Comparison of three acceptance strategies: a progress report

Robert G. Potter, Frances E. Kobrin, and Raymond L. Langsten
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PREFACE

An earlier draft of this paper was prepared for the Ninth Summer Seminar in Population, held at the East-West Center, Honolulu, 12 June to 8 July 1978. The authors gratefully acknowledge the helpful comments and data they received from W. Henry Mosley and A.K.M. Alauddin Chowdhury and the computer programming of Irene Gravel. The research was supported by the Ford Foundation, NICHD grant #1 RO1 HD 12100-01 and National Science Foundation grant #SOC76-12342.
ABSTRACT  Three main classes of contraceptive acceptance strategy may be distinguished: "fixed duration T" (for women counselled to accept T months after childbirth); "postamenorrheic" (for those counselled to accept directly after the first postpartum menses); and "mixed T" (for those counselled to accept T months after childbirth or after the first menses, whichever occurs sooner). Any two strategies may be compared by means of a probability model simulating the first passage times from childbirth to next pregnancy of two cohorts of mothers identical in their fecundity and in the effectiveness and continuation with which contraception is practiced, but contrasting in their acceptance regimens. Relative efficiency is measured by mean intervals to next conception. Of particular interest is the class of mixed T strategies, which have only recently come under theoretical study. The efficiency of the mixed T rule at least equals, and usually exceeds, that of the corresponding fixed duration rule. Conditions for the superiority of the mixed T over the postamenorrheic rule are also given. Altogether, six generalizations are discussed and illustrated with reference to a Bangladesh subpopulation.

When is the best time after childbirth to initiate contraception in order to maximize the delay until next conception? If lactation is prolonged, postpartum anovulation becomes lengthy, sometimes averaging over 20 months, and highly variable from one woman to another (VanGinnekin, 1978). To commence contraception immediately after parturition has the advantage of eliminating any risk of conceiving before precautions are started, but carries the disadvantage of appreciable overlap between practice of contraception and anovulation when the woman is protected already. Moreover, this fraction of redundant contraception becomes greater the poorer is contraceptive continuation.

One conjectures that a more efficient acceptance strategy is made possible by the woman using her own knowledge of when she resumes menstruation. Three general strategies may be distinguished according to the extent to which this information is exploited. Exploiting it to the fullest is the "postamenorrheic strategy," which counsels the woman to defer starting contraception until right after her first postpartum menses. At the other extreme, any fixed duration strategy that enjoins the woman to wait some predesignated T months after childbirth before initiating contraception is ignoring awareness of when
menstrual function has returned. An intermediate set of rules is the "mixed \( T \) strategies," which prescribe starting contraception \( T \) months after childbirth or after the first menses, whichever occurs sooner.

Note that if \( T \) is made low, the mixed \( T \) and fixed duration \( T \) strategies become nearly identical. Indeed, if \( T \) is set at 1.0—the minimum length of postpartum anovulation—one has the "postpartum strategy" for which the mixed and fixed duration rules are identical. If \( T \) is made very large—i.e., \( T \) large enough to encompass most anovulatory lengths—the mixed \( T \) rule becomes for all practical purposes a postamenorrheic policy.

One might think that a postamenorrheic strategy would always be the most efficient. By waiting until her first postpartum menses, the woman is avoiding overlap with amenorrhea while at the same time she is using her first menstrual onset as an indicator that she is no longer protected. Unfortunately, more often than not (Perez et al., 1971), an ovulation precedes the first potential menses by about two weeks, meaning an unprotected month under the postamenorrheic rule. It is of practical interest to know under what conditions a mixed \( T \) rule might promise longer delays to next conception than the postamenorrheic.

