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CODING SYSTEMS AND THE COMPREHENSION OF INSTRUCTIONAL MATERIALS

Ray Hyman

Oregon University

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CODING SYSTEMS AND THE COMPREHENSION OF INSTRUCTIONAL MATERIALS

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Ray Hyman
Professor of Psychology
(503) 686-4910 or 686-4962

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Research Financial Administrator
(503) 686-3146

0.0. Technical Report Summary

Basically, the purpose of this project is to investigate experimentally how new information is integrated into long term memory. One question has to do with how the content and organization of old memories affects how the new input is processed, assimilated, and altered. This question focusses upon the new input. How does it get transformed in terms of what the learner already knows? And as a result of this transformation to what extent is it available for later use? The second question focusses upon the old memory. How does it get altered as the result of having taken in new information? We are especially interested in those conditions that lead to little or no change in existing memory structures as opposed to those conditions that result in more or less permanent revision of memory. This last condition, of course, is a situation in which we say learning or growth of knowledge has taken place.

The approach to these questions is to take advantage of the knowledge gained and techniques developed during our previous contract on coding systems. In that earlier project we devised techniques for isolating processing and coding systems employed by humans in perceptual, motor, and cognitive tasks. Our picture of the human as an information processing system was developed in the context of experiments that employed simple and meaningless stimulus materials and that engaged subjects only for very short time spans. In the current project we use meaningful, prose material and we employ subjects for longer time periods, sometimes over several months.

Our plan for the three years of the project was to use the initial period as a time for "tooling up", for trying out a variety of paradigms, for deciding what paradigms we can carry over from the earlier work and in what ways we will have to develop new approaches. Consequently, we have been quite active during this first year, but have few hard conclusions to draw as yet. This is consistent with our time-schedule.

Some equipment problems and the move to Straub Hall in January slowed down our research efforts. At the end of the last reporting period the PDP-15, one of the two computers in our automated laboratory, developed symptoms which took over a month to finally correct. By that time, however, the time had arrived for moving the automated laboratory to its new facilities in the basement of Straub Hall. This resulted in another halt to our research because the computers had to be dismantled, reassembled, and then all new cabling had to be installed to connect the computers to the various experimental rooms.

These disruptions seriously slowed down our empirical research during our first year of activity. But in the long run, the new facilities and the advantages they give us will more than compensate for this slow-down.

Hyman completed the series of studies initiated in the preceding period. The major conclusion is that subjects tend to store information by keeping all properties about a concept or object or person together in memory. When he has to retrieve a specified property for that object, all the other properties connected to the object also become activated. Such an organization and retrieval strategy can result in slowing down and interference with certain tasks involving that concept, but also greatly facilitates retention of that information. Subjects can store the information in other ways, such as organized by attributes rather than concepts. In this latter case, selective retrieval of properties does not result in interference. On the other hand, accessibility of information about the relevant concept becomes much less.

Hyman began a new series of experiments involving the impression formation task. In one experiment, the subject is given information about a hypothetical individual. The information includes his name, the occupational category to which he belongs, and a character sketch based on a series of traits. The subject forms a coherent impression of this individual and then describes other characteristics that might also be true of him. Later we ask the subject to remember which traits were actually employed in the original description. The subjects can perform this memory task with only partial accuracy. This is because they confuse the traits used in the initial description with the inferences they made during the time they were trying to form an impression or "comprehend" the input. Of course, this should not surprise us. The value of this paradigm is that it enables us to study both the inferences and the comprehension structure employed by the subject. The confusions he makes during retention tell us at what level of generality and integration he has encoded the initial input.

Our initial experiments varied the degree of compatibility between the occupational category and the descriptors in the personality sketch. We were able to do this on the basis of normative data we collected in two earlier studies. We discovered that when the occupational category was highly compatible with the personality sketch subjects tended to falsely remember many descriptors that were compatible with the occupational category. But when the occupational category was incompatible with the sketch, they remembered just as many correct descriptors but did not falsely recall others. This suggests that subjects encode and store consistent information in a qualitatively different manner from the way they encode and store inconsistent information.

