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ABSTRACT

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THE CENTER FOR THE STUDY OF SOCIAL ORGANIZATION OF SCHOOLS

FEEDBACK AND SENTENCE LEARNING

BY

JOHN T. GUTHRIE

JUNE, 1970

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Abstract

The theoretical functions of external feedback in S-R and closed-loop models of verbal learning are presented. Contradictory predictions from the models are tested with a 3x3 factorial experiment including 3 types of feedback and 3 amounts of rehearsal. Ninety adult Ss were run individually and were required to learn 39 sentences verbatim. The results were: 1) feedback facilitated learning when it followed wrong responses; 2) feedback had no effect on learning following right responses; and 3) feedback consisting of both the stimulus and the response was superior to no feedback, whereas feedback consisting of only the response did not differ from no feedback. The findings are discussed in relation to the two learning models and programmed instruction.

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FEEDBACK AND SENTENCE LEARNING

In an extensive review of research on response feedback and learning, Adams (1968) has summarized two models of behavior which are intended to account for verbal learning as well as other phenomena. The first of these is the familiar S-R theory and the second is the closed-loop theory which is derived from engineering psychology. Adams (1968) claims that both of the models provide explanatory frameworks for certain learning phenomena and portrays the two models as contending for predominance in the theoretical arena.

S-R theory accounts for learning by positing that if the occurrence of a reinforcing stimulus is contingent upon the occurrence of a given response to a designated stimulus, the likelihood that the designated stimulus will evoke the response increases. The reinforcing stimuli, in this model, may be either external or internal. External reinforcers such as food or water may be administered by an experimenter. Internal reinforcers such as proprioceptive stimuli may be produced by the occurrence of the response. Such internal stimuli acquire value as secondary reinforcers as a consequence of their temporal contiguity with primary reinforcers.

That proprioceptive stimuli may become secondary reinforcers has been supported by Grice (1948), Skinner (1953), and Mowrer (1960).

Closed-loop theory accounts for learning by invoking an "internal reference level" which is the basis for the self-regulation of behavioral sequences (Adams, 1968). Given that a stimulus context is sufficient to elicit a relatively appropriate response, the response is modified by an error-nulling process. That is, the response is compared to the internal reference level, any error in the response is detected, and successive responses are corrected on the basis of the information resulting from the comparison. In this system, learning is produced by the acquisition of a memory trace and a perceptual trace (Adams, 1967). The memory trace is basically the S-R associative strength for given stimuli and responses. The perceptual trace, however, is the internal representation of stimuli which provides a basis for recognition of all kinds, including the recognition of responses as correct or incorrect. It is this perceptual trace which has been termed the "reference level." This reference level is acquired as a function of the stimulus aftereffects of a response. Such aftereffects may consist of either external (environmental) or internal (proprioceptive) stimuli. Feedback may be viewed as one of the stimulus aftereffects of a response.

These two models give rise to different predictions regarding the mechanism by which external consequences of a response facilitate learning. The S-R theory asserts that reinforcing stimuli increase the probability of occurrence of responses on which they are contingent. On the contrary, closed-loop theory maintains that feedback facilitates the acquisition of a reference level which provides the basis for the detection and elimination of erronenous responses. Correct responses are not necessarily strengthened by the occurrence of stimuli following them. Correct responses are rather maintained in the repertoire while erroneous responses are systematically eliminated. The question to which the present study addresses itself is: Does the effect of feedback on learning sentences conform more closely to the S-R or the closed-loop paradigm? If feedback seems to strengthen correct responses, the S-R interpretation is more reasonable; however, if feedback serves to eliminate and correct wrong responses, the closed-loop model may be viewed as a more cogent explanatory framework.

