EXCITATORY AND INHIBITORY PROCESSES IN THE DISCRIMINATION LEARNING OF SQUIRREL MONKEYS

By

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PREFACE

This thesis represents a modified replication of Ettlinger's (1960) study concerning discrimination learning in primates in which the theoretical position was a uniprocess excitation formulation in contrast to other workers' prevalent preference for duoprocess or uniprocess inhibition theories.

I wish to gratefully acknowledge the assistance and guidance of my theses adviser Dr. Larry T. Brown and the members of my theses advisory committee, Drs. William W. Rambo and Robert S. Beecroft.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

STATEMENT OF PROBLEM

Since Pavlov, the psychology of learning has been fraught with conflicting explanations of discrimination learning ranging from uniprocess inhibition and excitation theories to duoprocess formulations which emphasize the importance of both reward and nonreward (Behar, 1962). Exponents of excitation theories have contended that the important event in discrimination learning is the selection of the positive cue and the consequent reinforcement of the selection response. Other theorists have hypothesized that responses to negative cues which are not followed by reinforcement constitute the significant activities in discrimination learning so that the subject may be characterized as learning not to make incorrect responses because of nonreinforcement. Duoprocess theorists have assigned important roles to both reinforcement and nonreinforcement in their formulations.

Ettlinger (1960), hypothesized that, if one process is more important than the other, subjects trained to a criterion of performance on a discrimination task and then tested with a similar discrimination situation in which either the positive or negative cue has been spatially separated from its respective response manipulandum should exhibit differential performance decrements under the two conditions. Studies have indicated that the spatial separation of response, reward or both from the cue stimulus tends to impair performance in discrimination situations. Thus, if an excitatory process is involved in the learning of a discrimination task, a greater decrement in performance might be expected upon spatial separation of the positive cue stimulus from the manipulandum. If, however, an inhibitory process is dominant, one might expect a greater decrement resulting from the separation of the negative cue. If both processes are equally important, one might expect a similar performance decrement concurrent with spatial separation of either the positive or negative cue from its respective manipulandum.

This study represents a modified replication of one of Ettlinger's (1960) experiments. In the present study, subjects were trained to a criterion on a simultaneous two-object discrimination task. Subsequently, either the positive or negative discriminandum was spatially separated from its respective manipulandum and the effect of this separation on discrimination performance was measured.

CHAPTER II

REVIEW OF THE LITERATURE

One group of discrimination learning theories, uniprocess inhibition theories, postulates that there is a single basic process which underlies habit formation and that changes in response strength result solely from inhibition following nonreward. Harlow is one of the most significant advocates of uniprocess inhibition theory and he has interpreted a number of studies within the framework of this theory (e.g., Moss & Harlow, 1947; Harlow & Hicks, 1957).

In one phase of his 1957 study, Harlow used a multiple-problem technique to assess the effects of reward and nonreward on discrimination learning. Using a standard two-object discrimination task, Rhesus monkeys were given a series of problems in which they were presented either a rewarded or a nonrewarded object on the first trial, and then the original object was paired with an object of opposite reward value on a second trial. The apparatus used was a Wisconsin General Test Apparatus (WGTA), and a noncorrection procedure was utilized. Examination of correct second trial choices revealed two interesting things. First, subjects under both reward and nonreward conditions exhibited a rapid improvement over the series of problems, with improvement leveling off as the number of problems increased. Thus, the parallel form of the curves suggested that a single process might underlie learning under both the rewarded and nonrewarded procedures.

Second, while the form of the curves for both the rewarded and nonrewarded first-trial conditions was similar, the percentage of correct responses on the second trial was consistently higher following the nonrewarded first-trial condition, suggesting that nonreward was the more efficient method of training.

Another group of uniprocess theories are those which emphasize the importance of reward in discrimination learning. Ettlinger (1960) attempted to demonstrate the importance of reward with two experiments involving tactile and visual object discrimination situations. In the experiment, Ettlinger trained subjects to criterion on a simultaneous two-object visual discrimination task. He then spatially separated either the positive or negative stimulus object from its respective food well. Throughout the experiment, the subjects utilized multidimensional objects as cues, but manipulated adjacent food well covers which were of identical appearance for both positive and negative cue objects. Since some studies[1] have found a disruption of discrimination performance attendant upon separation of discriminandum and manipulandum, if discrimination learning does involve learning to approach the positive cue, it might be expected that the separation of the positive cue object from its food well should produce the most marked impairment of discrimination performance.

