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Dual Coding And The Representation Of Letter Strings

by

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Sub-strings derived from four-letter strings (e.g. ABCD) were presented to subjects using a variation on Bransford and Franks' (1971) paradigm. Each string was in either upper or lower case. Subjects were then tested for recognition of the strings, false recognition of translations of the strings into the other case, and false recognitions of new but legal strings. Subjects accepted previously seen strings most frequently, followed by translations, with New strings accepted least often. This replicates Rosenberg and Simon's (in press) findings with sentences and pictures that express the same concept. However, in the present experiment the two forms of a string were unbiased with respect to a verbal or pictorial encoding. The forms in which a string could appear (upper or lower case) were not confounded with the two types of encoding (verbal and pictorial) hypothesized by a dual coding theory. The results supported the view that the previously reported difference between the original form and a translation is best explained by a model which uses a single representation that preserves some form distinctions.

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DUAL CODING AND THE REPRESENTATION OF LETTER STRINGS

An interesting issue in recent years has been the problem of whether people have more than one underlying representational system. The dual coding hypothesis (Paivio, 1971) suggests that there are two systems for encoding concrete verbal concepts; one propositionally based, and the other dependent on visual imagery. This question also arises in other areas. For instance, do people who speak more than one language fluently represent a concept expressed in one language in the same form as when it is expressed in another? At least some researchers (Lambert & Rawlings, 1969) have suggested that it is possible that bilinguals may have different representational systems for each language, depending on the circumstances under which the languages have been learned.

Rosenberg and Simon (in press) investigated this problem by making use of a paradigm developed by Bransford and Franks (1971). Bransford and Franks used sentences containing four propositions. They presented subjects, in an acquisition phase, with derived sentences containing one, two, or three of those propositions. They discovered that subjects, in a later recognition test, would also accept derived sentences which they had not previously seen. However, although subjects often thought they had seen these new sentences, they did not accept as many of thesse as of the actually presented sentences (Franks & Bransford, 1974).

Rosenberg and Simon developed a set of pictures which corresponded in content to the set of derived sentences. They then presented some of the items as pictures, and others in sentence form. They hoped to determine the form of representation by testing for false recognitions to items translated into the form opposite from their initial presentation, and comparing performance on this task with correct recognitions of previously shown items.

Rosenberg and Simon's results showed that subjects were indeed confused and often accepted translated items as old, although not as frequently as items presented in the original form. A second experiment with bilingual subjects gave the same result with translations from one language to the other.

Rosenberg and Simon explained these results in terms of a model which used a single system for representing relations, integrating items which occurred in different forms into a single representation. However, modality information associated with occurences of lexical and visual tokens was preserved. The model thus postulated some difference in knowledge content given a different mode of expression for an item, while preserving a single underlying system in which to represent that information. The model, when implemented as a computer simulation, reproduced Rosenberg and Simon's experimental results. Acceptance of translations was explained by the fact that in a single storage model, many tokens in the internal representation had associated attributes from both forms in which items had occurred. This resulted from the fact that items containing those tokens, and occurring in both forms, had been merged into a single representation. However, some tokens had attributes associated with only one possible form, since in some cases no item containing that token in its other form was integrated into that representation. Consequently, subjects in some cases were able to decide that the test item was not identical to the original form, although the relations among tokens matched those in the test item. This produced lower acceptance rates for translated items compared to the originals.

Such a model, although more parsimonious than a dual coding model, does not exclude certain forms of a dual coding strategy. For instance, suppose subjects encoded each item into its primary representational system and stored that form of representation (i.e. propositional strings representing sentences are stored in verbal memory, while imagery representations of pictures are stored in pictorial memory). Suppose that some items are also translated into the alternate form and the representations for each form are stored in the appropriate memory. If the memories for the two kinds of representations (verbal and pictorial) do not interact during the recognition process, then translation of items which were not dually encoded are functionally new items in the recognition test, whereas translations of the dually encoded items are functionally old. The results obtained by Rosenberg and Simon can now be predicted given the assumption that the difference in acceptance between translated and new items represents the number of items dually encoded during acquisition. Since this difference was less than ten percent in Rosenberg and Simon's study, this model results in essentially non-interacting encoding systems. Thus, although less elegant, a dual coding model may also explain the partial confusion of subjects between items which have been seen before in the same form, and those which are translated.