Wickelgren and his students continued both theoretical and empirical research on the dynamics of memory retrieval. The most important contribution they made is the development of the speed-accuracy-tradeoff paradigm for the study of retrieval dynamics. The implementation of research using the paradigm is quite demanding. It requires the use of practiced subjects over many sessions, sometimes spanning months. On the other hand, it is the only approach that clearly separates out the performance level from the errors and latencies. Already, Barbara Dosher and Al Corbett, both under the direction of Wickelgren, are applying the paradigm to problems central to the project.

Reicher, with collaboration of Harold Hawkins, has returned to the phenomenon that bears his name: The Reicher Word Recognition effect. This time he hopes to determine how much of this effect depends upon organizational codes in the acoustic-articulatory system (pronounceability) and how much depends upon organizational units in the visual system (spelling patterns, etc.).

1.0. Introduction

The goal of this project on coding systems and the comprehension of instructional materials is ambitious. In a previous project on "Coding Systems in Perception and Cognition" we succeeded in developing a variety of experimental paradigms and procedures for experimentally isolating studying the subprocesses and coding systems that individuals use in coping with environmental inputs. We also developed a highly versatile automated laboratory facility which enables us to efficiently conduct a variety of experiments--many of which would have been impossible with existing experimental technology.

Out of that project emerged a conception of the human being as a processor of information. This processor has a limited capacity central system that can handle small units of information in a sequential fashion. To make such a system efficient and effective we have to consider ways to get around the central processing "bottleneck". One way is to automate as much of the information handling as possible. Automated processing takes place in parallel and apparently bypasses the central processor. Another way is to organize the input material into higher order codes. Apparently the central processor is limited not by the amount of information in the input, but by the number of separate units or "chunks" into which it can be divided. If the system can recode the input into higher order units such that each chunk contains more information, the capacity of the central processor is thereby increased. A final way to make the system more efficient is to find ways to ensure that it will selectively attend to the input. It can do this if it develops quick and early ways to decide what aspects of the input to ignore or skip over.

These principles for making humans more efficient at handling information have obvious implications for instructional technology. So the present project is oriented towards/attempts to extend our findings and procedures to the problem of instructional technology. We want to apply our findings to questions having to do with the comprehension and integration of instructional materials. How does what the learner already know affect his ability to understand and assimilate new material in a given area? How does the new material get added to long term memory? What consequences do different ways of presenting the new material and different ways of dealing with it at time of input have for later retrieval and use of that information?

But a gap exists. Our previous work and the model of man that emerges from it was based on stimulus materials that are relatively meaningless, simple, and artificial. The time spans over which subjects study the material and respond are extremely short with respect to instructional situations. This hiatus between conditions of laboratory tasks and real life tasks, of course, exists for all of experimental psychology.

A first objective, then, was to find ways to bridge the gap. Our idea was to see how far we could apply our current ideas and techniques to tasks in which the stimulus material was meaningful and of the same level of complexity of actual instructional materials. We also wanted to extend the time spans accordingly.

We expected to spend the first year trying out various sorts of materials and developing paradigms. This we have done. We have learned as much about what we cannot do as we have about what we can do in this more complicated realm. The most fortunate finding is that many of the principles and generalizations developed on the basis of simpler stimulus materials apparently hold for more complex, meaningful inputs. The major difference is that the units are much larger and more complex. So one continuing problem will be ways to characterize these units.

Now that we have gained some first hand experience about the problems of working in this area, we feel ready to develop a coherent framework for organizing the literature, research, and issues. We have been fortunate to interact with many of the key individuals--such as Roger Schank, Donald Norman, John Anderson, Herb Simon, James Greeno, etc.--in other laboratories who are also trying to extend cognitive psychology to the same sorts of problems. Out of this interaction and from our own experience, we feel ready to generate a pretheoretical
to
organization of the semantic memory domain as it applies the/comprehension and

integration of new information.

We expect to devote much of the second year of the project towards the development of this framework. Basically the framework will be a combination of the newest ideas in the psychology of memory along with the conception of man as a processor of information. In the memory domain, rapid and important changes are taking place. The short-term versus long-term memory distinction, along with its accompanying flow chart representation, has suddenly been abandoned by its proponents. Hyman discovered the full extent of this revolution when he attended the Attention and Performance V Conference in Stockholm in the summer of 1973. At the conference many of the key psychologists who were responsible for the division of memory into subsystems--each having its own time factors and each handling different sorts of codes, held an extraordinary meeting at which they agreed that this conception--itself a revolutionary change from the older idea of a monolithic memory--was no longer viable. At this meeting were such key figures as R. M. Shiffrin, A. F. Sanders, R. C. Atkinson, G. Mandler, D. A. Norman, D. E. Broadbent and others.