Ettlinger, utilizing a standard WGTA and noncorrection technique

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[1]For example, (Meyer, Polidora and McConnell, 1961), using Rhesus monkeys found that a two-inch vertical separation of the cue from the response and reward location produced a twenty-percent decrement in performance when both positive and negative cues were separated from their former positions contiguous to the response and reward loci. A large number of trials was often necessary to demonstrate any learning under conditions of spatial separation.

found that spatial separation of the positive cue from its respective response and reward location produced the more marked decrement in performance, although the number of subjects used was insufficient to permit a meaningful statistical analysis.

A third important theoretical position in discrimination learning theory is that of the duoprocess theories in which two distinct learning processes are postulated, approach resulting from reward and avoidance resulting from nonreward. Many duoprocess theories also contend that these two processes have differential effects on learning. Spence (1936) is one of the theorists who has advanced a discrimination learning theory which generates quantitatively different predictions for the effects of reward and nonreward. More recently, Zeaman and House (1962) have advocated a duoprocess approach to learning theory. Using the ambiguous cue technique developed by Thompson (1954), Zeaman and House investigated the role of reward and nonreward in mentally retarded human subjects. In the ambiguous cue technique, there are three cue stimuli, A, B, and C. Stimulus A is paired with Stimulus B on one problem in which Stimulus A is paired with Stimulus B on one problem in which Stimulus A is positive. In a second problem, Stimulus A is paired with Stimulus C, but Stimulus A is now negative. Thus, over a series of problems Stimulus A has an ambiguous reward value, while all other stimuli are consistently associated with either reward or nonreward. In one series of experiments, Zeaman and House included another set of stimuli of consistent reward value, D and E. Subjects were confronted with a series of problems in which Stimuli A and B, A and C, and D and E were paired and presented in an alternating order. After a series of problems, the ambiguous Stimulus A or another stimulus novel to the subjects are paired with Stimulus D or Stimulus E. It was found that "....Substitution of a neutralized, ambiguous stimulus for either the positive or negative cue in an established two-choice discrimination causes only a slight decrement in performance regardless of whether it is the positive or negative stimulus which is replaced," (p. 372). Moreover, it was found that the effects were the same for a novel stimulus, although the decrement was more pronounced for a novel stimulus.

Over a series of similar experiments, Zeaman and House (1962) concluded that approach tendencies were formed more rapidly than avoidance tendencies early in learning, but that approach and avoidance tendencies have approximately equal strength in an established discrimination.

The theoretical position of D'Amato and Jagoda (1961) is similar to that of Zeaman and House in that they recognize the existence of both approach and avoidance types of learning in discrimination talks, but differs in that D'Amato and Jagoda emphasize the importance of avoidance learning over that of approach. In their rather novel approach to a theoretical explanation of discrimination learning, D'Amato and Jagoda contend that an animal in a maze, WGTA apparatus, or similar discrimination situation will exhibit approach tendencies corresponding to previous reward experiences, almost as unconditioned responses. Since this approach tendency already exists strongly, the real learning which takes place in the discrimination task is an intermittent checking of alternative, negative "solutions." In other words, D'Amato and Jagoda suggest that approach learning is almost a foregone certainty while avoidance learning of possible alternative behaviors constitutes the more important aspect of discrimination learning.

CHAPTER III

EXPERIMENT I

Subjects

Nine male and three female mature squirrel monkeys, _Saimiri sciurea_, which had been previously used in several discrimination learning experiments, served as subjects.

Apparatus

A modified small-scale WGTA apparatus was utilized. This consisted of a metal box, 30 in. long by 14 in. wide by 14 in. deep, divided into two compartments by a series of horizontal bars. One compartment housed the subject during the testing; the other compartment, which was the test area, was equipped with a single overhead 25-watt light source, a movable three-well test tray, and the stimulus objects and food-well covers. At the experimenter's end of the test area there was a one-way mirror, with a heavy black curtain at its base, which prevented the subject from observing the experimenter's movements but enabled the experimenter to observe the subject. The test tray measured 13½ in. wide by 9 in. long by 3/4 in. thick and the food wells were spaced 2½ in. apart and positioned 2½ in. from the edge of the test tray facing the subject.