In Rosenberg and Simon's experiments one form, the sentence form, was biased towards a verbal encoding, ensuring storage of that form of an item solely in the verbal memory component of a dual coding model. The pictorial form was biased towards a pictorial encoding, resulting in storage of this form of an item only in the pictorial memory component of the dual coding model. Thus the two forms of an item were stored in different memories. Dual coding explanations are based on that fact. This confounding between the two forms of a test item and the two encoding systems does not allow us to determine whether the result is due to the two functionally independent systems of representation (as the dual coding model hypothesizes). An alternative hypothesis is that it is due to form differences of any sort, whether or not these are divided between verbal and pictorial codes. Suppose that stimuli are chosen so that information about both forms of an item is available in one code (e.g.pictorial). If subjects still accept some translated items, but fewer translated items than previously seen items, we will be able to argue that the result in the earlier experiments is explicable without positing two internal representation systems, since the information required to accept or reject translations is available within a single representation. Such an explanation is desirable since it is more parsimonious than one based on dual coding.

EXPERIMENT 1

One type of material which fits our criterion are strings derived from from longer letter strings (eg. ABCD). These can occur in either upper or lower case. Reitman and Bower (1973) have shown that Bransford and Franks' results concerning false acceptances are replicated when instead of being shown sentences, subjects are shown strings of letters or numbers. The following experiment used upper and lower case letter strings rather than the sentences and pictures or two languages employed by Rosenberg and Simon.

Method

Subjects The subjects were 48 male and female undergraduates at M.I.T. All were paid volunteers.

Materials and Design The following letter strings were used as the "concepts": ABCD, QRST, WXYZ. Each of these concepts can be decomposed into four 1 letter strings, six 2 letter strings, and four 3 letter strings. If the number 1 is assigned to the first letter in a concept, 2 to the second letter, and so on, all of the sub-strings can be represented as:

One letter	1	2	3	4
Two letter	23;12	34	14;13	24
Three letter	134	124	234	123

The experimental design was a modified Latin square. Since there are six 2 letter strings, two of these have been randomly grouped with other 2 letter strings, to form the above rectangle. We wish to design our Latin square so that each column and each diagonal contain all the letters in the concept. Then in order to form an acquisition list, we need only do the following for each concept. First we delete one column, and then we superimpose the following square:

U	L	N
N	U	L
L	N	U

Where N means that this item does not appear in the acquisition list; U means it appears in upper case form; and L means it appears in lower case form. Since there are four possible columns to delete, there are four possible acquisition lists which can be formed: one for each column deleted.

To form a recognition list, we take one column and present each string in both upper and lower case form. Each recognition list then has six strings for each of the three concepts: two Olds (items actually seem in this form before); two Translations; and two News (items never before seen, but which are exemplars).

A recognition list formed using a particular column cannot be used with the acquisition list that was formed by deleting that column. Therefore for each acquisition list there are three possible recognition lists. This gives a total of twelve cells in the square. Four subjects were tested in each cell. Using these lists, each string appeared once in upper and once in lower case, in the acquisition lists. In the recognition lists, each string appeared once in each form as an Old, Translation and New item.

In constructing lists from the three concepts, the constraints on the randomization of order were that no more than two strings derived from the same concept could occur in a row; nor could more than two strings of the same complexity or case occur together.

Procedure The experiment took about an hour to perform. Subjects were seated in front of a tachistoscope and told they were being tested in a short term memory task. They were then presented with the items in an acquisition list. Following Reitman and Bower's procedure, each item appeared for two seconds, during which time it was read aloud. Then after a second pause, a three digit number appeared for six and a half seconds. Subjects immediately began counting backwards by threes, out loud, and as quickly as possible. On the disappearance of the number subjects were given up to 10 seconds to recall the original string.

After proceeding through the acquisition list in this way, subjects were shown one of the recognition lists. They were told that they would be tested on identifying the character strings shown in the acquisition phase, some of which might be new. Each item in the list was displayed for up to nine seconds. During this time subjects were told to make up their minds as quickly as possible whether the string was identical to one they had seen previously. They were informed that although accuracy was primary, speed of response was also important.

