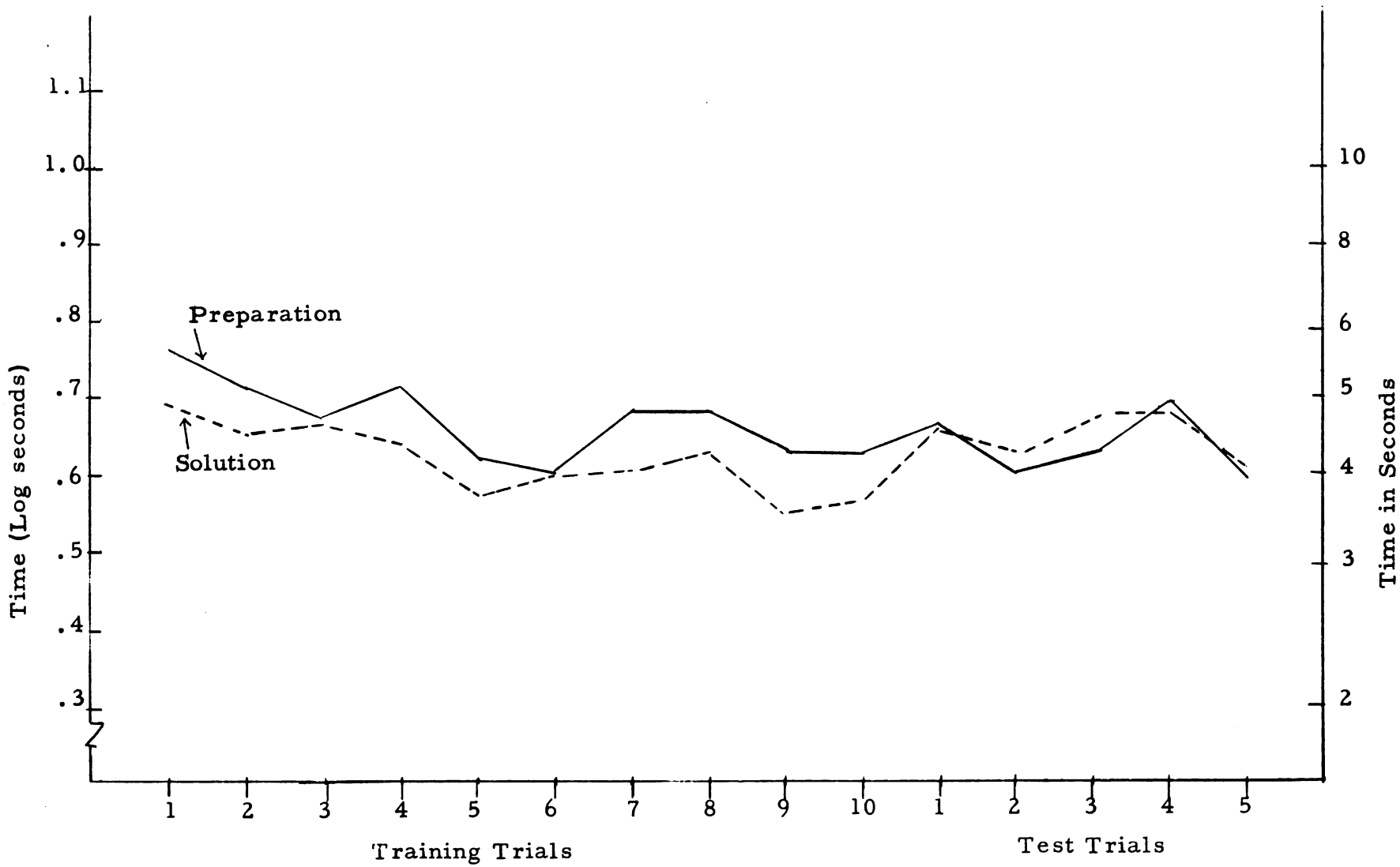


Figure 3. Preparation and Solution Times for Training and Test Trials--Group II