It will be shown that under the assumptions being adopted and for \( T \) greater than the minimum length of anovulation, the mixed \( T \) is always more efficient than its fixed duration counterpart. Nevertheless, an administrative advantage attaches to fixed duration rules. If the date of a woman's confinement is known to program personnel, then the date when \( T \) postpartum months have elapsed is also known and reminders or home visitors can be sent if necessary. However, except under special circumstances of recurrent contact, the date of return of menses before duration \( T \) is not likely to be known to others so that entire reliance must be placed upon the woman herself to inaugurate precautions at the proper time. Of practical interest, then, is the amount of efficiency sacrificed when administrative considerations favor use of the fixed duration \( T \) rather than the mixed \( T \) strategy.

Though ideally such questions are answered with field experiments, in practice one has to substitute paired comparisons of hypothetical cohorts of postnatal women followed from childbirth through the postpartum anovulatory and fecundable periods to next conception. The two cohorts, simulated by a probability model of the Markov renewal type, are made identical with respect to fecundity and the characteristics of the contraceptive being practiced (i.e., effectiveness and continuation), while they differ only in their acceptance strategy.
Mean months added to the interval to next conception measures the relative efficiency of the two strategies.

In an earlier application of this approach (Potter and Masnick, 1971), optimal values of T for fixed duration strategies were investigated. A second analysis (Potter, Masnick, and Gendell, 1973) compared the efficiencies of the postpartum and the postamenorrheic rules. An improved and expanded algebra extending coverage to the mixed T strategies, a class not previously studied, is presented in Potter, Kobrin, and Langsten (1979) and is being applied through three computer programs, MIXEDT, FIXEDT, and POST. The main objective of this paper is to review findings to date. In the next two sections, assumptions of the model are enumerated and its parameters briefly discussed. Results and discussion follow.

ASSUMPTIONS

Each cohort of women is represented by a discrete-time, Markov renewal process designed to follow the women from a childbirth through anovulatory and fecundable periods to next conception. The women are homogeneous with respect to their fecundity and characteristics of their contraceptive; all probabilities—other than that of acceptance—remain constant over duration; and no durations are truncated. The time unit is one month, which all menstrual cycles are assumed to equal.

Amenorrhea and anovulation are measured in whole months. Amenorrhea is the interval from childbirth to first menses post partum. Anovulation extends from childbirth to start of the first ovulatory cycle. If the first menstrual cycle is anovulatory and the second ovulatory, then the two intervals, amenorrhea and anovulation, coincide. When the first menstrual cycle is ovulatory, with an ovulation preceding by roughly two weeks the first menses, amenorrhea exceeds anovulation by one month. It is assumed that the probability of the first cycle being ovulatory is λ, whereas the probability of amenorrhea and anovulation sharing the same length is 1−λ.

Women share a common probability distribution of anovulation <a_j>, j=1, 2, ... . They also share a common natural fecundability f, that is, monthly chance of conception when fecundable and not practicing contraception. During anovulation the monthly chance of conception is zero. During the last month of amenorrhea, it is f or 0 depending whether the first cycle is ovulatory or not.

Some additional assumptions simplify the algebra but scarcely affect results:
(i) women always initiate contraception near the start of a month;
(ii) they discontinue near the end of the month;
(iii) they conceive about the middle of the month;
(iv) if a woman has not accepted prior to conceiving, then the continuing absence of menses for more than two weeks after conception alerts her not to accept during the pregnancy.

A contraceptive is characterized by two parameters: its monthly discontinuation rate $d'$ and its effectiveness $e$, both parameters having the range of 0 to 1. During an anovulatory month the risk of discontinuation is $d'$. During a fecundable month, there is a probability $p = (1-e)f$ of accidental pregnancy, a risk $d = (1-p)d'$ of discontinuing for reason other than pregnancy, and a chance of $1-d-p$ of continuing usage into the next month. Thus "residual fecundability" $p$ is that fraction $(1-e)$ of natural fecundability $f$ left over from practicing contraception of effectiveness $e$.

After discontinuing contraception, a woman does not reaccept before the next pregnancy. To allow for reacceptance one may appropriately lower the discontinuation rate $d'$.

Another assumption is that any acceptance rule is followed scrupulously, all initiations of contraception being at prescribed times without procrastination or anticipation.