Results

Figure 1 shows the percentage of acceptances for Old items, Translations, and New strings, broken down by complexity. An analysis of variance was performed on the proportions accepted. The independent variables were type of item (Old, Translation, or New), and complexity (one, two, or three letters in the string). Both the type of recognition item and the complexity of the item were significant. ($F(2,243) = 20.96$; $p < .01$; and $F(2,243) = 12.11$; $p < .01$, respectively.) To make sure that the difference between Old and Translation items was significant, contrasts were done, using the Scheffe test. This produced a significant difference between the Old and Translation strings ($F(2,243) = 13.34$; $p < .005$). Similarly, significantly more Translations were accepted than New items ($F(2,243) = 7.87$; $p < .025$).

Discussion

The results replicated Rosenberg and Simon's findings. Subjects accepted many translated items as having been presented originally in that form, although not as frequently as strings shown in the original form. In either case, they accepted more strings which had been shown previously in some form, than never before seen strings. The results also replicated Bransford and Franks' finding that acceptances increase as a function of increasing complexity.

In the present experiment the two versions of a string (upper and lower case) are equivalent in the readiness with which they can be encoded verbally or pictorially. There is no confounding between the form a string occurs in (upper or lower case), and the representation of that form hypothesized by dual coding theories (verbal or pictorial). This rules out a dual coding explanation that depends on a biased encoding of items by form; for example, a model that claims that items of one case, say lower, are always represented in one code, say verbal, while the upper case is always stored in the pictorial code. In this type of model a Translation test item goes first to the opposite representation from that of its original form. With the encoding distinction removed, the plausibility of a Translation cannot be determined by comparing the form of a string in the pictorial code with its form (or non-existence) in a verbal code. Thus the use of those two codes as a necessary part of the ability to distinguish translations is eliminated when the two forms of items are equally pictorial and equally verbal.

Once the pictorial and verbal confounding in encoding is removed, it has to be the case that form information is preserved within one code, (according to the dual coding model) and not between the codes. In a dual coding theory, form information is presumably preserved in a pictorial encoding. The distinction between upper and lower case would not be retained in a verbal encoding unless subjects explicitly add a verbal tag (e.g. abc-lower). That is unlikely since the case of the strings was irrelevant in the task subjects were instructed to perform.

In a dual coding model, if form information is fully preserved in one code, we might expect subjects to reject Translations, (despite their representation in verbal memory), since the subjects can determine that the string is not present in that form in the other code. If form is not preserved (as when subjects verbally encode without marking the form, and do not store images of any items) then translated items should be accepted as frequently as previously seen items. Neither happens.

In considering the form a dual coding model for these results might take, we must consider two alternative types of models. The first sort postulates that subjects check for the presence of a string, but do not use the existence of the original form of an item in pictorial memory as a criterion for rejecting a translation. The most plausible form of dual coding model, given this strategy, is one where subjects first check verbal memory for an item, and then check pictorial memory if the item is not found in verbal memory. Since the item will never be found in pictorial memory if it is a Translation, but may be there if it is an Old item, this would produce the required result.

New items provide a baseline for the acceptability of semantically consistent strings which have not been seen before. Translations of items which have been entirely forgotten should be accepted as frequently as New items. Since neither New nor Translation items are found in pictorial memory, the greater proportion of Translations accepted over New items represents the proportion of Translations for which a match was found in verbal memory. This results in the prediction that only about 12 of the items were retained in verbal memory! This is simply not plausible, given the task and the observed percentages of acceptances. (Subjects were instructed not to guess.)

There is another possible version of a dual coding model, given that subjects are able to reject items if they find the opposite form in pictorial memory. This would allow for acceptances of Translations of items when the verbal code is retained but the pictorial code has been forgotten, and rejections for Translations of those items remembered in pictorial form. This would produce the actual result of many Translations being accepted, but fewer Translations than previously seen items. However, the Translations of items which are represented at least in the pictorial code should be consistently rejected. The corresponding New items may be accepted, since there is no alternate form to cause rejection. Thus this model predicts that fewer Translations than New items should be accepted. Since subjects in fact accept significantly more Translations than New items, the dual coding model cannot explain the results.

Evidently, some but not all form information is retained in a useful form. This suggests a model in which the difference between Old strings and Translations represents the proportion of items for which form information allows rejection. The extent to which subjects can reject Translations over Old items will then represent a measure of the degree of useful form information which is retained within a single representation. Since the Olds and Translations are identical except for this case information, it provides the only possible criterion for rejecting a Translation when the equivalent Old is accepted. This implies that all except this proportion of learned strings lose, or cannot use, the form property as a unique distinguisher.