Although no research has been focused directly on the question raised in the above paragraph, several studies contain pertinent findings. In a discovery learning experiment, Wittrock (1963) required subjects to decipher sentence cryptograms. The independent variables consisted of providing or withholding a rule for deciphering the cryptogram and providing or withholding feedback which consisted of the correct response. The results on both learning and retention measures were that feedback facilitated performance if the rule was absent, but feedback had no effect if the rule was provided. Since the rule was usually sufficient to elicit the correct response, and the correct response was rarely produced in the absence of the rule, it appears that feedback facilitated learning following wrong responses and did not affect learning following correct responses.

Additional evidence for this interpretation of the effects of feedback is contained in studies by Snelbecker and Downs (1967), and Melching (1966). In the former, subjects were required to perform a series-completion task which included both easy and difficult items. The result was that feedback facilitated learning on the difficult items but not on the easy items. However, a ceiling effect was observable in the data which may have rendered the study insensitive to possible effect on the easy items. In the latter experiment using linear programmed instruction (Melching, 1966), it was found that the error rate on frames on which subjects requested feedback was 28 per cent; whereas, the error rate on frames on which no feedback was requested was only 4 per cent. These latter results suggest that subjects may attend more closely to feedback when it follows an error than when it follows a correct response.

The primary hypothesis tested in this study was that feedback facilitates learning from sentences when it follows incorrect responses and feedback has no effect on learning when it follows correct responses. Although no other explicit hypotheses were formulated, the study included the investigation of the effects of different types of feedback and different amounts of rehearsal on sentence learning.

Method

Subjects. The Ss were 90 undergraduate men who were paid $1.50 per hour.

Materials. The stimuli were based on a selection on magnetism from the *Encyclopedia Britannica*. The passage consisted of 39 sentences which were edited to lengths of 20-30 words each. From each sentence a cloze test item was constructed by deleting one word from the sentence. The position of the deletion in the beginning, middle, or end was determined at random for each sentence. There were thirteen sentences with each type of deletion. The omitted words included only nouns, verbs, adjectives, and adverbs.

Treatment Conditions. The design was a 3x3 factorial including three different feedback conditions and three levels of rehearsal. The different conditions of the feedback factor included: 1) providing both the stimulus and the correct response (SR); 2) providing the correct response (R); and (3) withholding any form of overt feedback (No

Feedback). The rehearsal conditions included: 1) requiring the subject to write the stimulus and response following feedback on each trial (Required Rehearsal); 2) providing an interval following feedback during which no explicit behavior was required of the Ss (Permitted Rehearsal); and 3) requiring the Ss to cancel 9's from a series of random numbers (No Rehearsal).

Procedure. All Ss were assigned at random to one of the nine treatment conditions and were run individually. E and S were seated on opposite sides of a table and were separated by a tall wooden divider. After reading the instructions for the learning task and informing S that he would be tested, E administered one practice trial. The learning task was then presented. On each trial S was presented one sentence and presented a cloze test item consisting of the original sentence with one word deleted. The S was given 10 seconds to write the answer on paper. Next, one of the feedback conditions, SR, R, or No Feedback, was administered. Following the feedback condition, one of the three types of rehearsal was provided, i.e., Required Rehearsal, Permitted Rehearsal, or No Rehearsal. After the rehearsal period terminated, the next trial was begun. The learning task consisted of 39 trials. The learning task was immediately followed by a retention test consisting of 39 cloze items identical to the cloze items presented during learning. The S was required to write the answers to the items which were presented one at a time with 10 seconds for each item.

Results

The first analysis was undertaken to determine whether feedback affected learning primarily by strengthening right responses or correcting wrong responses. For this analysis four proportions were computed. Two proportions consisted of the number of responses which were right on the retention test and were also right during learning, divided by the total number of responses which were right during learning. This provided a measure of the probability that a response which was correct in learning, _i.e._, before feedback was given, would also be correct on the retention task, _i.e._, after feedback had been administered. One proportion was obtained for _S_s who received feedback, either SR or R; a second proportion was computed for _S_s who received no feedback.

Two proportions were established to determine the likelihood that a response which was wrong during learning would be corrected by feedback and appear correct on the retention task. The number of responses which were right on the retention task and wrong during learning was divided by the total number of responses which were wrong during learning. One proportion was computed for _S_s who received one of the forms of feedback and a second proportion for _S_s who received no feedback. (See Table 1.)

