What is so difficult about negation?

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Previous experimental study of this topic suggests that negation is typically difficult to process. This notion, by now widely accepted, seems to rest on a view of negation as an operation on statements. We question this view by arguing that difficulty in processing negatives is a question of a complex of issues concerning the material to be processed, e.g., ambiguity, confusability, and context. Experimental results are presented indicating that a decrease in confusability facilitates the processing of true negative and false affirmative statements; these results are interpreted as consistent with predictions arising from the general argument. The results of a number of previous studies are then reconsidered and preliminary conclusions adduced.

Previous experimental studies of negation fall under two main headings. First, in the area of concept attainment-formation and matching problems, papers by Smoke (1933), Whitfield (1951), Hovland and Weiss (1953), Bruner, Goodnow and Austin (1956), and Donaldson (1959) suggest the conclusion that Ss have greater difficulty in handling negative information than equivalent positive information. Second, in the area of natural language processing experiments, papers by Wason (1959, 1961, 1962), Eifermann (1961), Miller (1962), McMahon (1963), Slobin (1963), and Wason and Jones (1963) again suggest the conclusion that negation is somehow difficult to process. In this paper we wish to reopen discussion of the topic of negation by questioning the conclusion that negation is typically difficult to process. We begin with a brief look at some results arising from the second set of papers above since their evidence for the conclusion appears equivocal; we will return to the first set of papers later.

Throughout this paper we will use the following abbreviations for statements of different types: TA (true affirmative), FA (false affirmative), TN (true negative), FN (false negative).

One of the most persistent students of this topic has been Wason, who has frequently observed that negative statements take more time to process than affirmative statements. More specifically, he observed that in processing statements of the four types just mentioned, order of difficulty was: TA, FA, TN, FN (from easiest to hardest) (Wason, 1959), and that in a construction task, the same result was observed, while in a verification task the only significant difference was between negative and affirmative statements, regardless of truth-value (Wason, 1961). In his 1962 paper, Wason suggests on consideration of his Ss' introspective reports that negative statements are processed by (a) extracting the negative, (b) processing the remainder to determine the truth-value, and (c) altering the truth-value obtained in (b), i.e., reinserting the negative.

Three papers originating from Harvard deal with an attempt to observe whether or not performance data dance to the tune of the theory of competence of the transformational grammar suggested by Chomsky (1957). Miller reports that in a sentence-matching task, passive transformations took longer to match than did negative transformations. But McMahon argued that this task was carried out on a purely verbal basis entailing no concern with meaning. Using a different task, he found the opposite, passives taking less time to process than negatives; this leads him to suggest that negatives involve greater semantic complexity, since, transformationally, passives are more complex than negatives, and errors were found to cluster on negatives rather than on sentences that were grammatically more complex. But whereas he found that TA statements were processed faster than FA statements, he found no difference between TN and FN statements. Slobin's results, with children and adults, indicate the order of difficulty of processing to be: TA, FA, FN, TN (Miller, 1962; McMahon, 1963; Slobin, 1963).

Considering those aspects of the results that agree, and the first set of papers above, one can appreciate the origin of the conclusion that negation is somehow difficult to handle when being processed. It is this conclusion that we now wish to examine, for it seems to us that the prevailing interpretation of data so far mentioned relies heavily on the notion that negation is some sort of operation on statements (whether cashed as a "mental operation" and/or in transformational terms). If the operation of negation is carried out on (affirmative) statement S(A), we obtain the resultant (negative) statement S(N). And such a notion does have some face validity, for compare S1 with S2, where "number" is restricted to "integer":

S1	The number is even
S2	The number is not even

Moreover, the move in the opposite direction seems to work; when the operation of negation is carried out on (negative) statement S(N), we obtain the resultant affirmative S(A).