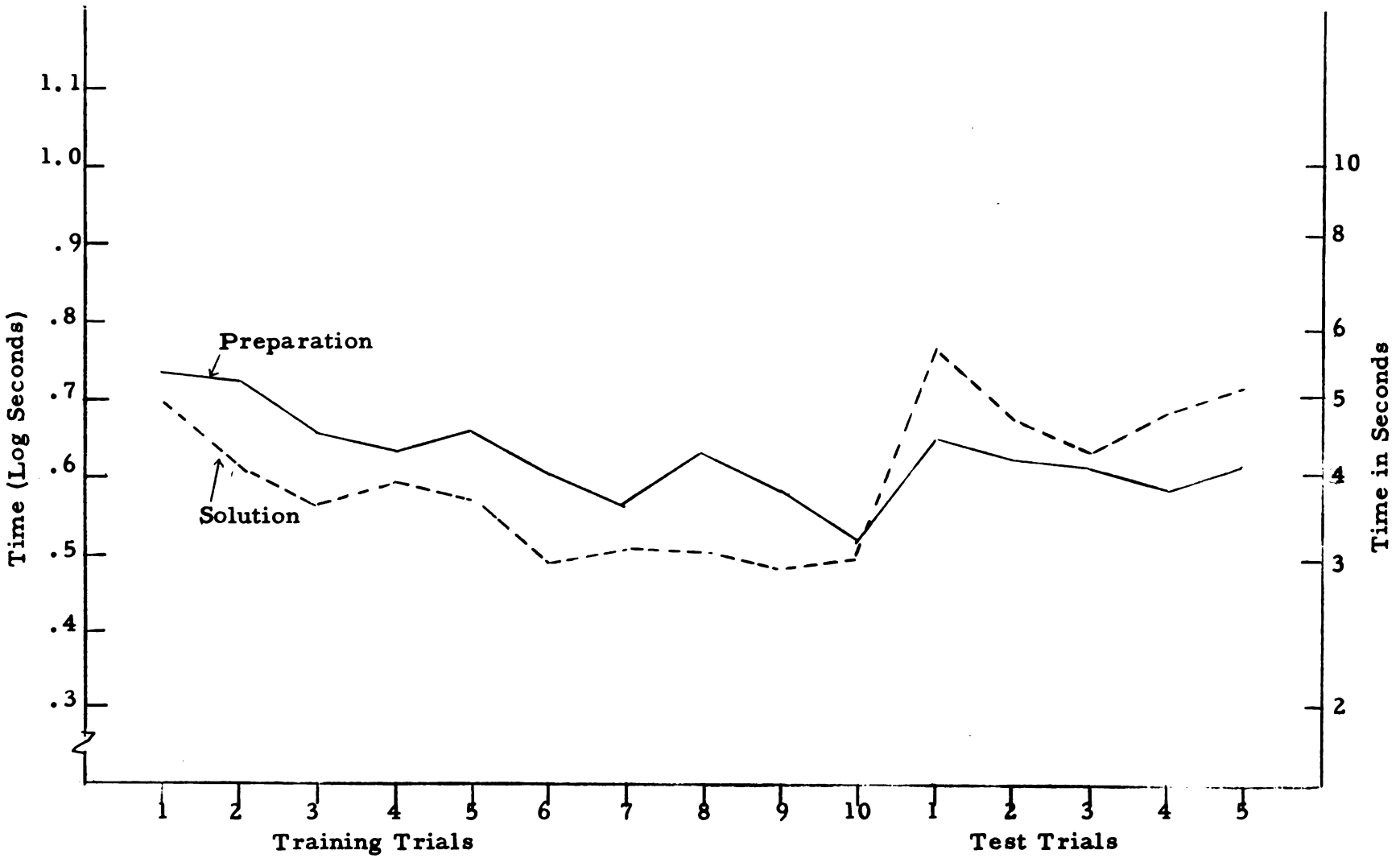


Figure 4. Preparation and Solution Times for Training and Test