These data were analyzed with two t-tests. The two proportions obtained when the responses were right during

Table 1

Effects of the Presence of Feedback

on Right and Wrong Responses

Learning	Feedback: Present		Feedback: Absent	
Right	$\frac{rR}{rR + rW}$	.426	$\frac{rR}{rR + rW}$	.443
Wrong	$\frac{wR}{wR + wW}$	.321	$\frac{wR}{wR + wW}$	.057

Note.—The lower case letters denote whether responses were right (r) or wrong (w) during learning; the upper case letters denote whether they were right (R) or wrong (W) on the retention measure. For instance, rR represents responses which were right during learning and also right on the retention test.

learning and right on the test were .426 with feedback present and .443 with feedback absent. These proportions were not significantly different ($t = 0.425$, $df = 88$, $p > .05$). This finding indicates that the presence of feedback did not increase the probability that a response which was right on one trial would also be right on a successive test trial. However, the two proportions based on the responses which were wrong during learning and right during the test were .321 when feedback was present and .057 when feedback was absent. A significant difference exists between these proportions ($t = 10.56$, $df = 88$, $p < .01$). This difference demonstrates that when feedback is present, a response which is wrong on a learning trial may be corrected and appear right on a test trial. In the absence of feedback, however, such correction occurs very rarely. Thus, feedback following wrong responses increases the probability that those responses will be right on a test; whereas, feedback following right responses does not affect the likelihood that the response will be correct on a successive test trial.

The scores on the test were analyzed with a two-way analysis of variance to determine the effects of the different types of feedback and the varying amounts of rehearsal. A significant portion of the variance was attributable to the feedback factor ($F = 5.58$, $df = 1/81$, $p < .01$). The main effect for rehearsal and the interaction of feedback and rehearsal were not significant. The means of each of the groups are presented in Table 2. Post-hoc comparisons of the feedback conditions were conducted with the Neuman-Keuls procedure (Winer, 1962). The result was that although feedback consisting of the presentation of the response (R) was not significantly different from no feedback, feedback consisting of the presentation of both the stimulus and the response (SR) was superior to the no feedback condition (q = 4.73, df = 81, $p < .01$.). This finding has important implications for programmed instruction which are outlined in the Discussion section.

A control group was run independent from the other Ss in the study. The group included 23 Ss drawn from the same population as the experimental Ss except that they received no payment. This group was given the test consisting of cloze items without having read the passage on which the test was based. This group provided a baseline for performance on the test based on guessing. The mean number correct was 4.09. This mean was compared to the lowest group mean found in Table 2, 8.70. These means differed significantly (t = 2.69, df = 33, $p < .01$), indicating that even the poorest of the experimental groups learned as a consequence of the learning task. It is interesting, though not surprising, that this lowest experimental group received no feedback and no rehearsal.

Table 2

Means of Feedback and Rehearsal Groups on Test

	Rehearsal			
Feedback	None	Permitted	Required	Total
Sentence	17.90	14.60	16.60	16.37
Word	14.80	12.20	14.10	13.70
None	8.70	15.30	10.00	11.33
Total	13.80	14.03	13.57	13.80

Discussion

The closed-loop model of learning (Adams, 1968) as summarized in the introduction makes different assumptions about the function of external feedback than the S-R learning paradigm. In the former, external feedback is a stimulus which is represented internally for the S and is established as a reference level for the identification of correct and incorrect responses. On the basis of the reference level, incorrect responses are detected and eliminated and the new responses are then generated by the S and tested for their correctness. In this model, learning results from the successful elimination of incorrect responses from a continuous succession of responses. In the S-R model, on the other hand, learning results from the strengthening of correct responses by the occurrence of reinforcing stimuli following the responses.