However, it seems to us that such moves are sanctioned simply by the nature of the material involved: the antonym pair *odd-even* may be said to be *contradictory* where "contradictory" is defined as "mutually exclusive and exhaustive"; when we consider this view of negation with respect to other sorts of antonym pairs that are not contradictory but *contrary*—e.g., *hot-cold*—we soon begin to encounter difficulty. (We will return to discussion of this contradictory-contrary distinction later.) Consider the negation of S3 in S4:

S3	The drink is hot
S4	The drink is not hot

S3 as S(A) has been negated in S4 as S(N). So far so good. The first hint of trouble in regarding negation as an operation on statements becomes apparent when we try to operate in the opposite direction, for we do not know in any precise way the meaning of S4 since it is variable. In fact it is infinitely variable—here we will artificially restrict consideration to two points along the hot-cold continuum, which we will label "lukewarm" and "cold." That is, then, we cannot distinguish between S4.1 and S4.2 as senses of S4:

S4.1	The drink is cold
S4.2	The drink is lukewarm

So far so bad, for we can see that it is unwarranted to argue that negating S4 lies in an operation that simply deletes *not* from S4 to produce S3. First assume that S4 has the sense of S4.1. It is not necessary that the negation of S4 as (i.e., which now has the sense of) S4.1 result in S3—it could result in S4.2. Second, assume that S4 has the sense of S4.2; again it is not necessary that the negation of S4 as S4.2 result in S3—the resultant could be S4.1. (The complexity of the linguistic issues involved here are discussed in Campbell and Wales, in press.)

This far, our argument runs that negation as an operation on statements does not always deal satisfactorily with negative statements [S(N) to S(A)] unless we know the specific sense of the negative statement—sometimes we do, e.g., S2, but sometimes we don't, e.g., S4. We now wish to argue that negation viewed as an operation can also be shown to fail to deal satisfactorily with the original move S(A) to S(N). If we do hold that negation is an operation on statements, then we might expect that if the operation is carried out on S(A), we should obtain the resultant S(N). The trouble with this view is that it has no clear way of saying what the resultant S(N) will look like; in fact, whether we may say of resultant S(N) that it is *the* negation of S(A), or only that S(N) is *a* negative form of S(A), is a moot point. For compare S6.1 through S6.4; what is the negation of S5?

S5	The circle and the triangle are red
S6.1	The circle and the triangle are not red
S6.2	The circle but not the triangle is red
S6.3	The triangle but not the circle is red
S6.4	Neither the circle nor the triangle is red

If the negation-as-operation view holds that S6.1 is *the* negation of S5, and that S6.2 through S6.4 are simply possible senses of S6.1, then this betrays the notion that difficulty with negation consists in the operation involved, and suggests that the issues are far more complex: Is it not the case that difficulty in processing strings like S4 and S6.1 arises not just because such strings contain a negative element, but also because of the very nature of the materials that compose such strings? That is, doesn't the problem here consist in deciding what has been negated?

Instead of looking for one simple account of negation and attempting to relate all data to it, there seem to be good reasons for holding that we consider other possibly interrelated issues that may differentially determine processing difficulty with respect to different types of material. Here we are thinking of such issues as complexity, ambiguity, specificity, topicalization, confusability, meaning, sense, truth-value, context, and so on. Some credibility is lent to our view by the most recent paper that Wason has published on this topic, where he reports that given a situation wherein denial (the use of negative statements) is as plausible as assertion (the use of affirmative statements), such negative statements are relatively easy to process (Wason, 1965). We take Wason to be suggesting that one consider not only the structure of negative statements, but also their context of application. Despite an anomaly in Wason's results that we will return to later, this represents a turning point in our conception of the whole topic, for it encourages us to consider issues, apart from context, that compose the complex we have just mentioned. It is an initial consequence of our view, then, that we provide an exhibition of the relative ease of processing of negatives if we manipulate some such variable as confusability. If we are correct in arguing that difficulty in processing negatives may be a function of the confusability of the material to be processed, then we are required to show that when we lessen the confusability of the material, we observe facilitation in processing. Our experiment attempts to test this consequence.

EXPERIMENT

Subjects

Sixty psychology students at Edinburgh served as Ss; 30 were male. All Ss were unpaid volunteers whose native language was English. Their age range was 18.6-31.7 years. Ss were assigned at random to three equal groups; the first was a control group, the second received special training, and the third evaluated material some of which had been reduced in confusability. These groups are thus designated: Group 1—Control; Group 2—Training; Group 3—Material.

Material

Examples were constructed of four types of statements (TA, FA, TN, FN), using arithmetic statements about triads of digits that were asserted to sum to 15. Each example had the following form: If adding up to 15, is the following statement true or is it false? *Given x and y, the next number * z.* x, y, and z were always different digits. The * gap was filled with "is" for affirmative examples, and with "is not" for negative examples: Examples were true or false depending on how the gap was filled and on whether or not the three digits summed to 15.