Nine pairs of plywood placks measuring 2 in. wide by 5 in. long by 1/4 in. thick and painted flat gray were used as food-well covers. The placks may be thought of as divided into five one-inch square sectors (Sectors 1, 2, 3, 4, and 5). The first end-sector, Sector 1, covered the food well. A "junk" object of approximately 1 cu. in. in volume was centered in Sector 2. All objects were radially symmetrical so as to present an identical appearance when viewed from either side of the plack to which it was mounted. A plack was placed with Sector 1 covering a food well; Sector 2 immediately adjacent to that covering the food well was occupied by the "junk" object, while the remaining three sectors, Sectors 3, 4, and 5 extended laterally away from the food well. When revolved 180^{o} about the center sector, Sector 3, so that Sector 5 now covered the food well, the plack appeared to remain stationary but the object appeared to have been displaced laterally 2 in. along the surface of the plack. One of each pair of objects was assigned a positive reward value and the other a negative value.

Procedure

All subjects were given a three-day pretraining series in which they received one problem per day with a criterion of 15 correct choices out of 20 consecutive trials or until 60 trials had been given. Subjects were then divided into two groups of six subjects each, matched on the basis of their total error scores during the pretraining series.

Both groups then received one problem per day for the next six days, with both the positive and negative cue objects adjacent to the food wells as in the pretraining series. Immediately upon reaching criterion, one of the stimulus objects was rotated so that the object was displaced laterally 2 in. from its former position. For one group of subjects the positive cue was separated and for the other group the negative cue was separated. Subjects were then retrained to criterion while error measures and trials to criterion were recorded. Throughout all procedures, the noncorrection method was utilized and the spatial position of the rewarded object was governed by the Gellermann series. Dried currants were used as rewards.

Results

The total errors for each subject in the two groups is given in Appendix A. The groups which were matched on the basis of performance during pretraining differed in their preseparation performance during the next six test days. It was therefore decided that daily scores in the form of ratios of errors after separation to errors before separation would most accurately reflect the effect of the two treatments.

The mean of the six daily ratio scores was computed for each animal. The difference between the means of these mean ratios for the positive and negative separation groups was evaluated using student's *t*, (t=.497, df=10, p<.05). These means are presented in Table I.

TABLE I

MEAN NUMBER OF ERRORS AND MEAN RATIO OF ERRORS AFTER SEPARATION TO ERRORS BEFORE SEPARATION OF POSITIVE AND NEGATIVE CUES

Training Condition	Mean Score		
	Before Separation	After Separation	Ratio After/Before
Days 1-3 Pretraining			
Positive	6.8	- -	- -
Negative	7.5	- -	- -
Days 4-9 Test			
Positive	8.1	6.1	.75
Negative	6.3	3.0	.57

On the basis of ratio scores, which reflect the relative decrement in performance resulting from cue separation, no significant difference between the two separation conditions was observed.

An analysis of trials to criterion after separation failed to reveal any significant difference between the positive and negative spatial separation groups (t=.556, df=10, p<.05). Moreover, an analysis of the ratios of trials after to trials before separation also failed to yield a significant difference (t=.142, df=10, p<.05). Total and mean trials to criterion as well as mean ratio scores, collapsed over six problems, are given in Appendix B, for both the positive and negative separation groups.

CHAPTER IV

EXPERIMENT II

Since both groups in Experiment I showed a rather steady improvement from pre-separation to post-separation, there seemed to be considerable room for doubt as to the efficacy of the separation procedure in producing a disruption in discrimination performance. Consequently, it was decided to modify the experimental procedure and design an attempt to effect a disrupting separation procedure and to attain greater experimental control. Pilot work was done using a vertical separation between separate food-well covers and stimulus objects, but subjects failed to perform above chance levels under these conditions. Using long placks for food-well covers and moving the stimulus objects away from the subjects seemed to be a more promising approach. It was also decided to employ a design in which each subject served as his own control.

Subjects

The subjects used in this experiment were the same as those employed in Experiment I.