The ability of subjects to retain some information about form of presentation for words has long been known (Hintzman, Block, & Inskeep, 1972; Kirsner, 1973; Kolers & Olstry, 1974; Light & Berger, 1974; Light, Berger & Bardales, 1975). Consequently, also finding this effect in letter strings which do not form words is not surprising. However, as Light and Berger (1976) point out, this result alone does not support an imagery model over an abstract encoding one. Since the recognition process for translations is a function of the preservation of information within a single code, dual coding models of the present experiment introduce superfluous elements. They are also unable to explain the partial confusion of subjects in a way which is consistent with the acceptances of New items.

Rosenberg and Simon have developed a parismonious model which utilizes a single underlying representation. This model is equally appropriate for the current experiment, since it does not rely on assumptions of encoding bias to produce the observed differences. Thus it provides a parsimonious explanation of all three experiments. We should note that Rosenberg and Simon were not suggesting that imagery does not exist. Rather, they were proposing that both imagery and verbal encodings are implemented in the same internal system, and differ through their information content in that system.

EXPERIMENT II

Our argument is dependent on Reitman and Bower's original finding that Bransford and Franks' results can be replicated using concepts formed from letter and number strings. Consequently this experiment replicates theirs, to ensure the basic result the first experiment is founded on. We expected that the results would replicate theirs, and also replicate the pertinent results of the first experiment. The same results for complexity and for Old versus New strings should be found in all three experiments.

Method

Subjects The subjects were 48 male and female undergraduates of M.I.T. All were paid volunteers.

Materials and Design Once again, a modified latin square design was used. This provides a more balanced design than in the original Reitman and Bower method, since each string functions as both an Old and New item. In this experiment the acquisition and recognition lists were formed from the concepts: ABCD, HIJK, WXYZ, and 4567. Each concept contains four 1 element strings (either a letter or a number), six 2 element strings, and four 3 element strings. Two acquisition lists were formed by randomly dividing the total set of substrings from each concept into two sets of two 1 element strings, three 2 element strings, and two 3 element strings. This division was subject to the constraint that each element appear at least twice in each list. Two 4 element strings were then added to each acquisition list so that no 4 element string was assigned twice.

Two recognition lists were formed such that each recognition list contained (for each concept) one 1 element string, either one or two 2 element strings, and one 3 element string from each acquisition list. In addition, one 4 element string from each acquisition list was added to each recognition list, so that no 4 element string appeared twice in a recognition list. The constraints on this were that each recognition list contain at least one of each letter or number occuring in either acquisition list. The same constraints on ordering the lists held as in the last experiment.

Each recognition list can be used with either acquisition list, since half of the items will have appeared in that acquisition list and half will have not. All four combinations were used, resulting in each item occuring once as an Old, and once as a New string in the experiment. This process was repeated three times to give 12 acquisition-recognition combinations. Four subjects were run in each cell.

Procedure The same procedure was used as in the first experiment, except that there was only a half second pause between presenting an item and presenting the three digit number.

Results and Discussion

An analysis of variance was performed on the percentages of acceptances. The independent variables were item complexity, and whether it was an Old or a New string. Figure 2 shows the proportions accepted. Both the complexity and type of item were significant ($F(2,330) = 28.5$, $p < .01$; $F(1,330) = 27.1$, $p < .01$, respectively.)

The results replicated Reitman and Bower's, and also those of the first experiment for complexity. As strings increased in complexity, subjects were more likely to accept them. However, as Reitman and Bower, Franks and Bransford, and Rosenberg and Simon found, fewer New items were accepted than Old.

Reitman and Bower suggested that either subjects store the concept together with rules for its generation, or else they store the concept together with many of the strings. It is unlikely subjects adopt the first alternative in these experiments, since in that case there is no way to distinguish among Olds and Translations. Therefore they must store some strings, or at least some attributes of items. Rosenberg and Simon's model suggests that they might integrate strings derived from the same concept. Of course, in this case subjects should be unable to distinguish the form of an item by matching against this stored concept. However, as Reitman and Bower point out, Bransford and Franks' design overloads subjects by presenting multiple items from several concepts. They argue that "the Bransford and Franks materials and procedures may have arranged conditions in such a manner as to cause massive forgetting of the particular exemplars." This suggests that subjects may form not one, but several partial mergings of strings, forming more or less whole instances of the concept. Depending upon which of these a recognition item is matched against, the following might occur. Both the original and the translated form (if it is given), will be subject to a component of forgetting which depends on how well subjects have succeeded in merging strings to form the concept, and on the rules for matching against this concept. However, the translated form, if given, will be subject to a component of rejection due to the fact that the letter tokens may not all have the neccessary attributes for that form in these partially merged concept instances. This will produce somewhat lower levels of acceptances for these items. This would result in the current finding that in some but not all cases subjects cannot distinguish the form of the input.