Trials--Group III

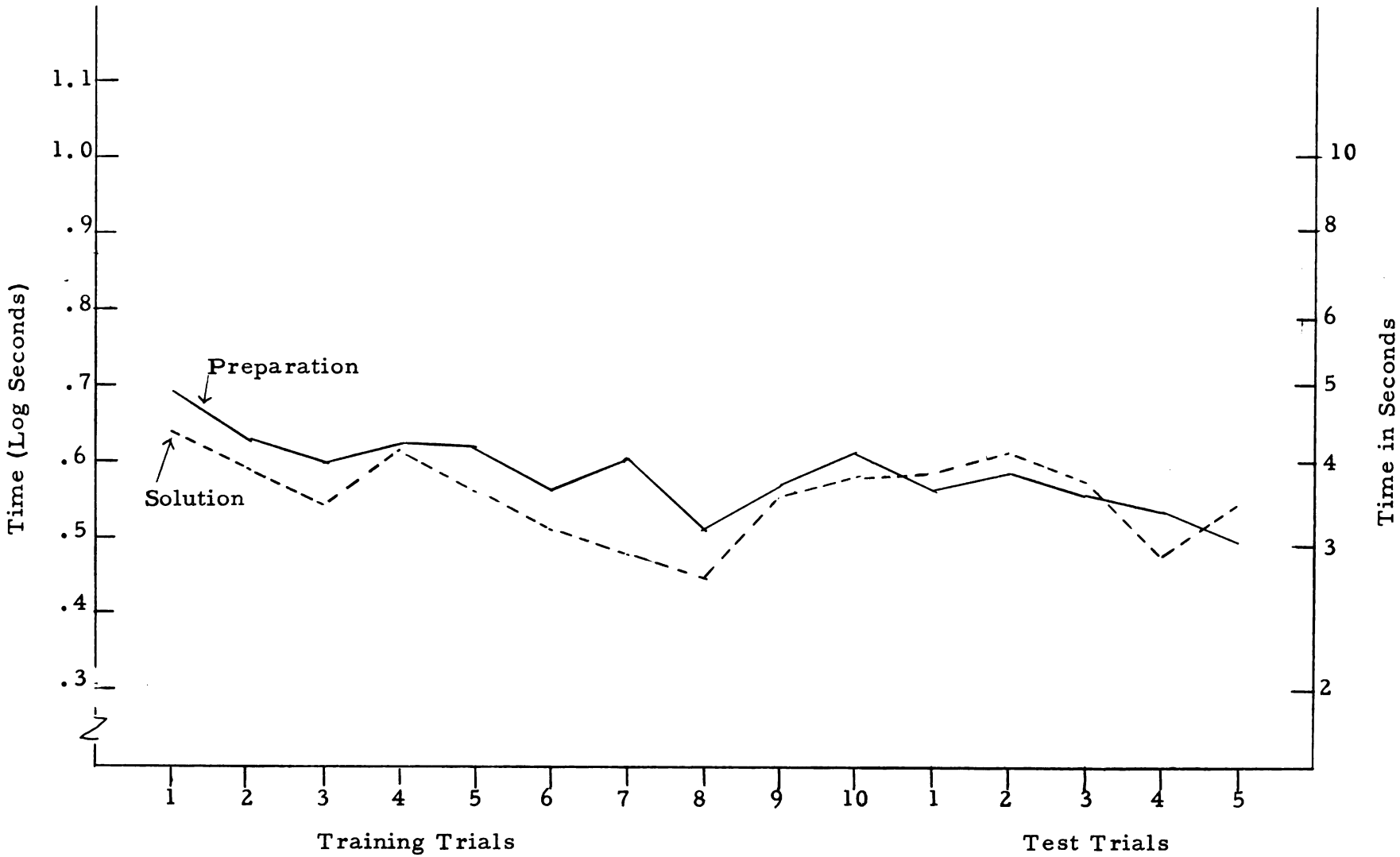


Figure 5. Preparation and Solution Time for Training