Efficiency is measured by the mean interval $M$ from childbirth to next conception, including into the average those women who conceive before the prescribed time for acceptance. An equivalent measure is the added months $\Delta$ to next conception over the duration to be expected in the absence of contraception.

PARAMETERS

As background for the results to be reviewed, it is worthwhile to comment briefly on the four parameters ($d'$, $e$, $f$, and $\lambda$) and the probability distribution $<a_i>$ that have to be specified.

Modern contraceptives such as the pill or IUD yield a high level of protection when in use (Tietze, 1970). Accordingly, the parameter $e$ will be set at .95, a high enough level so that unless continuation is lengthy ($d'$ small), accidental pregnancy is of secondary consequence.

As an experimental variable, the monthly discontinuation rate $d'$ will be taken in a broad range of values. Values of .0838, .0561, .0289, and .0119 correspond to expectations of 12, 25, 50, and 75 percent continuing at least two years. Values of .0289 and .0561 are representative of rates commonly reported from field programs. The
very high rate of .0838 has been measured for pill use in the Com-
paniganj area of Bangladesh (Langsten et al., 1978). At the other ex-
treme, .0119 corresponds to a higher level of continuation than is
likely to be attained in any large field program.

Respecting average levels of fecundability, .10 is low enough to sug-
gest an important role for temporary separations of spouses, .20 may
be construed as a medium value, whereas .30 is perhaps higher than re-
liably reported for any general population (Leridon, 1977).

The proportion of ovulatory first cycles is uncertain and little is
known about its pattern of variation. Direct measurements involve
endometrial biopsies, examination of cervical mucus, and like tech-
niques. Evidence that \( \lambda \) might be well over .5 at least for women who,
several months after childbirth, have reached the stage of supplement-
ing breast milk with other foods, is reviewed in Perez et al. (1971). A
more indirect approach is to ascertain the proportion of women be-
coming pregnant without an intervening menses. Interpreting this pro-
portion as the product \( \lambda f \), one needs in addition only an estimate of
mean fecundability \( f \) in order to infer the value of \( \lambda \). This approach ap-
plied to data from the Khanna Study (Wyon and Gordon, 1971) and
from the Matlab area (Chen et al., 1974) yields estimates close to .70,
a value which is assigned \( \lambda \) in the numerical exercises below.

The most problematic input is the probability distribution \(<a_j>\) of
anovulation. This distribution is affected by a number of factors. Most
important are the lactation customs of the population—the frequency
of breastfeeding at all and the lengths of “full” and “partial” nursing
when food supplements are first withheld and then later used to sup-
plement breastmilk. Together these lactational factors, possibly rein-
forced by variations of maternal nutrition, cause mean anovulation to
vary over a range of 2.5 to over 20 months.

A retrospective study permits one to calculate a mean and variance
of amenorrhea lengths; but it also tends to yield data subject to gross
heaping, usually on multiples of six months. A prospective design
yields less heaping; but because of limited duration, it affords only
percentiles for the first and middle portions of the distribution. Qual-
ity of interviewing determines the extent to which early onsets of
menstruation are distinguished from postpartum bleeding.

Only if the sample is screened to remove women who do not nurse
or who suffer an infant death is the distribution likely to be unimodal.
This unimodal case may be usefully represented by a modified Pascal
distribution having three parameters: one to control the minimum
length of anovulation and the other two to generate an appropriate
mean and variance. In the numerical application to be reviewed, based on Bangladesh data, the mean is taken at 23 months and the variance at 110. A mean of 23 may be considered very lengthy anovulation, 11 as medium, and six as short (for a sample composed wholly of lacta-
tors).

A heterogeneous sample typically yields a bimodal distribution. For example, the postpartum anovulation of nonlactators exhibits a mode at one month (Leridon, 1977), to which mothers suffering neo-
natal deaths also contribute. The anovulation of this subpopulation may be represented by a geometric distribution with origin at 1.0 and parameter 2/3, resulting in a predicted mean length of 2.5. The degree of bimodality is largely governed by the weight in the total sample of the minority of nonlactators and mothers suffering infant deaths.