The two present experiments argue for a model in which information about the form of an item is preserved in a single memory system in which related items expressed in different forms are merged into one representation. This view parsimoniously explains both the current experiments and Rosenberg and Simon's study. Dual coding models fail to explain the current results. In addition, they require different formulations for the current experiment than for Rosenberg and Simon's, although the results of both are the same.

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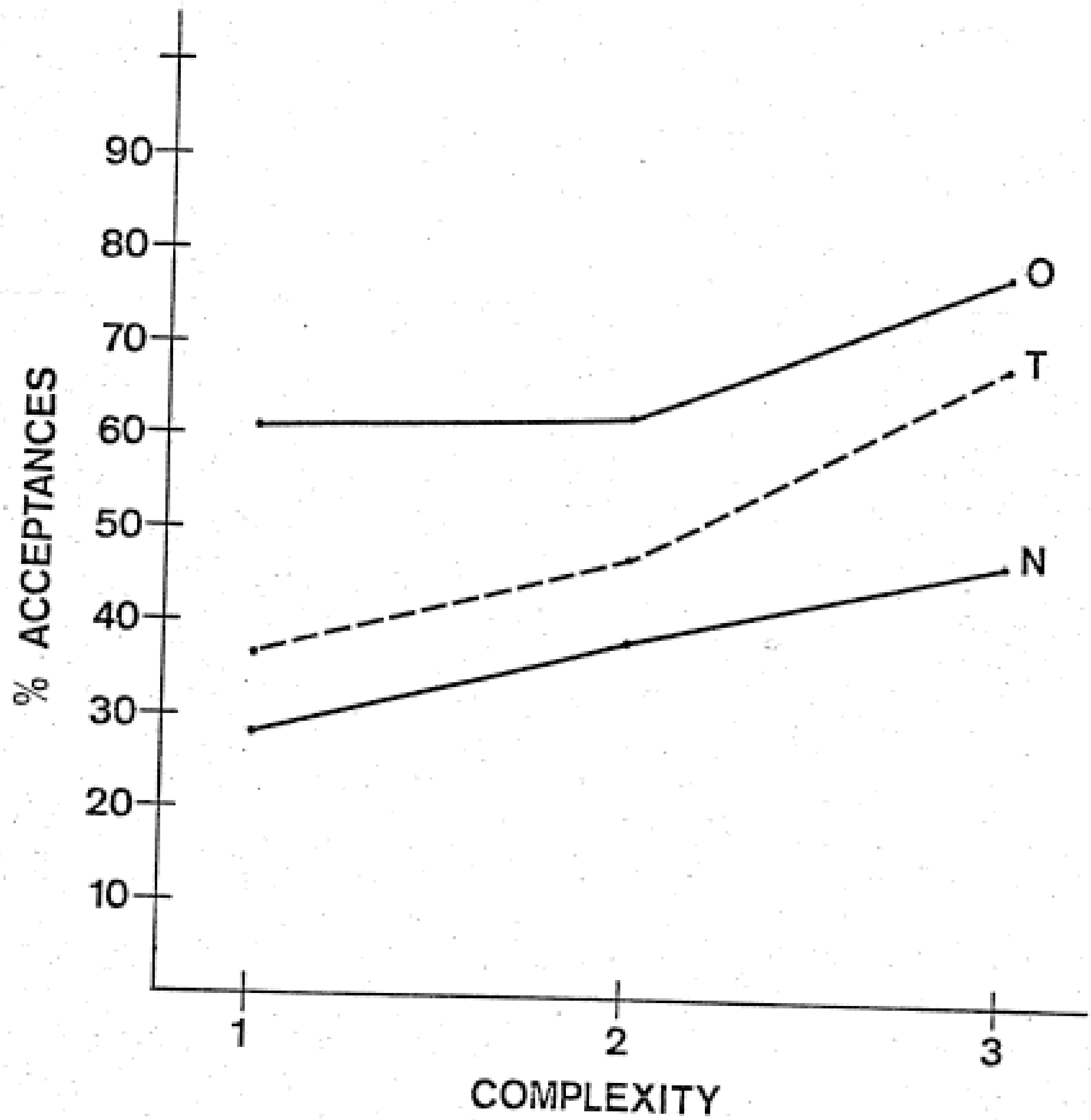
Footnote

1. I would like to thank Dr. Mary C. Potter for her helpful editorial advice.

Figure Captions

Figure 1. Percent of Old, Translation and New exemplars accepted in Experiment 1.