In rough form the framework will include ideas from the "levels of processing" framework suggested by Craik and Lockhart (and also developed by Restle). In this approach, memory is no longer divided into short and long term components, each with its own codes. Rather, input is processed to various degrees of "depth" depending upon the task, its importance, and its consistency with what is already in memory. Our adaptation of this framework separates out at least three aspects: the code or format into which the input is encoded; the amount of transformational processing to which the input is put; and the level of organization to which the input ultimately gets integrated. One can imagine that these three factors need not covary as is implied in current applications of the levels of processing framework.

In addition to this framework, we also separate the act of comprehending into a number of subprocesses--these subprocesses need not be sequential. One major subprocess is the activation stage or generalized expectancy about what sorts of information to expect in the input. This is the key stage because it controls the "top-down" analysis of the input. It can be more or less broad-band or narrow-band tuned. It serves as a search model and anticipatory schema around which to organize and integrate the input. It is also what is revised as the input conveys new information. At the other extreme is the sensory analysis stage--the parsing of the physical input into features, dimensions, chunks and patterns. This is the stage that determines the "bottom-up" processing of the input--the peripherally guided part of the comprehension system. In between these stages are a number of intermediate stages corresponding to such things as surface structure strings, propositional representation, and higher order integrations of input. The general idea is that during the initial stages of input there is a balance between centrally-guided control of the comprehension process and peripherally-guided control. But as the integration of the input continues, and provided that it is generally consistent with the growing comprehension model, the central control becomes more and more dominant. When the central control is completely dominant, the learner fully "comprehends" the material and need no longer sample input.

This model will be developed and tested during the second year of the project and will be reported on more fully at the end of the second year.

Wickelgren and Hyman, with the cooperation of Doug Hintzman began a seminar on semantic memory to further explore the issues relevant to the contract. One major focus was the new book by Anderson and Bower on "Human Associative Memory." The three major projects on semantic memory that are related to our own project are the system created by Anderson and Bower, the ELINOR system being created by Donald Norman and David Rumelhart at the University of California, San Diego, and the system for representing meaning in mem. y being developed by Walter Kintsch at the University of Colorado. All three systems take strong stands about the fomat or way in which information is represented in memory. Essentially Kintsch and Norman and Rumelhart agree in using a relational syntax or case grammar to represent propositional information. In such a system the relation (usually a verb or adjective) is central. Anderson and Bower, on the other hand, employ a predicate syntax in which the subject is isolated from the predicate which includes both the relation (verb) and object. A third possible syntax is an operator syntax which chunks together the subject and the relation (operator) rather than the relation and object. It is possible, as Wickelgren speculates, that the operator syntax is more characteristic of what we call nonpropositional knowledge (imagery, motor programs). We were fortunate to have John Anderson visit us at the time we were considering his book. We also had visits from Roger Schank, Terry Winograd, Sylvia Farnham-Diggory, and Elissa Newport during this six-month period. Both the ongoing seminar and the interaction with these visitors has helped us keep abreast of the latest thinking in the field.

Our move to Straub Hall in January disrupted our research as mentioned in the summary. But the new quarters for the automated laboratory will eventually enable us to do the sorts of work we have in mind in a very efficient manner.

2.0. Hyman and his Associates

During this period, Hyman, Polf and Wedell completed their series of experiments on selective retrieval from memory. The three major experiments all employed the following paradigm. The subject first had to memorize or store a data base. The data base consisted of information about hypothetical individuals who lived in a hypothetical town. Each individual is characterized by a name and a series of properties. Each property is a value on an attribute such as geographical location, occupation, hobby, and stance on an issue. Once this data base is mastered, which may take anywhere from one to four experimental sessions of practice and testing, the subject is then tested for selective retrieval in a series of additional experimental sessions. A given testing session would focus on only one of the attributes.

The subject would be presented with a pair of names and his task was to press the appropriate reaction key to indicate whether the pair of indicated individuals were the same or different on the target dimension. As expected, the subjects showed a marked effect of the non-target or irrelevant dimensions in making their judgments. They were fastest in responding to a pair of individuals as "same" on, say, geography, if the same pair of individuals were also the same on occupation, hobby, and issue. The speed of recognizing two individuals as the same on a given target dimension was a direct and approximately linear function of how many of the irrelevant dimensions they were also the same on.