Each experimental session involved use of introductory cards, practice or training cards, and evaluation cards, in that order. Introductory cards, consisting of four cards showing an example of each type of statement using a simple two-digit addition, were presented to all groups of Ss simply to accustom them to the task and the apparatus. Practice cards were presented to Groups 1 and 3, and training cards to Group 2. One set of evaluation cards was presented to Groups 1 and 2, and another set to Group 3. Details are as follows:

Practice cards. These were eight cards showing a three-digit addition to 14, 15, or 16. The eight cards comprised two examples of each type of statement. Presentation order was erratic: The first four cards contained all four types, and no type started the next block of four if it had ended the previous block of four. Types TA and FN must sum to 15; Types FA and TN must not. In order to get our Ss to compute Types FA and TN similarly to Types TA and FN, we made such FA and TN examples sum to either 14 or 16. Thus, of the eight cards, two TA summed to 15, two FN summed to 15, one FA and one TN summed to 14, and one FA and one TN summed to 16.

Training cards. The same eight practice cards as above were used, but above each of the statements there was printed a 3 by 3 matrix, or magic square, using all of the digits from 1 through 9.

2	9	4
7	5	3
6	1	8

By training Ss on this material, we intended to facilitate access to the patterns of information relevant to evaluation of the test cards. From a pilot study, we learned that the matrix was not always employed, so we printed it on a separate card and gave this to Ss during training. Training consisted in asking Ss to justify their responses (TRUE or FALSE) with reference to the matrix, where any row, column, or diagonal sum to 15.

Evaluation cards, Set 1. There were 16 cards, each showing a three-digit addition to 15 (TA and FN), 14 or 16 (FA and TN), balanced as before. There were four examples of each type of statement, presentation being erratic as already described.

Evaluation cards, Set 2. Of the 16 cards in Set 1, the same eight examples of TA and FN statements were used. But the FA and TN statement examples were withdrawn and eight cards substituted whose sums were nearer the extremes of three-digit addition using just the digits 1-9. That is, these eight examples (balanced) approached either 6 or 24 rather than 15 (minimum and maximum values, respectively, since $0 < x \neq y \neq z < 10$). Note that all three digits must always be taken into account in this set since in the examples we give below FA might terminate with 9, making it TA; and TN might terminate with 1, making it FN. We intended the addition of digits in FA and TN statement

Table 1
Significant Effects in Analyses of Variance

	Significant effects	Fastest	Fastest through Slowest
Group 1-Group 2	B	.05 (F: 4.52)	.05 (F: 4.84)
	C	.01 (F: 22.35)	.01 (F: 22.60)
	BC	.01 (F: 9.01)	.01 (F: 10.34)
Group 1-Group 3	A	.01 (F: 11.53)	.01 (F: 12.54)
	C	.01 (F: 12.81)	.01 (F: 12.98)
	ABC	.05 (F: 6.29)	.01 (F: 11.25)

A = groups effect   B = truth-value effect   C = affirmation-negation effect

examples to be readily recognized by Group 3 Ss as being distinctly greater or distinctly smaller than 15, by contrast with the additions to 14 or 16 of these types of statement in Group 1 (control), and hence less confusable in processing.

The way in which we have manipulated our material is brought out in the following examples:

(TA) Given 2 and 4, the next number is 9 } Set 1 and Set 2
(FN) Given 6 and 8, the next number is not 1

(FA) Given 2 and 4, the next number is 8 } Set 1
(TN) Given 6 and 8, the next number is not 2

(FA) Given 2 and 4, the next number is 3 } Set 2
(TN) Given 6 and 8, the next number is not 9

All examples of the four types of statement were typed, 10 characters per inch, in the center of white cards measuring 6 x 4 in.

It now remains for us to set out our hypotheses more specifically. Our interest will lie in control-experimental group comparisons. First, we expect to observe some general facilitation in processing when we compare Group 1 (control) with Group 2, which has received some special training in 15-sums relevant to evaluation. Second, we expect to observe facilitation in processing material that has been lessened in confusability, but no facilitation on material that has remained unaltered. That is, we expect the processing times of FA and TN statements in Group 3 to be significantly less than in Group 1, but to find no such difference between these groups in processing TA and FN statements.