MATHEMATICAL RESULTS

In the absence of contraception, the mean interval from childbirth to next conception equals mean anovulation plus the expected fecun-
dable months under natural fecundability: in symbols, \( \Sigma a_j + 1/f \).

Thus the net added delay to next conception contributed by contra-
ception is \( \Delta = M - \Sigma a_j - 1/f \). Several insights respecting \( \Delta \) are ob-
tained from study of the equations derived in Potter, Kobrin, and Langsten (1979). They are conveniently reduced to a set of six gen-
eralizations which are here enumerated and in the appendix discussed with the aid of formulas.

1. Even given effective contraception (\( e \) near 1), the absolute size of \( \Delta \) cannot be large unless continuation is good (i.e., small \( d' \)).

l.a. A corollary is that the subtraction from \( \Delta \) as a result of contraceptive failures cannot be large unless not only is \( e \) well be-
low 1.0 but the monthly discontinuation risk \( d' \) is also low.

2. The ranking among acceptance strategies depends on the respec-
tive proportions of mothers "benefiting" from contraception, that is, having their practice coincide with one or more fecundable months.

This proportion benefiting, \( P_f + P_x \), is composed of two elements, the proportion \( P_f \) who accept contraception while fecundable and the propor-
tion \( P_x \) who accept during anovulation but continue into the fe-
cundable period. Interestingly enough, parameter \( e \) does not figure in any of the expressions for \( P_f \) and \( P_x \), meaning that under the assump-
tions adopted, the ranking of \( \Delta \) among strategies is independent of the effectiveness of the contraceptive being practiced.

3. Conditions enhancing the relative efficiencies of the post-
amenorrheic and other high $T$ strategies are longer anovulation, lower natural fecundability, a lower frequency of ovulatory first cycles, and weak continuation. Conversely, favoring low $T$ strategies and the postpartum rule are shorter anovulation, higher natural fecundability, more frequent ovulatory first cycles, and good continuation.

4. For any $T$ greater than the minimum length of anovulation, the mixed $T$ is more efficient than its fixed duration counterpart; and this difference is augmented by a later prescribed time $T$, a higher natural fecundability $f$, or a lower proportion $\lambda$ of ovulatory first cycles.

5. For any given set of fecundity parameters—excluding sterility—there is a discontinuation risk $d'$ below which the mixed $T$ rule holds an advantage over the postmenorrheic rule. This minimal continuation standard becomes less stringent as fecundity parameters are made more favorable to low $T$ strategies.

6. Initiating contraception at all (instead of conceiving before the prescribed time for acceptance) may be selective of longer than average anovulation. This selection does not exist for the postpartum or postmenorrheic rules and is weak for any mixed $T$ rule. Under a fixed duration strategy, it is stronger the longer is anovulation, the higher is $T$, and the higher is natural fecundability. An important implication of this selectivity is that efficiency comparisons between a high $T$, fixed duration strategy and another rule can be badly biased in favor of the former when only the experience of acceptors is consulted instead of all postnatal women.

**NUMERICAL APPLICATION**

Owing to the recency of development of the three computer programs POST, FIXEDT, and MIXEDT, the only numerical application completed to date pertains to a rural area of Bangladesh served by the Cholera Research Laboratory (CRL). Here a field comparison of pill distribution under the mixed 6 and mixed 18 rules is being undertaken (Huber, 1977). This field study has created an interest in the relative efficiencies of the mixed 6 and mixed 18 not only relative to each other, but also relative to their fixed duration counterparts and to the postpartum and postmenorrheic strategies as low and high $T$ extremes.

Considered to be appropriate parameter assignments are $f = .10$, $d' = .0838$, $e = .95$, and $\lambda = .70$, sources for these estimates being cited in Langsten et al. (1978). Three progressively lower values of $d'$ are also investigated to gauge sensitivity to this factor. Adopted as a proba-
bility distribution of anovulation \(<a_j>\) is that modified Pascal distribution which most closely approximates a minimum length of two months, a mean of 23, and a variance of 110, in conformity with unpublished data kindly provided by A. Chowdhury from CRL files. The data derive from a sample of more than 1,000 lactators screened against infant deaths.