The outcome of this study provides support for the closed-loop model. When feedback was present following an erroneous response on a learning trial, the probability was .3 that the response would be correct on a later test trial. However, when feedback was absent following an erroneous response, the probability was .06 that any correction would occur. On the contrary, on learning trials on which a given response was right, the probability was about .4 that the response would be correct on a test trial regardless of whether feedback was present or absent. Thus, feedback facilitated learning from sentences when initial responses were wrong, but no facilitation occurred when those responses were right.

The effectiveness of the different types of feedback has an important implication for programmed instruction. In linear programmed instruction, a frame containing feedback typically follows a frame which presents a stimulus and requires a response. The feedback frame invariably consists of the presentation of the right response. The findings of this study suggest, however, that such a feedback format may not be an improvement over no feedback at all. The superior form of feedback in this study consisted of the presentation of the stimulus as well as the response. This type of feedback facilitated learning compared to no feedback whereas the presentation of only the response did not differ in effectiveness from no feedback. Thus, learning from programmed instruction would likely be increased by the provision of feedback consisting of both the stimulus and the correct response.

In linear programmed instruction, which is based on the operant model, it has been assumed that the elicitation of correct responses is desirable. Indeed, a 90 per cent correct response rate has been advocated by several programmers (Markle, 1964). However, the results of the present study indicate that feedback corrects wrong responses but does not strengthen correct responses. If these findings are generalizable, the importance of a high correct response rate is questionable. It is possible that the amount of new learning may be increased by lowering the correct response rate. One consequence of a lower correct response rate would be the elimination of frames on which no learning occurred but on which a correct response was given based on prior knowledge. Thus, a number of false positive frames would be omitted. Furthermore, the errors which occur in the more difficult program are likely to be corrected by feedback and consequently it is not probable that wrong responses and misconceptions will be learned. Although the precise level of correct responses which maximizes learning remains to be determined by further research, at least it is clear that the principle of minimizing the error rate in linear programmed instruction requires reappraisal.

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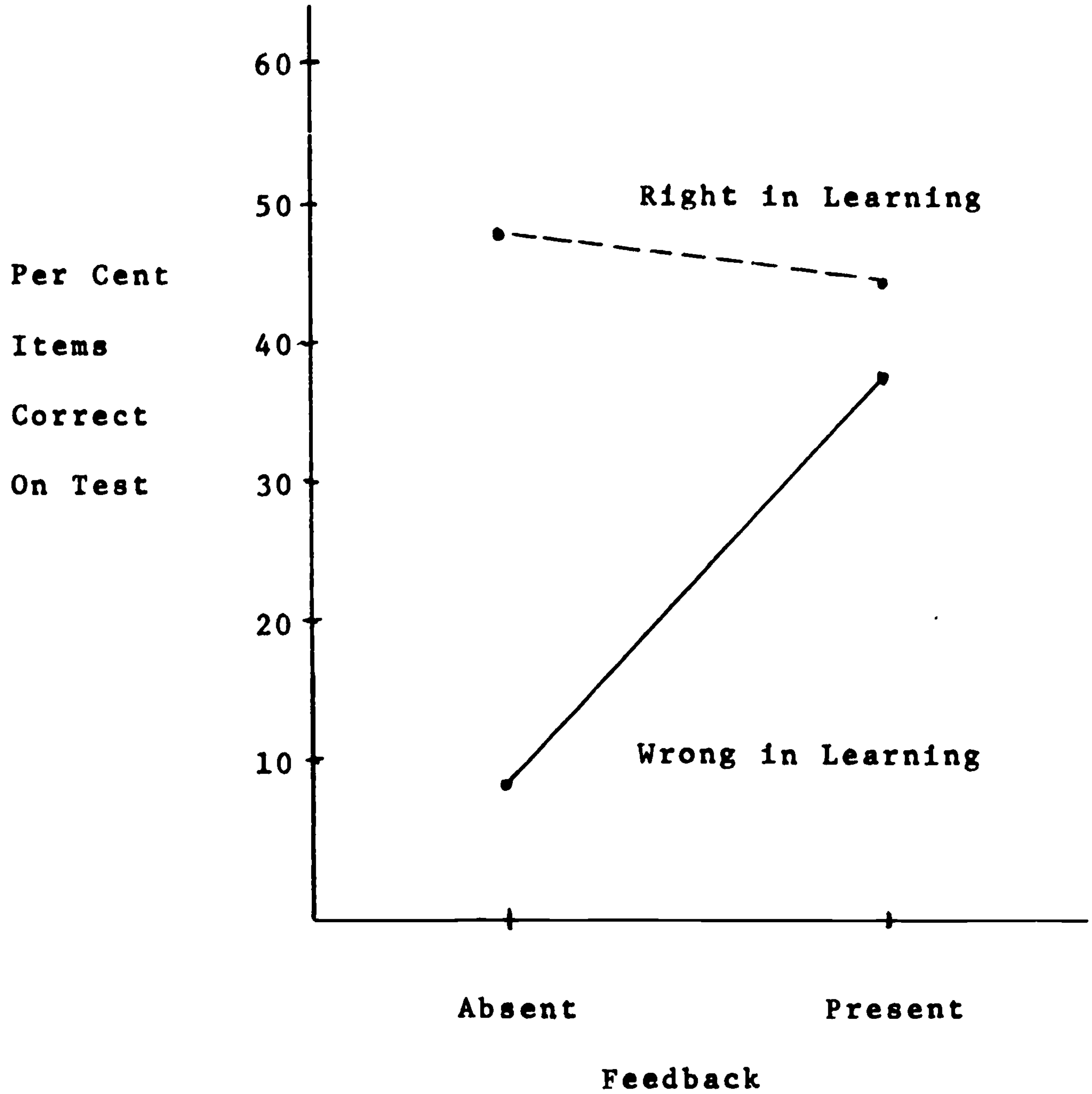