and Test Trials--Group IV

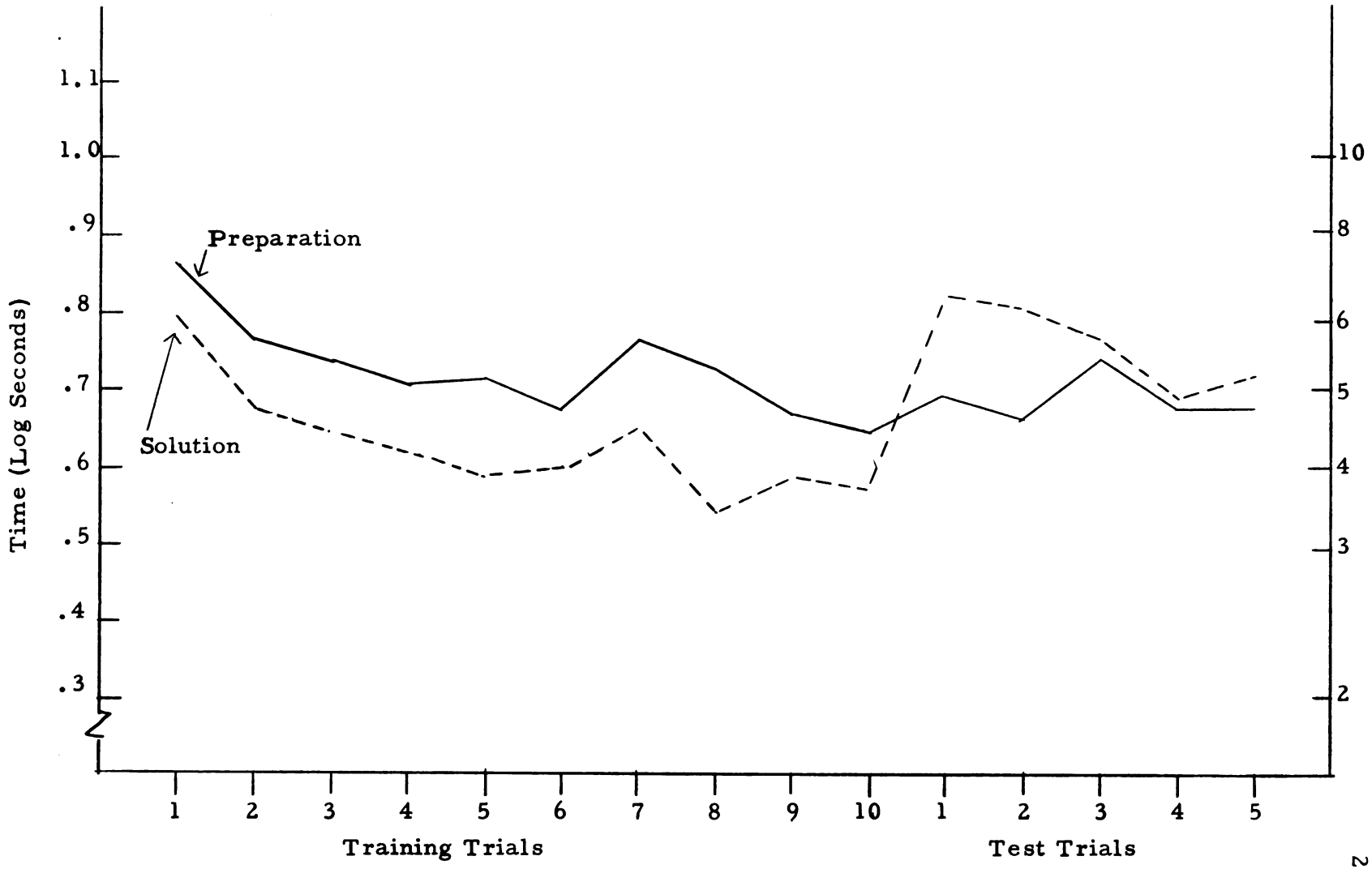
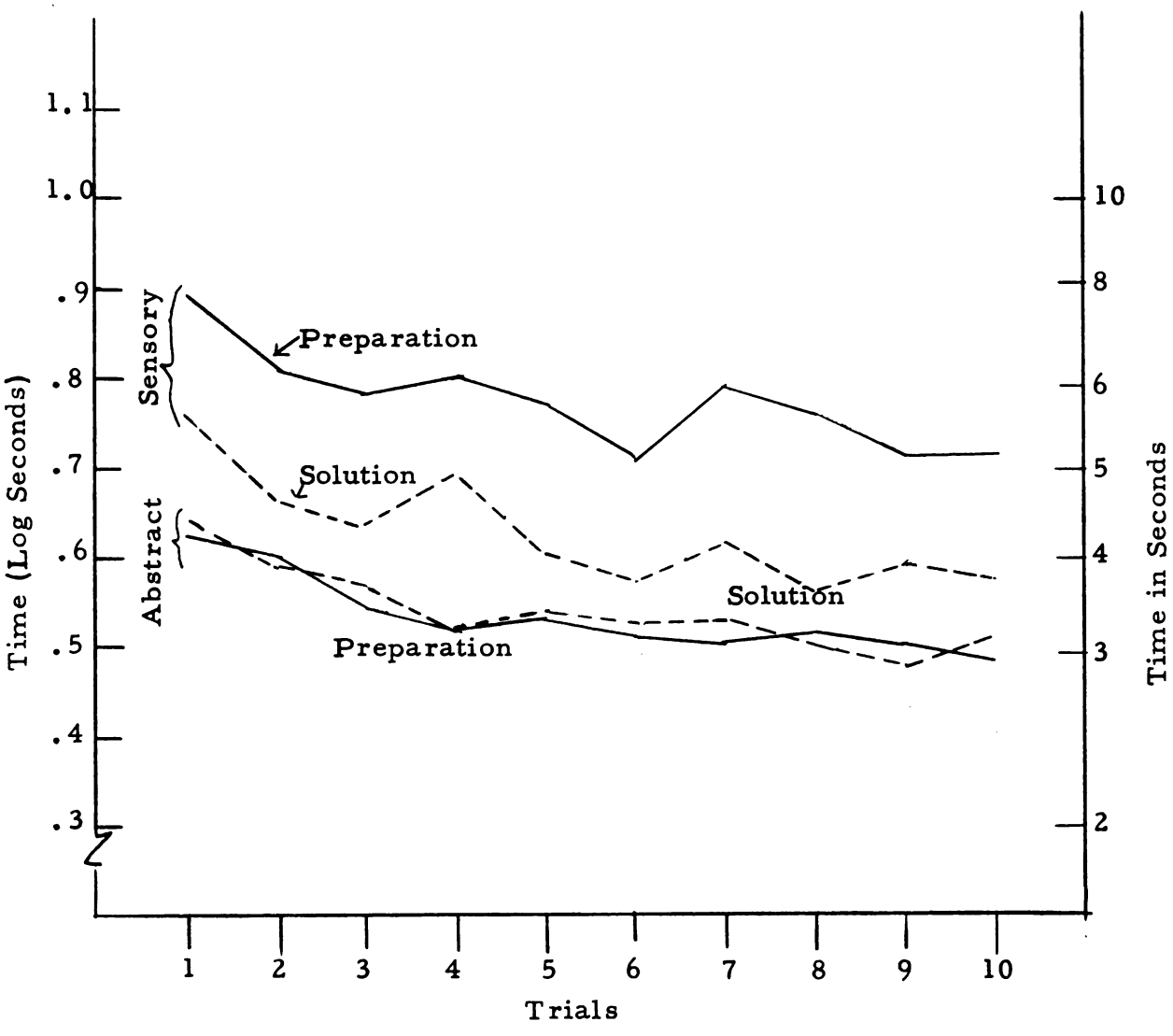