Procedure

The Ss were tested by the same E; each session took about 15 min. S and E sat at opposite sides of a table with the apparatus assembled between them so that S could see only a response keyboard and a presentation screen. S rested his hands on the two keys, labeled TRUE on the left and FALSE on the right, of the keyboard. Ss were told that on each trial they would see a statement about digits summing to 15. Their task was to decide whether the statement was true or false, and to press the appropriate key as soon as they had made a decision, but not to sacrifice accuracy for speed. E said "ready" and then pressed a switch that exposed a card on the presentation screen and simultaneously started an electronic timer, preset to zero, measuring in hundredths of a second. When S pressed either the TRUE or FALSE key this stopped the timer, cut illumination of the card on the screen and, by means of pilot lights, informed E which key had been pressed by S. Incorrect responses during practice or training were corrected by E. In the evaluation conditions, Ss were not informed about the correctness or incorrectness of their responses.

Results

For each S we have four response times for each type of statement. Emphasis on the importance of accuracy was largely successful for there were few errors; the mean error percentage for all statements for all Ss was 2.08. Where we have observed incorrect responses, we have recorded the next slowest but correct response time of the same type of statement. There are five errors for which there is no slower correct response time; these remain unaltered. We report the results of analyses on the fastest, and also on the fastest through slowest, processing times.

We have carried out analyses of variance (Winer, 1962, pp. 283-285) comparing Group 1 (Control) with Group 2 (Training), and Group 1 with Group 3 (Material). Significant effects, at the levels indicated, are summarized in Table 1.

It can be seen that the only difference across these analyses is that the three-factor interaction is significant at different levels in the Group 1-Group 3 comparison. Subsequent analysis has been conducted on the fastest processing times.

Table 2 shows group means (m), in seconds, and standard deviations (SD) by statement type for the fastest processing times.

By inspection, there is some facilitation between Group 1 and Group 2 in the expected direction, but these results fail to confirm our training hypothesis—while training Ss by exposing them to patterns of information relevant to evaluation does result in some facilitation, such facilitation is not significant.

However, the results do confirm our material hypothesis: between Group 1 and Group 3, Types TA and FN are not significantly different, while Types FA and TN are (for FA, $t = 2.329$, $p < .02$; for TN, $t = 3.654$, $p < .01$). Thus while average processing times remain constant for unaltered material (TA, FN) altering the nature of the material that Ss have to process by lessening the confusability of that material results in significantly shorter

Table 2
Group Means (Sec) and SDs by Statement Type

	TA		FA		TN		FN	
	m	SD	m	SD	m	SD	m	SD
Group 1	2.17	(.57)	2.31	(.63)	3.00	(.88)	2.39	(.70)
Group 2	2.15	(.48)	2.17	(.39)	2.77	(.47)	2.41	(.48)
Group 3	2.10	(.44)	1.94	(.35)	2.20	(.44)	2.32	(.64)

processing times, whether the material be affirmative or negative (Group 3: FA, TN). This result holds for fastest through slowest processing times.

DISCUSSION

We suggest, then, that our experimental data underwrite the initial consequence of our argument that negation is more closely concerned with the nature of the material to be processed in terms of its complexity and confusability rather than simply concerned with an operation on statements.

Having exhibited an initial consequence of our view, we are now faced with a problem germane to this whole topic: What limits are we to set on the extent of generalization? Having shown a significant effect for material lessened in confusability with respect to arithmetic statements, how far may we extend any conclusion to other sorts of material? This is a difficult problem, and we don't pretend to know a complete answer. Instead, in what follows, we will abide by our intention to reopen discussion of the whole topic by seeing how far our view of negation begins to account for the results of some previous studies. Any conclusions we may adduce are essentially preliminary.