Fig. 1. Feedback Effects on Right and Wrong Responses.

Appendix B

Analysis of Variance of Effects of Feedback and Rehearsal on Learning

Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio
Feedback (F)	380.4667	2	190.2333	5.58**
Rehearsal (R)	3.2667	2	1.6333	<1
FR	332.6666	4	83.1667	2.44NS
Within (error)	2761.9983	81	34.0987	

Note.— ** designates $p < .01$

NS designates $p > .05$

Appendix C

Reading Passages on Magnetism

(Trial) Magnetic properties of many ferromagnetic materials are so sensitive to the application of stress that stress is ranked with field strength and temperature as a primary factor affecting magnetic change.

1. One type of stress to be distinguished is the large stress that permanently deforms the material almost invariably producing a decrease in permeability.
2. The second kind of stress is within the elastic limit and may either increase or decrease the permeability, depending on the nature of the material.
3. When moderate tension is applied to a specimen of nickel, permeability is decreased, although with some materials the effect of tension is to increase permeability.
4. The effect of stress on magnetization is closely related to magnetostriction, the change of dimensions that occurs when a body is magnetized.
5. Iron and some other materials have magnetostriction that is sometimes positive and sometimes negative, with the magnetostriction of iron being positive in weak fields.
6. According to the domain theory, in a material with positive magnetostriction, the magnetization of a single domain will tend to be parallel to the direction of tension.

7. Improvements in the technique of growing large metallic crystals have opened to investigation the magnetic properties of single crystals of iron, cobalt, nickel, and many alloys of these elements.
8. Crystals of some metals, such as nickel and nickel-iron alloys, are grown by slow-freezing a melt of pure material, but this method is not adapted to iron.
9. Single crystals of iron are grown by stretching a pure specimen a definite amount and then heating it for a long time just below the phase transformation temperature.
10. In the cubic crystals of iron and nickel the magnetic properties depend on the direction, with respect to the crystal axes, in which these properties are measured.
11. The direction for which the magnetization curve lies highest is the direction in which magnetization is most easily acquired, and is called the direction of easy magnetization.
12. In iron this direction of easy magnetization is parallel to a cube edge, and in nickel the direction is parallel to a cube diagonal.
13. According to the domain theory the direction of easy magnetization in crystals determines the actual direction of magnetization in single domains that are not subject to magnetic field or strain.
14. In unmagnetized iron the domains are oriented in each of the six directions parallel to a cube edge so that the net magnetization is zero.