Figure 6. Training Trials Performance for 48 Subjects Having Each Concept



DISCUSSION

The data of Table I support the conclusion that the training materials were highly effective in establishing sets for a particular kind of resolution of the ambiguous situation. Both concepts were effective in determining choices. Hence, with effective sets established, giving problems not consistent with pretraining should have provided information relevant to the reformulation process.

It was expected that a numerical index of reformulation based on an objective, quantifiable measure of subject behavior could be obtained by the methodology of the experiment. Set formation is assumed to be an important factor in successful problem solving. Set largely determines the aspects of the stimulus situation that the subject will attend to and directs the solution of the problem. Faced with a problem for which an existing set is inappropriate, the subject must reformulate the problem in such a way that a new, more appropriate set leading to a solution is formed. The effectiveness of a set may be measured in terms of the frequency and quickness of appropriate solutions. The method employed in this experiment allows for both kinds of measurement and also permits for a study of the reformulation process.

Johnson (14) in his experiment with geometric figures obtained an objective index of reformulation from the number of times subjects turned a toggle switch back to the preparation side before they could solve a problem for which a set established by training was inappropriate. The present study, using highly familiar verbal materials so arranged as to establish concept-sets, did not obtain

predicted differences in the switchback index of reformulation. Several reasons, primarily in terms of the amount and kinds of materials used in each experiment, can be given to account for this failure. Among them are the span of immediate memory, past experience as it affects the nature of the task and other factors relating to the effectiveness of the training sets including the "intrinsic" nature of the task.

Differences in the amount of materials used to form the respective concepts in each experiment may partly account for the differences in results, namely, the failure in the present experiment to obtain the objective index of reformulation. Probably one of the most important reasons for failure to obtain differences in switchbacks in this experiment is the span of immediate memory (22). This experiment employed only five relatively simple words during the preparation period. Subjects could not only form concepts, or perhaps rather concept sets, based on these five words but many could also apparently remember all or enough of these familiar words to preclude the necessity of "taking another look" at the problem (i.e. by switching back manually). In Johnson's experiment ten figures were displayed on the preparation side of the card. To retain ten detailed and unfamiliar figures in immediate memory while searching for a solution may be an impossible task for most subjects.

Essentially subjects in Johnson's experiment solved their problems in the same manner as subjects in this experiment; namely, by forming concepts (shape or texture). Johnson's subjects apparently abstracted out the one aspect, either shape or texture common to all of the figures. Retaining only this one aspect in memory,

subjects could then switch to the solution side and solve the problem. Having learned and retained only one relevant aspect of the problem, Johnson's subjects were totally unprepared for a "set change" and it was necessary for them to switch back and re-examine the parts of the problem before they could solve it.

To solve problems based on the unfamiliar figures required a greater amount of learning than the verbal materials. The kinds of materials used in each experiment apparently interacted with the amount variable and also possibly established concept sets of differing strengths and perhaps at different levels (9) in each experiment. The past experience of the subjects as it affected familiarity with the materials, and, in turn, the amount of learning during the training series interacted with the span of immediate memory to contribute to the failure to obtain an index of reformulation.