This effect of the irrelevant dimensions was expected. But we were interested in finding the conditions, if any, under which subjects could retrieve a selected target attribute without being affected by related but irrelevant attributes. We found that, under the conditions of our experiment, extended practice at retrieving just the target dimension did not diminish the effect of the irrelevant dimensions.

We did find evidence, however, that the influence of the irrelevant dimensions upon retrieval was a function of how subjects originally organized the data base during initial learning. One subject was successful at retrieving information on the target dimension independent of the irrelevant dimensions right from the start. She was also the fastest of our subjects, which eliminated the possibility than she was simply taking a fixed and ample amount of time for each response. The protocols indicated that, unlike the other subjects, she had stored the original data in terms of attributes rather than in terms of individuals. Our typical subject, for example, apparently stored all the properties about a given individual in the form of an ordered list attached to the name. When he was later presented with an individual's name, all the properties on the attached list were automatically activated or retrieved.

Our deviant subject, however, organized the information about individuals and attributes by each property separately. She learned the names of all the individuals who lived in the East part of the town. She then learned the names of all the individuals who worked as Planters. Although both these lists contained some overlapping names, she did not store any of the information in terms of names. Thus, when she saw an individuals name and had to retrieve information about where he lived, she scanned her list of names for those who lived in the East. If the test name was on the list she knew he lived in the East; if not she knew he lived in the West. We conducted a supplementary experiment to make sure that this indeed was the way she had the data organized in her memory. We tested her and the other subjects directly for their speed of retrieval of properties for each name. The other subjects showed strong and significant correlations between speed of retrieving one property for a given name with the speed of retrieving other properties for the same name. Our deviant subject showed complete independence on this test. Furthermore, she showed four times as much forgetting of the original material after two weeks when compared with the other subjects. This probably indicates that the typical strategy of storing information under names provides a richer network that is more resistant to forgetting, but is also inefficient for the selective retrieval task.

We conducted a third experiment to try to manipulate the way subjects organized the data base. If we could successfully manipulate the way subjects filed the material in their memories, we could then test various implications of this organization upon subsequent retrieval and utilization of the information. Our experiment was only partially successful. This was the time that the PDP-15 was acting erratically and would frequently break down in the middle of an experimental session. The disruptions make our data somewhat suspect. Until we repeat this experiment under better conditions, we will refrain from drawing conclusions.

One peculiarity of the data from the preceding experiments is that the effect of irrelevant dimensions showed up only on the positive ("same") responses. The negative responses were typically slower than the positive ones and showed no obvious influence of the number of irrelevant dimensions on which the pair of names differed. We have considered and tested a number of possible models. The only ones that even approximately account for this difference tend to be highly implausible. At the moment, the best possibility seems to be something like this. On being given two pairs of names, the subject makes a quick scan of how they match up on all properties--both the target property as well as the irrelevant ones. If they match on everything, he immediately responds "same" without further checking. If they match on none or only a few, he then goes through a slower memory search to see if they do indeed match on the target item.

Near the end of this period Hyman, Polf and Neill began a new series of experiments to test out a new paradigm. The new paradigm is another way to investigate the way subjects use inferences and prior knowledge to comprehend input and to elaborate upon it. One of the key questions within this context is how the degree of consistency between what a subject already knows about a topic and what the input contains about that topic affects his mastery of new material.

At one extreme, the new input could be completely consistent and redundant with what the student already knows. In such a case no new information is conveyed and we would expect no changes in knowledge. At the other extreme, the input could be quite inconsistent or novel with respect to what the student already knows. In this latter case, it is not clear what to predict. In terms of information theory, such an input conveys maximum information. And in terms of Bayes' Theorem, such an input calls for the most revision of existing knowledge. But, in terms of psychological theory, to the extent that there is any thoery that deals with this problem, the situation is unclear. If the information is truly novel, one could argue that existing theories indicate that the learner would have no way of responding to it and it would have no impact on cognitive and memory structures. If the information is contradictory to what the subject knows, he might reject it or distort it to make it consistent. Or he might revise his initial ideas. In this latter case, we would have maximum change in prior knowledge.