15. Magnetization curves of single crystals of a silicon-iron alloy are of special interest because this is the first case in which measurements were extended to very low inductions.

16. They are also of interest because the permeabilities obtained in these crystals are enormous compared with those in commercial silicon-iron sheet with the same silicon content.

17. These data were obtained by cutting a single crystal in the form of a hollow parallelogram with all sides parallel to equivalent directions in the crystal.

18. Thus, the sides were parallel to diagonals of cube faces and so formed a closed magnetic circuit which could be measured in the usual way.

19. A theoretical study of the properties of crystals has made it possible to calculate the magnetization curve for any direction in a single cubic crystal like iron or nickel.

20. The anisotropy constant, the measure of the difference between the magnetization curves in different directions, and numerically equal to four times the area between the curves, must be known.

21. The constant is positive for iron, negative for nickel, and is approximately zero for iron-nickel alloys with 65% to 80% nickel.

22. The theory does not account for energy associated with the lower and middle portions of the magnetization curve, so calculated curves do not correspond to true curves below their knees.

23. In a polycrystalline material the magnetization curve is a combination of the separate curves for the many small single crystals of which it is composed.

24. Such a composite curve has been calculated to show how the magnetization curve approaches saturation, and shows fair agreement with empirical data.

25. In iron and nickel the anisotropy constants decrease as temperature increases, so these metals are isotropic over a considerable range of temperature before they become nonmagnetic at the Curie point.

26. At very low temperature the constant for nickel is ten to fifteen times what it is at room temperature while for iron the corresponding ratio is only 1.5.

27. Unusual magnetic properties are found in alloys with small anisotropy constants, such as the permalloys with 60% to 80% nickel, in which range the constant goes from positive to negative.

28. At times the anisotropy is small, and the orientation of the domain therefore is controlled only weakly by crystal structure.

29. Under this condition the material responds easily to magnetic field or to mechanical stress, and so it saturates in relatively weak fields and is unusually strain sensitive.

30. The small anisotropy of the permalloys with 60% to 80% nickel is associated with their unusual properties under heat treatment in a magnetic field.

31. Cobalt differs from the other ferromagnetic elements, iron and nickel, by having a hexagonal crystal structure rather than a cubic crystal structure.

32. At room temperature the direction of easy magnetization is parallel to the hexagonal axis of the crystal, and when unmagnetized the domains thus lie in one of two orientations.

33. Such a small number of easy directions means that the whole magnetic structure may be regarded as a bundle of needles magnetized initially in either direction at random.

34. This picture is supported by powder patterns and by L. H. Germer's measurements of magnetic fields close to the surfaces of a single crystal of cobalt.

35. The crystal anisotropy of cobalt is large, and so a strong field is necessary to saturate a crystal in the direction of most difficult magnetization.

36. At higher temperatures cobalt becomes isotropic, and above 300 degrees C. the hexagonal axis is the direction of most difficult magnetization, all directions at right angles to the axis being equally easy.

37. The magnetostrictive change in length of a single crystal is not the same in all crystallographic directions, as found especially pronounced in iron.

38. Iron expands when the field is applied parallel to a crystal axis and contracts when it is applied parallel to a cube diagonal.

39. In the direction of the face-diagonal the crystal expands in weak fields and contracts in strong fields, while nickel contracts in all field strengths in all directions.

Appendix D

Cloze Test

(Trial) Magnetic properties of many _______ materials are so sensitive to the application of stress that stress is ranked with field strength and temperature as a primary factor affecting magnetic change.