In Johnson's experiment, the ten unfamiliar figures required a high degree of attention and learning by the subject in order to form an effective concept or set. The five relatively simple words used in this experiment had undoubtedly been seen by the subjects hundreds of times during their lives; consequently, the task of the present experiment involved manipulative skills as much as or more so than it did learning. That little actual learning occurred in the experiment is shown by the learning curves in Figures 2, 3, 4, 5 and 6. Over the ten training trials, subjects improved their performance by only about two seconds. This would indicate the materials were already highly learned and should be relatively easy to recall if the situation demanded it (cf 25). Except for Group III there is little indication that the subjects learned a set that facilitated response.

When the subject turned to the solution side and found that his set was not appropriate he could reformulate the problem (i.e. assume

a new set or direction towards the problem) in one of two ways. He could "switch back" to the preparation period as some did or he could utilize his memory to recall the preparation material as others apparently did. Some of the subjects apparently interpreted the set change as a challenge to their abilities as several verbalized that they "almost had" to switch back. All of these factors would serve to depress the total number of switchbacks.

As both experiments involved the attainment of concepts in the establishment of sets, an attempt at an interpretation of the results in terms of some of the demonstrated or suggested features of concept formation would seem to be in order. Wohlwill (27) has suggested that two different cognitive processes may be involved in concept formation. One process is a perceptually determined process of abstraction which consists of a selective response to a given aspect of a stimulus. The other process he refers to as conceptualization which he considers as a process of "mediated generalization and, as such, being primarily a function of the prior experience and stage of mental development of the individual." The formation of concepts by this latter process is seen as being accomplished by the activation of "response sets" in the experimental situation which were formed during the course of mental development and experience.

Thus the formation of concepts in Johnson's experiment could be interpreted in terms of a perceptually determined abstraction process. In this experiment, concept formation could be interpreted in terms of a "supra-perceptual" process of conceptualization.

Heidbreder suggests that concepts are more readily attained at a perceptual level than they are at an intellectual level (9, 10). "Concepts are more readily attained as the contexts in which their

crucial features are presented permit--conceptualization at a more perceptual rather than a more intellectual level" (9). The greater the "thing quality" of an object (10), that is, the more concrete its representation, then the more readily attainable is the concept.

Reinterpreting Heidbreder in terms of the two experiments under discussion here, the suggested explanation is that the conditions of Johnson's experiment kept the whole course of conceptualization close to the perceptual level, whereas the verbal materials took the course of conceptualization to a more intellectual level. In other words, Johnson's subjects perhaps came to rely only on their perceptions of the figures to guide them in solving problems and made little or no attempt to integrate their perceptual responses with other information. Consequently, when the condition arose where a perceptual response of the kind they had been making was not appropriate and having no other information to guide them, it was inevitable that they should switch back to the preparation side where they could reformulate or restructure the problem.

The familiar verbal materials already well learned and integrated allowing for conceptualization at a more intellectual level also allowed for the accessibility of additional information when the established set failed. Consequently, switchbacks were not always needed in order to make correct solutions.

Rees and Israel (23) demonstrated that sets can function at different levels of awareness. They found that their letter order set operated at an almost automatic, unconscious, or at least unverbalizable, level to direct the solutions of the ambiguous anagrams. Their category set however was almost always accompanied by conscious awareness. That the automatic set was more effective

than the conscious set was shown by the arousal of both kinds of set in the same experiment.

Rees and Israel interpreted the greater effectiveness of the letter order set over the category set to be a function of the intrinsic nature of the task. They reasoned that anagram solution was primarily a process of rearranging letters and secondarily a process of searching for solution words, hence, letter order set should be more effective. While this paper would not argue with the general finding that the effectiveness of set is dependent on the nature of the task, the kind of analysis being used here would go beyond their explanation and would consider the nature of the materials used as well as the task itself.

Essentially, their letter order task involved making perceptual responses to the concrete structure of anagrams. Their category set task was a more intellectual task in the sense that it activated old responses and old associations in the search for category solution words. It may be that the "blinding" effects of set are due to too complete reliance on the perceptual apparatus alone at the expense of integration and assimilation of the materials learned or being learned. Consequently, when there is heavy reliance on perception of concrete instances of concepts, it becomes an easy task to "trick" the subjects by merely changing what they perceive. The automatic functioning of certain kinds of sets may be due to perceptual factors whereas conscious awareness of the set may be due more to intellectual factors.

Johnson's figures may have developed more automatic sets than the verbal materials developed. Consequently, the automatic set would serve to more effectively "blind" the subjects to alternate

methods of solution (cf Luchin's Einstellung 16), and make switch-backs a necessary aid to correct problem solution. The sets established by the familiar verbal materials could have remained at a more conscious level with at least partial awareness of their operation by the subjects. Consequently, in the ambiguous situation the effectiveness of the conscious set would be lessened either in terms of appropriate solutions or in terms of lengthening response times. This latter condition appears to have occurred.