Apparatus

The apparatus used in this experiment was similar to that used in Experiment I. The test tray contained two food wells located 2 in.

apart and 2 in. from the front of the test tray. Since the food-well covers extended away from the subject, the subject was able to reach the end of the food-well covers but was prevented from handling the stimulus objects, thus eliminating tactile stimulation as a variable. The test tray, which was painted gray, was 13½ in. wide, 12 in. long, and 3'4 in. thick. Twelve wooden placks 1 in. wide, 5 in. long, and 1/4 in. thick, identically finished and painted gray, were used as food-well covers.

The food-well covers may be thought of as divided into five 1 sq. in. sectors, Sectors 1, 2, 3, 4, and 5. The food-well covers were placed perpendicular to the subjects' end of the test tray so that Sector 1 covered the food well and the remaining sectors extended behind Sector 1, away from the subject, during training. A radially symmetrical "junk" object of approximately 1 cu. in. in volume was centered in Sector 2. During the test phase, the food-well covers were turned 180° so that the stimulus object was apparently displaced two inches away from the subject to Sector 4.

Procedure

Three of the six object pairs were assigned to each subject; each object pair served the same separation condition for two subjects. Each subject received three conditions, one on each of three successive days, and the order in which the subjects received the three conditions was randomly determined with the restriction that two subjects receive each of the six possible orders. Subjects were trained to a criterion of 15 correct out of 20 consecutive trials, or until 60 trials had been given. Immediately upon reaching criterion subjects were subjected to the same procedure, with the same stimuli, but with either the positive, negative or neither stimulus object displaced 2 in. from its position adjacent to the food well and away from the subject.

The noncorrection procedure was used throughout the experiment. Dried currants were used for rewards.

Results

Total error scores and scores representing the ratios of errors after separation to errors before separation are given in Appendix C. The mean ratio scores of errors after to errors before separation were 1.19, 1.69, and 0.64, for the positive, negative and no separation conditions, respectively.

An analysis of variance of these ratio scores revealed significant differences in performance under the three conditions of separation (F=4.1016, df=2/22, p<.05).

TABLE II

ANALYSIS OF VARIANCE FOR MEANS OF RATIOS AFTER SEPARATION TO ERRORS BEFORE SEPARATION FOR POSITIVE, NEGATIVE AND NO SEPARATION CONDITIONS

Source of variation	Sum of squares	Degrees of Freedom	Mean square	F	$F_{.95}$
Total group	45.9	35			
Between subjects	13.9	11	1.27	1.19	
Between conditions	8.7	2	4.34	4.10	3.44
Error	23.5	22	1.06		

The greater decrement resulted from the spatial separation of the negative cue from its response and reward location. Separation of the positive cue from its response and reward location also produced a decrement in performance although this decrement was less marked than that produced by separation of the negative cue.

The average ratio scores for Experiment I, and Experiment II, are plotted in Fig. 1, which suggests that the separation method used in Experiment II, was more effective in disrupting discrimination performance than the method used in Experiment I.