1. One type of stress to be distinguished is the large stress that permanently deforms the material almost invariably producing a decrease in _______.
2. The second kind of stress is within the _______ and may either increase or decrease the permeability, depending on the nature of the material.
3. When moderate tension is applied to a specimen of nickel, permeability is decreased, although with some _______ the effect of tension is to increase permeability.
4. The effect of _______ on magnetization is closely related to magnetostriction, the change of dimensions that occurs when a body is magnetized.
5. Iron and some other materials have magnetostriction that is sometimes positive and sometimes negative, with the magnetostriction of iron being positive in _______ fields.
6. According to the domain theory, in a material with positive magnetostriction, the _______ of a single domain will tend to be parallel to the direction of tension.

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8. Crystals of some metals, such as nickel and nickel-iron alloys, are grown by _______ a melt of pure material, but this method is not adapted to iron.
9. Single crystals of iron are grown by stretching a pure specimen a definite amount and then heating it for a long time just below the _______ transformation temperature.
10. In the cubic crystals of iron and nickel the magnetic properties depend on the direction, with respect to the crystal axes, in which these _______ are measured.
11. The direction for which the magnetization curve lies _______ is the direction is which magnetization is most easily acquired, and is called the direction of easy magnetization.
12. In iron this direction of easy magnetization is parallel to a _______, and in nickel the direction is parallel to a cube diagonal.
13. According to the domain theory the direction of easy magnetization in crystals determines the actual direction of magnetization in single domains that are not _______ magnetic field or strain.

14. In unmagnetized iron the domains are _______ in each of the six directions parallel to a cube edge so that the net magnetization is zero.

15. Magnetization curves of single crystals of a silicon-iron alloy are of special interest because this is the first case in which _______ were extended to very low inductions.

16. They are also of interest because the permeabilities obtained in these crystals are _______ compared with those in commercial silicon-iron sheet with the same silicon content.

17. These data were obtained by cutting a single crystal in the form of a hollow parallelogram with all sides parallel to _______ directions in the crystal.

18. Thus, the _______ were parallel to diagonals of cube faces and so formed a closed magnetic circuit which could be measured in the usual way.

19. A theoretical study of the properties of crystals has made it possible to calculate the magnetization curve for any _______ in a single cubic crystal like iron or nickel.

20. The anisotropy constant, the measure of the _______ between the magnetization curves in different directions, and numerically equal to four times the area between the curves, must be known.

21. The _______ is positive for iron, negative for nickel, and is approximately zero for iron-nickel alloys with 65% to 80% nickel.

22. The theory does not account for energy associated with the lower and middle portions of the magnetization curve, so _______ curves do not correspond to true curves below their knees.

23. In a polycrystalline material the magnetization curve is a combination of the separate curves for the many small single _______ of which it is composed.

24. Such a _______ curve has been calculated to show how the magnetization curve approaches saturation, and shows fair agreement with empirical data.

25. In iron and nickel the anisotropy constants decrease as temperature increases, so these metals are isotropic over a considerable range of temperature before they become _______ at the Curie point.

26. At very low temperature the constant for nickel is ten to fifteen times what it is at _______ while for iron the corresponding ratio is only 1.5.

27. Unusual magnetic properties are found in alloys with small _______ constants, such as the permalloys with 60% to 80% nickel, in which range the constant goes from positive to negative.

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39. In the direction of the face-diagonal the crystal expands in weak fields and contracts in strong fields, while nickel contracts in all _______ in all directions.

Appendix E

Experimental Design

		Feedback		
		Sentence Feedback (SR)	Word Feedback (R)	No Feedback
	Required Rehearsal			
Rehearsal	Permitted Rehearsal			
	No Rehearsal			

Note.—Ten subjects were run in each cell.

—On the cloze retention test, an equal number of items were drawn from the beginning, middle, and end of the sentences. The items were presented in the same order for all subjects. An individual's score on the whole test was the unit of analysis. The position of the deletion in the beginning, middle, or end was omitted from the analysis since any main or interaction effects of this variable would not be conceptually meaningful.