Figure 2. Percent of Old and New items accepted in Experiment 2.



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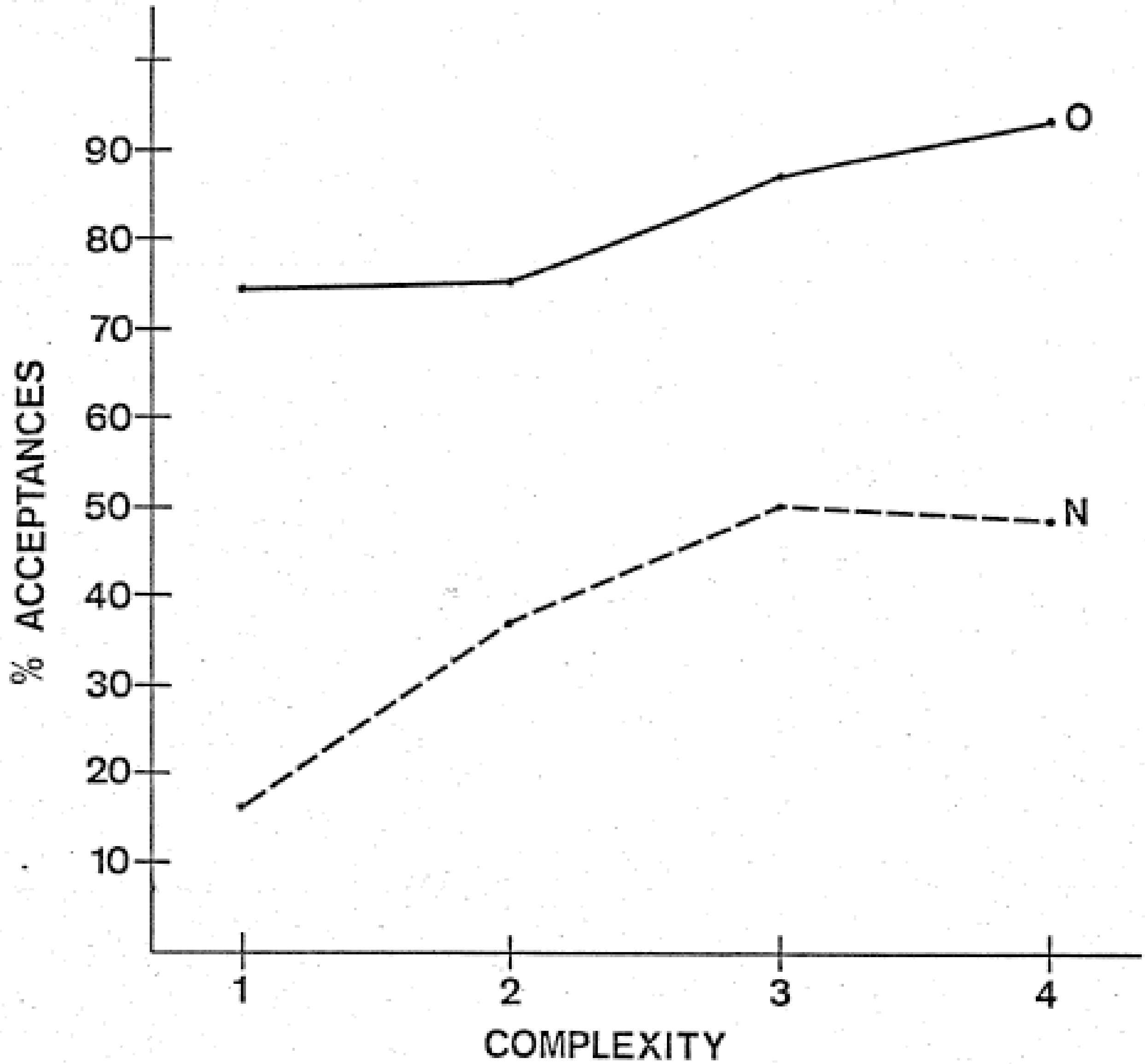

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