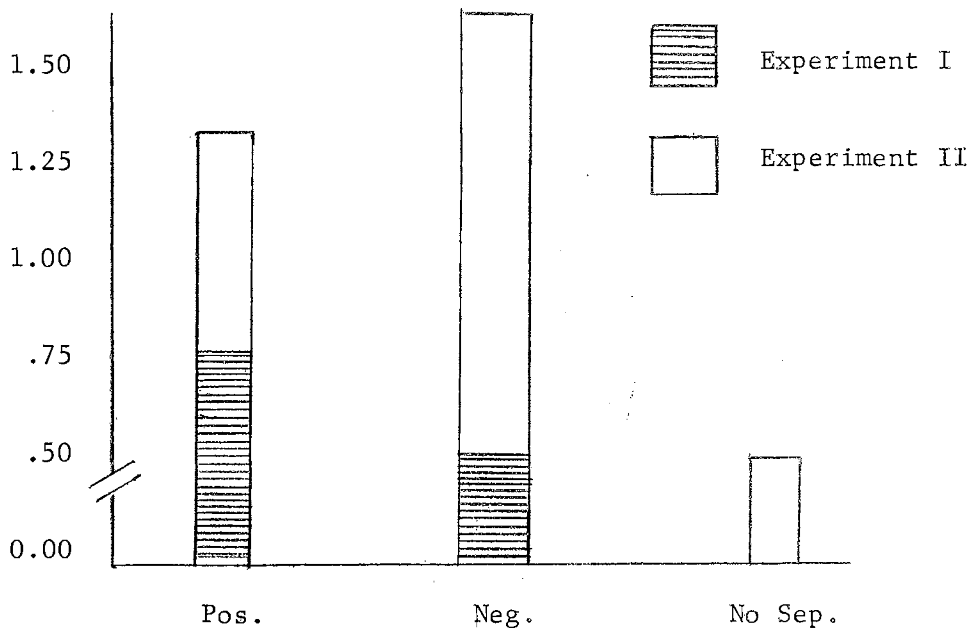

Fig. 1. Mean ratios of errors after to errors before separation for two separation conditions of Experiment I and three separation conditions of Experiment II.

In Experiment I, the subjects reached criterion with fewer errors in the post-separation phase than in the pre-separation phase, while in Experiment II, only the condition of no separation produced a ratio score less than one.

Analysis of trials to criterion using either the raw trial data or the ratios of trials after separation to trials before separation was complicated by the fact that many of the subjects reached criterion within the minimum of 20 trials, thus markedly skewing the distributions and violating the assumption of normalcy necessary for the analysis of variance. The error data, however, more nearly approximated normalcy. Nevertheless, analyses of variance were performed using the pre-separation, post-separation and ratio data. The analysis of trials to criterion before separation revealed no significant differences (F=1.749, df=2/22, p<.05).

TABLE III

ANALYSIS OF VARIANCE FOR MEANS OF TRIALS TO CRITERION BEFORE SEPARATION FOR POSITIVE, NEGATIVE AND NO SEPARATION CONDITIONS

Source of variation	Sum of squares	Degrees of Freedom	Mean square	F	$F_{.95}$
Total group	2735	35			
Between subjects	563	11	51.22	.60	3.44
Between conditions	298	2	149.29	1.75	
Error	1871	22	85.35		

However, the analysis of trials to criterion after separation revealed a significant separation effect. The means were 21.92, 32.17, and 20.08, for the positive, negative and no separation conditions, respectively, (F=9.568, df=2/22, p<.05).

TABLE IV

ANALYSIS OF VARIANCE FOR MEANS OF TRIALS TO CRITERION AFTER SEPARATION FOR POSITIVE, NEGATIVE AND NO SEPARATION CONDITIONS

Source of variation	Sum of squares	Degrees of Freedom	Mean square	F	$F_{.95}$
Total group	3125	35			
Between subjects	939	11	85.3	1.61	3.44
Between conditions	1018	2	509.0	9.59	
Error	1168	22	53.1		

The analysis of the ratios of trials after to trials before separation did not reveal any significant differences (F=0.82, df, 2/22, $p < .05$), but the distributions were markedly skewed because so many of the ratio scores equalled one.

TABLE V

ANALYSIS OF VARIANCE FOR MEANS OF THE RATIOS OF TRIALS AFTER SEPARATION TO TRIALS BEFORE SEPARATION FOR POSITIVE, NEGATIVE AND NO SEPARATION CONDITIONS

Source of variation	Sum of squares	Degrees of Freedom	Mean square	F	$F_{.95}$
Total group	8.78	35			
Between subjects	2.69	11	.224	.82	3.44
Between conditions	.07	2	.036	.13	
Error	6.02	22	.274		

CHAPTER V

DISCUSSION AND CONCLUSIONS

The results of Experiment I, were inconclusive because the method of spatial separation of cue and response-reward location employed apparently failed to produce any major disruption in discrimination performance. In Experiment II, the use of a control condition in which the same problem was presented twice in succession with no spatial separation provided a basis for gauging the effects of separation in the other two conditions. Fig. 1 clearly indicates that the separation procedure used in Experiment II did produce a substantial decrement in discrimination performance efficiency relative to a comparable task involving no separation.

The decline in discrimination performance in Experiment II, which occurred under both conditions of separation, failed to confirm Ettlinger's uniprocess excitation hypothesis. Rather, the results of this experiment are compatible with a duoprocess formulation which places greater emphasis on avoidance learning than approach learning in visual discrimination tasks (Cross, H. A., & Brown, L. T., 1965; D'Amato, M. R., & Jagoda, H., 1961).