The material in Wason's 1959 study was conjunctive, and we find that with negation, his Ss interpreted the negative as applicable to both conjuncts rather than as applicable to just one, the latter being logically adequate for the task. This may be characterized as a failure to apply one of de Morgan's laws: not (p and q) was interpreted as (not-p and not-q), instead of (not-p or not-q). Possibly this arose because Wason's questions contained NOT BOTH . . . AND . . . which, Wason reports, were interpreted as NEITHER . . . NOR . . . . This result may be a reflection of the issues we introduced with S5 through S6.4 above. Similarly, with the set of papers we mentioned above in the area of concept attainment-formation, where the conjunctive nature of the material employed put a premium on positives, to achieve equivalent results, the use of negatives would have been less economical. But in studies that used, say, disjunctive material, the situation would be reversed: to achieve equivalent results, the use of positives could be less economical than negatives; for some evidence, see Bourne (1967).

In his 1961 study, Wason used strings exemplified in (a) and (b), finding the former to be more quickly verified than the latter:

(a) 4 is an even number
(b) 7 is not an even number

Here it is impossible to manipulate confusability, since the material is contradictory; *odd-even*, applied to integers, is a mutually exclusive and exhaustive antonym pair. If (b) were:

(b′) 569 is not an even number

one would expect little difference in evaluation processing times between (a) and (b) and (a) and (b′). But one might expect a different result to emerge from the following, assuming, say, that all are comparisons with zero:

(a) 4 is a low number
(b) 7 is not a low number
(b′) 569 is not a low number.

The relevant part of McMahon's study is subject to a similar argument, for compare (a) through (b′) with (A) through (B′):

(a) 7 always follows 5
(b) 5 never follows 7
(b′) 5 never follows 77
(A) 7 is larger than 5
(B) 5 is not larger than 7
(B′) 5 is not larger than 77.

A further point of interest arises in Eifermann's replication of Wason's 1961 study, using Hebrew (Eifermann, 1961). Eifermann used two words to express negation: *lo* and *eyño*. The former "negates any part of a sentence or any sentence as a whole," whereas the latter may only be used for sentence negation (Rosén, 1962, pp. 13, 15). Eifermann's findings show that *lo* sentences were significantly more difficult to evaluate than were *eyño* sentences. This suggests to us that *eyño* sentences might have been easier to process than *lo* sentences either because the *lo* negative strings are possibly ambiguous, but unambiguous for *eyño* strings, or because *eyño* sentence negation only seems to be used with such contexts as locative or existential sentences. However, as negation in Hebrew seems a complex matter (see, for example, Rosén, 1962, 36.2, 211-213), we must regard these remarks on Eifermann's results as at present speculative.

A study by Fillenbaum (1966), which utilized statements like those we cited above in S3 and S4, required Ss to recall the gist or sense of statements that involved different sorts of antonym pairs; Fillenbaum gives as examples: hot-cold (contraries) and open-closed (contradictories). He observed that recall for the gist of such strings as *The door is not open* was likely to produce meaning-preserving errors like *The door is closed* rather than meaning-changing errors like *The door is open.* A by far less marked effect was found for contraries: *The drink is not cold, The drink is hot, The drink is cold.* These results are consistent with the position for which we have been arguing; but there is a definitional point at issue, for the asymmetry in entailment relations for contraries, but not for contradictories, that Fillenbaum calls to attention (Fillenbaum, 1966, p. 219, footnote) hold only for what we may call "absolute" cases (as distinct from comparative and superlative cases). While it is true that *The drink is hot* entails *The drink is not cold,* and whereas the converse is false, and while it is true that *The door is open* entails *The door is not closed,* and vice versa, the very fact that we may use comparatives and superlatives with both these sorts of antonym pairs—contraries, hot-cold, and "contradictories," open-closed—suggests that there are contradictories and contradictories, for compare *Door a is more open than door b* with the string of nonsense, *5 is an odder number than 6* (Campbell & Wales, in press). The nature of the antonym pairs *hot-cold* and *odd-even* is quite different, only the former being "gradable"; we suggest that Wason's 1961 material is somewhat unusual in nature, since it is eccentric to use a negative with either member of an antonym pair whose range is logically exhaustive.[3] We do not usually say, *5 is not an even number*; that we say it is odd, that is, that we have a separate word for what is not-even, is in itself significant. Were there only two colors in all the world, say red and blue, then we would not usually say, *this object is not red*; we would say, *this object is blue* (see Ayer, 1952, and Strawson, 1952).