What Hyman and his colleagues wanted to set up was an experimental paradigm in which they could observe the various possibilities about how individuals cope with consistent, inconsistent, contradictory, irrelevant, and novel information. The goal was to find those conditions under which new input results in meaningful revisions of existing knowledge as compared with those conditions under which new input is distorted to fit existing expectancies or is ignored or discarded because it does not "fit in".

One task that promises to provide some information on this issue is that in which the subject must integrate various items of information about an individual in order to form a coherent impression about that individual. In the paradigm being developed, Hyman and his colleagues have already conducted two normative studies to get necessary background data. These studies provide us with norms about what traits or descriptions come to mind for our subjects when they are presented with various occupational categories such as "accountant", "lawyer,", etc. They also provide us with norms about what descriptors are activated when certain personality sketches are presented.

These materials enable us to set up a number of studies to investigate how subjects comprehend and integrate both consistent and inconsistent input. One of the first series of studies being considered will present subjects with sketches of hypothetical individuals. Each individual will be assigned to an occupational category that is consistent with his personality, that is moderately inconsistent with his personality, or that is very inconsistent. Our subjects will be required to form a coherent impression and describe this impression to us. The theory indicates that subjects will be forced to make many inferences and generate connecting links in the case in which the sketch and the occupation are moderately incompatible. But when consistency is high, he will not have to make any inferences or add information from his memory in order to make sense of the input. When the inconsistency is extreme, we also predict that the subject will not generate many new inferences. Rather than make a connection between sketch and occupation, he will store the sketch as that of an individual who is "deviant". Each of these predictions suggest different consequences for subsequent memory of the original information.

Hyman plans to present a paper on the first experiment in this series at the Tenth Annual Carnegie-Mellon Conference on Cognition to which he has been invited. The Conference will take place in June and a report on the outcome will be given in the next semi-annual technical report.

3.0. Wickelgren and his associates.

Wickelgren continues both his theoretical and empirical work on trace dynamics. He has recently abandoned his advocacy of a dual trace theory and now has developed a theory that handles the previous distinctions between short- and long-term memory in terms of a single trace. He and his students have been developing a new paradigm based on the speed-accuracy tradeoff to enable investigators to study retrieval without the potential artifacts inherent in using accuracy or speed measures separately from one another. Wickelgren claims, for example, that the so-called serial scanning process that is so widely accepted as a fact today by those who use the Sternberg procedure may be an artifact due to the sensitive variation of latency with even small changes in error rate. Indeed, he feels that his new technique justifies the conclusion that the scan is not serial at all, but parallel in nature.

The technique, when fully developed, can have wide and important ramifications for all research based on information porcessing models. It will enable us for the first time to coherently handle both errors and latencies within a single model.

Barbara Dosher and Al Corbett, two graduate students working under Wickelgren, are already planning to apply this new technique to the study of issues central to this project. Dosher will do a thesis to compare three different models for how information is represented in memory. Corbett will do his thesis on how individuals learn to categorize individuals. He will be trying to separate and compare three different models--including those investigated by Hyman and Frost in pattern recognition.

4.0. Reicher and Associates

Reicher and Harold Hawkins, who is visiting us this year, have been working on word recognition (the phenomenon which Reicher originally made famous in his doctoral dissertation). Reicher originally demonstrated that subjects can identify a letter more accurately when it is embedded within a meaningful word than when it is presented in isolation. Since that discovery, much research, theory, and debate has been devoted to this phenomenon. Its importance is obvious. It tends to indicate that higher order units, such as words, are in some sense more primary than their constituents such as letters.

Reicher and Hawkins believe that an understanding of why words are recognized better than most strings of letters might lead to clues about handling meaningful groups in reading and other skills.

Reicher has concluded that his initial hypotheses about how segmentation in meaningful input occurs were wrong. He now no longer believes that familiarity of elements is itself very important in the ability to segment. He plans to return to the problem after rethinking about it.

The experiments on coding by rules versus coding by rote memory showed very little difference in later utilization of the codes in long term memory. This is an interesting finding if true, but Reicher plans to perform another series of experiments before making such a conclusion.

5.0. Schaeffer

Schaeffer joined our project on his return from his sabbatical this fall. He has spent this period preparing for work on semantic memory. His major project is a long term one that involves teaching subjects to read with an entirely new alphabet.

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