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APPENDICES

APPENDIX A

Experiment I

TOTAL AND MEAN ERRORS TO CRITERION AND MEAN RATIO OF ERRORS AFTER TO ERRORS BEFORE SEPARATION FOR EACH MONKEY IN THE POSITIVE AND NEGATIVE SEPARATION GROUPS

Positive Separation Group

Monkey	1M	2M	4F	5M	6M	11M
Total Before	121	136	245	195	120	163
Total After	120	120	256	125	120	149
Mean Before	20.17	22.67	40.83	32.50	20.00	27.17
Mean After	20.00	20.00	42.67	21.83	20.20	24.83
Ratio After/Before	.29	.65	1.50	.35	.91	.79

Negative Separation Group

Monkey	5F	8M	9M	10M	12M	12F
Total Before	160	120	166	120	148	146
Total After	120	120	139	120	140	129
Mean Before	26.67	20.00	27.67	20.00	24.67	24.33
Mean After	20.00	20.00	23.17	20.00	23.33	21.50
Ratio After/Before	.51	.31	.86	.42	.59	.77

APPENDIX B

Experiment I

TOTAL AND MEAN TRIALS TO CRITERION AND MEAN RATIO OF TRIALS AFTER TO TRIALS BEFORE SEPARATION FOR EACH MONKEY IN THE POSITIVE AND NEGATIVE SEPARATION GROUPS

Positive Separation Group

Monkey	1M	2M	4F	5M	6M	11M
Total Before	121	136	241	195	120	163
Total After	120	120	256	125	120	149
Mean Before	20.2	22.5	22.0	32.5	20.0	21.2
Mean After	20.0	20.0	42.6	20.8	20.0	28.8
Ratio After/Before	.95	.92	1.15	.74	1.00	.92

Negative Separation Group

Monkey	5F	8M	9M	10M	12M	12F
Total Before	160	120	166	120	148	146
Total After	120	120	139	120	140	129
Mean Before	26.7	20.0	27.7	20.0	24.7	24.4
Mean After	20.0	20.0	23.3	20.0	23.3	21.5
Ratio After/Before	.79	1.00	.93	1.00	1.03	.89

APPENDIX C

Experiment II

TOTAL ERROR SCORES AND RATIOS OF ERRORS AFTER TO ERRORS BEFORE SEPARATION FOR POSITIVE, NEGATIVE AND NO SEPARATION CONDITIONS

	Positive			Negative			No Separation		
	B	A	A/B	B	A	A/B	B	A	A/B
1M	6	5	.83	6	3	.50	3	0	0.00
2M	4	5	1.25	3	0	2.44	1	0	0.00
4F	4	8	2.00	9	22	2.44	12	3	.25
4M	4	6	1.50	4	11	2.75	15	3	.20
5M	8	3	.37	19	10	.53	3	1	.33
5F	5	4	.80	13	10	.77	5	2	.40
6M	6	4	.67	2	6	3.00	5	3	.60
8M	3	4	1.33	1	6	6.00	7	3	.43
9M	4	9	2.25	24	25	1.04	5	5	1.00
10M	2	4	2.00	9	6	.66	1	2	2.00
12M	11	2	.18	12	15	1.25	1	1	1.00
12F	6	7	1.17	5	7	1.40	4	6	1.50

APPENDIX D

Experiment II

TOTAL TRIALS TO CRITERION AND MEANS OF RATIOS OF TRIALS AFTER TO TRIALS BEFORE SEPARATION FOR POSITIVE, NEGATIVE AND NO SEPARATION CONDITIONS

	Positive			Negative			No Separation		
	B	A	A/B	B	A	A/B	B	A	A/B
1M	21	20	.95	21	20	.95	20	20	1.00
2M	20	20	1.00	20	20	1.00	20	20	1.00
4F	20	27	1.35	25	52	2.15	31	20	.64
4M	20	26	1.35	20	35	1.75	44	20	.51
5M	25	20	.80	43	32	.74	20	20	1.00
5F	20	20	1.00	37	36	.97	20	20	1.00
6M	28	20	.70	20	21	1.05	20	20	1.00
8M	20	20	1.00	20	22	1.10	26	20	.80
9M	20	20	1.00	60	60	1.00	20	20	1.00
10M	20	20	1.00	25	20	.80	20	20	1.00
12M	28	20	.52	34	42	1.24	20	20	1.00
12F	23	22	.96	20	26	1.35	20	21	1.05

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