A significant increase in solution time scores was shown for Group I. This increase may have been due to an element of "doubt" in the subjects' judgments which was created by at least partial awareness of an alternative solution. It may be that at least some of the subjects realized that an alternate solution was possible but that they still made choices consistent with their sets as this is how they had been solving the problems; but, apparently the set was not as firm as the one established by Johnson's figures. Rees and Israel (23) demonstrated that the establishment of antagonistic sets would serve to lengthen response times as the presence of one set tended to hinder the operation of the other. In this case, the response sets brought into the experimental situation were probably activated by the familiar material on the ambiguous cards and interfered with the task-induced set to the extent of increasing time scores.

Significant increases occurred in both preparation and solution time scores for Group II, the reformulation group, and also in solution time scores for Group IV which was also a reformulation group but which was not allowed to use the switch back as an aid to reformulation. As previously stated the kind and amount of materials in this experiment allowed for reformulation, defined as

a change in the established set such that the correct solution of the problem is attained through the process, to come about in either of two ways. Subjects in Group II could reformulate the problem either by switching back or by utilizing their powers of recall. Subjects in Group IV could only reformulate on the solution side. Both groups had equivalent error scores. Consequently, reformulation appears to have been approximately equal for both groups.

At an earlier point in the paper, it was stated that reformulation was contingent upon a return to preparation to re-examine the parts of the problem and to assess cues that had not previously been responded to. The manual return to preparation and the "visual search" by Group II subjects who could not or preferred not to utilize memory to reformulate is seen as being responsible for the increase in preparation time scores.

Solution time scores for Group II increased partly as a result of inflation of the scores by the return switchback. The larger part of the increase, however, was probably due to the subjects' use of memory for purposes of reformulation. Faced with a problem for which their established sets were inappropriate, many subjects in Group II and almost all in Group IV apparently returned to preparation by a symbolic process of memory rather than a manual process of switching back. Thus solution time scores increased for these two groups because of the recall process. Reformulation is assumed to have occurred as a result of this recall because of the small number of errors.

The failure to obtain an objective index of reformulation based on switchbacks by no means invalidates the method. It suggests rather that highly learned verbal material may not be amenable to study by this method--that the only index of reformulation that can be

obtained with this kind of material is a temporal one. It may be possible to devise an experiment similar to the present one which would overcome the difficulties of the memory span but the selection of appropriate materials is extremely limited.

The separate timing of the preparation and solution periods make it possible to investigate each process separately. Through this method it is possible to search for factors which might contribute to one or both phases. One technique would be through the correlation of sub-tests of general screening tests with each phase of problem solving. Some tentative overtures have already been made in this direction.

Another approach to problem solving by this method would be to present different kinds of problems to subjects to see whether time spent on preparation and/or solution remains constant over problems of approximately equal difficulty. Individual differences in problem solving can also be assessed by this method.

Set has been used previously in investigations of concept formation (26). The methodology of the present experiment allowing for a study of set establishment also allows for a study of concept formation. Given a problem for which an established set is inappropriate, the subject must essentially invoke or form a new concept in order to solve the new problem. Using a series of such problems, it may be possible to obtain information relevant to the nature of concept formation by studying the separate reformulations and analyzing time records of the subjects.

SUMMARY AND CONCLUSIONS

A method of studying problem solving processes was utilized in an experiment designed to afford an objective index of reformulation based on quantifiable observable subject behavior. Two concepts were used in a training series to establish task-induced sets in the subjects. The subjects were then given problems for which the established set was inappropriate. It was expected that the number of times they returned to the preparation part of a problem by a switchback procedure would yield an objective index of reformulation.

It was found that set was established as expected, but that the predicted differences in reformulation did not appear. It is suggested that time score increases are a sign of reformulation during the solution period of a problem and that this reformulation was made possible by the subjects' ability to recall the familiar verbal material of the problem obviating the necessity for switching back.

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APPENDIX

MATERIALS

The following instructions, printed on an index card, were shown to all subjects after they were seated:

> "This is an experiment in forming concepts on the basis of common characteristics shared by the objects represented by words.
>
> It will help you if, during the experiment, you try to form a global impression of how the objects, taken as a group, would appear together."

The following instructions were placed in the box for all subjects to read:

On this side of the box, you will next see a group of words which are all similar in some way. You are to decide what these words have in common. The common element will be easy to find in others. After you have discovered what the common aspect is, remember it as you will have to find another example on the other side of the card.