We said above that we would attempt to account for an anomaly in the results in Wason's 1965 paper, where he reports confirmation of one of two hypotheses concerning the context of application of negative statements; specifically, his exceptionality hypothesis was confirmed—"given a set of similar stimuli $x_1, x_2, \ldots, x_n$ and a stimulus y which is perceived to differ from these in one important attribute, it is more plausible to assert that y is not x than to assert that x_i is not y"—while his ratio hypothesis was not confirmed—"given two sets of stimuli which differ considerably in magnitude, it is more plausible to deny that the smaller set possesses a property of the larger set than to deny the converse [Wason, 1965, p. 7]." The anomaly in these results arises from failure to qbserve confirmation of *both* hypotheses. We wish to suggest that failure to confirm the ratio hypothesis arose as a function of the complex of issues that we mentioned above concerning the nature of the material. In the material used to test the exceptionality hypothesis, what the statements refer to, whether affirmative or negative, is clear, and we find that the hypothesis is confirmed. But with the unconfirmed ratio hypothesis, the nature of the material employed involves difficulties in terms of ambiguity and confusability.

Wason used two groups to test his two hypotheses: E group (exceptionality) and R group (ratio). Ss inspected arrays like those described below, and were asked to complete appropriate sentence frames so that the resultant statement would be true. In these arrays, R = red circle, B = blue circle (for a full description, see Wason, 1965).

R group:	R	R	R	B	R	R	R	R
E group:	1	2	3	4	5	6	7	8
	R	R	R	B	R	R	R	R

Statements about these arrays took four forms, dubbed DA, DN, SA, and SN (D = dissimilar, S = similar, A = affirmative, N = negative). Examples would be:

R group		E group
Exactly one circle is blue	(DA)	Circle 4 is blue
Exactly one circle is not red	(DN)	Circle 4 is not red
Exactly seven circles are red	(SA)	Circle 7 is red
Exactly seven circles are not blue	(SN)	Circle 7 is not blue

The difference between DA and DN statements in R group was found to be significant, failing to confirm the ratio hypothesis; but the exceptionality hypothesis was confirmed since DA and DN statements in E group were not significantly different, indicating facilitation on DN statements. The anomaly then lies in the relatively long mean processing times for DN statements in R group.

We offer as a suggestion that DN statements in R group are essentially ambiguous; consider a DN statement for the R group array above:

(DN) Exactly one circle is not red

This statement seems to have two distinct senses that depend on a referential difficulty: to which circle in the array does "exactly one" refer? For the statement may be held to be true either because:

(DN_1) Exactly ONE circle is not red (seven are)

or because:

(DN_2) Exactly one circle is not RED (it is blue).[4]

In the (DN_1) sense, the statement subject may be deemed inappropriate for the predicate, and in the (DN_2) sense, the predicate may be deemed inappropriately predicated of the statement subject. When we consider what happens when such a possibility of referential confusability does not arise for DN statements, as in E group, where the statement subject is unalterably selected by being numbered, "Circle 4 is not——," and where there is now only one ground for truth, we find on average a 22% drop in processing time. Hence, failure to observe confirmation of the ratio hypothesis may have been no more than coincidental with the nature of Wason's material for the ratio group.

To conclude: we have been concerned above not only in suggesting what some of the difficulties with negation might be, but also in trying to suggest how one might begin to account for data so far obtained. From our discussion, it seems clear, at least to us, that it is time for widening discussion to a more general level; some possibly useful nonexperimental contributions appear in Jespersen (1917, 1924), Klima (1964), Patton (1968), Sommers (1965, 1967), and Thorne (1967). The conclusion we wish to draw from our examination of experimental studies is that negation viewed as an operation on statements appears unsatisfactory, and negation is better viewed as closely concerned with a complex of issues concerning the nature and application of the negative material to be processed.

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NOTES

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3. Except, of course, in special circumstances, where "the function of such statements is ... to emphasize that a fact is contrary to an expectation [Wason, 1965, p. 7]"; or, "No doubt negative forms of expression are very frequently used to deny some previous suggestion... [Ayer, 1951, p. 799]." But given the circumstances of Wason's 1961 study one cannot expect that any of his Ss believed 7 to be an even number.

4. This might be understood as an issue merely involving the scope of the negative operator. That this is an incomplete account is shown by comparing the removal of "exactly" from SA or SN statements in R group with its removal from DA or DN statements; the semantics of "exactly" must be taken into consideration.

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