When you feel that you know what is common, turn the switch on the box to light up the other side. This side will become dark and you will see only the right side. (You may switch back if necessary).

Now turn the switch.

On this side of the box, you will next see five numbered alternatives. Pick the one that is another example of the other side. Indicate your choice by pressing the corresponding button on the board in front of you. HOLD the button down until the experimenter says O.K. Then release the button and turn the switch back to its original position.

Now press any number on the board to show that you have finished reading the instructions and we will begin.

SAMPLE CARDS

1.

five	1. hate
eight	2. miss
seven	3. toy
four	4. six
nine	5. junk

2.

republic	1. imagination
representatives	2. amendments
congress	3. portrait
legislate	4. conclusion
elect	5. helicopter

3.

science	1. minister
laws	2. sonnet
proof	3. heaven
results	4. bullet
evidence	5. conclusions

- indicates a correct answer.

SENSORY SET

emerald	1. erg
lawn	2. tweezers
ivy	3. braid
dollar bill	4. spinach
cucumber	5. scamp
glacier	1. brimstone
iceberg	2. tongue
snow	3. coral
icecube	4. tape
december	5. cold
globe	1. head
wheel	2. crash
barrel	3. room
dome	4. crazy
ball	5. dog
atom	1. noon
capsule	2. trap
germ	3. mad
village	4. hinge
gnat	5. small
chalk	1. table
milk	2. smash
sugar	3. curse
teeth	4. white
ivory	5. sing
rock	1. window
hailstone	2. house
helmet	3. hard
stone	4. nest
iron	5. hope
ammonia	1. skunk
garlic	2. able
garbage	3. scatter
cigar	4. trail
sewer	5. brain
dandelion	1. sugar
butter	2. yellow
gold	3. throb
mustard	4. brown
canacy	5. scooter

continued

SENSORY SET - Continued

doughnut	1. fast
saucer	2. circular
button	3. book
baseball	4. door
spool	5. table

apple	1. crab
beet	2. soup
blood	3. red
blush	4. fancy
cranberry	5. glade

ABSTRACT SET

hammer	1. budget
saw	2. nod
pliers	3. wrench
screwdriver	4. cape
drill	5. madam
zipper	1. snap
button	2. baker
clasp	3. wing
hook	4. raid
pin	5. cave
perch	1. melon
bass	2. tuna
pike	3. caper
carp	4. lamp
trout	5. stove
river	1. birch
ocean	2. jewel
stream	3. meat
lake	4. pond
bay	5. bowl
umbrella	1. rose
boots	2. rubbers
hat	3. whittle
slicker	4. paint
raincoat	5. nail
chest	1. course
bed	2. flour
sofa	3. cable
table	4. pepper
lamp	5. rug
charleston	1. rhumba
fox trot	2. bottle
waltz	3. match
cha cha	4. silly
tango	5. casket

continued

ABSTRACT SET - Continued

potatoes	1. porch
meat	2. cup
rice	3. eggs
bread	4. board
soup	5. floor
aircraft carrier	1. home
destroyer	2. plant
gunboat	3. cinder
battleship	4. cruiser
submarine	5. power
fire	1. cricket
torch	2. bottle
lantern	3. silly
lamp	4. vault
flare	5. match

"TEST CARDS"

	Ambiguous	Sensory Reformulation	Abstract Reformulation
asparagus	1. biscuit	1. drawer	1. biscuit
lettuce	2. vehicle	2. vehicle	2. vehicle
cucumber	3. green	3. biscuit	3. green
spinach	4. truck	4. truck	4. truck
peas	5. tomato	5. tomato	5. snore
cherry	1. problem	1. problem	1. problem
apple	2. blood	2. bush	2. blood
tomato	3. cushion	3. cushion	3. cushion
beet	4. banana	4. banana	4. bottle
cranberry	5. key	5. key	5. key
london	1. diamond	1. diamond	1. diamond
chicago	2. holt	2. holt	2. break
berlin	3. mercy	3. mercy	3. mercy
tokyo	4. hospital	4. hospital	4. hospital
moscow	5. large	5. bored	5. large
circumference	1. round	1. plant	1. round
cylinder	2. baby	2. baby	2. baby
sphere	3. hexagon	3. hexagon	3. plant
circle	4. plant	4. train	4. help
arc	5. reap	5. reap	5. reap
sulphur	1. carbon	1. carbon	1. closet
formaldehyde	2. night	2. night	2. night
ether	3. clock	3. clock	3. clock
chloroform	4. smelly	4. ribbon	4. smelly
ammonia	5. money	5. money	5. money

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