Selected results are gathered into Tables 1–3. Some preliminary observations about the consequences of the above parameter assignments are afforded by Table 1. Without any contraception at all, the expected interval to next conception is \(\Sigma a_j + 1/f\), or 33 months. If effectiveness of contraception is .95 and natural fecundability .10, then residual fecundability equals \(p = (1-e)\theta = .005\). Given such a low monthly risk of accidental pregnancy, the discontinuation rate \(d = (1-p)d'\) during a fecundable month (column [1] of Table 1) scarcely differs from an anovulatory month. That fraction \(P_f+P_x\) of postnatal women whose practice of contraception starts during, or extends into, the fecundable period has a probability \(d/(d+p)\) of ending that practice still fecundable and a probability \(p/(d+p)\) of ending it accidentally pregnant. Among the \(P_f+P_x\) benefiting from contraception, average lengths of contraceptive practice during the fecundable period if \(e = 1.00\), if \(e = .95\), and the difference between the two are tabulated in columns (4)–(6). When the discontinuation rate is high, accidental pregnancy plays a minor role, but it exercises a progressively larger influence as \(d'\) is lowered.

The figures in Tables 2 and 3 may be profitably considered with reference to the six generalizations enumerated in the previous section.

When \(d'\) is as high as .0838, \(\Delta\) remains small regardless of acceptance strategy. Indeed, in its range of .0838 to .0119, \(d'\) is a much more powerful factor than is acceptance strategy. The combination of long anovulation, low natural fecundability, and very high discontinuation—\(\Sigma a_j = 23, f = .10,\) and \(d' = .0838\)—plainly favors high \(T\) strategies. When the discontinuation rate is lowered, the proportion \(P_c\) conceiving before the prescribed time for acceptance is unaffected, but the proportion \(P_{18}-P_x\) whose contraception is entirely redundant is reduced. As a consequence, the \(\Delta\) ranking of strategies comes to depend more closely on relative values of \(P_c\). Since its \(P_c\) value is so high, the relative efficiency of the fixed duration 18 rule slips as \(d'\) is lowered. Contrariwise, the low \(P_c\) values of low \(T\) strategies assure that their relative efficiencies will ascend as continuation improves.

For \(T = 6\), the mixed and fixed duration strategies are hardly differ-
TABLE 1 Functions of the monthly discontinuation rate $d'$, given effectiveness $e = .95$ and natural fecundability $f = .10$

<table>
<thead>
<tr>
<th>Discontinuation rate $d'$</th>
<th>$d=(1-p)d'$ (1)</th>
<th>$d/(d+p)$ (2)</th>
<th>$p/(d+p)$ (3)</th>
<th>$1/d'$ (4)</th>
<th>$C$ (5)</th>
<th>Difference (4)-(5) (6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>.0838</td>
<td>.0834</td>
<td>.943</td>
<td>.057</td>
<td>11.9</td>
<td>10.7</td>
<td>1.2</td>
</tr>
<tr>
<td>.0561</td>
<td>.0558</td>
<td>.918</td>
<td>.082</td>
<td>17.8</td>
<td>15.6</td>
<td>2.2</td>
</tr>
<tr>
<td>.0289</td>
<td>.0288</td>
<td>.852</td>
<td>.148</td>
<td>34.6</td>
<td>28.1</td>
<td>6.5</td>
</tr>
<tr>
<td>.0119</td>
<td>.0118</td>
<td>.702</td>
<td>.298</td>
<td>84.0</td>
<td>56.3</td>
<td>27.7</td>
</tr>
</tbody>
</table>

NOTE: $C = 1/(d+p) - [p/(d+p)](1/f)$. (If $e = 1$, $C = 1/d'$.)

TABLE 2 Mean months $\Delta$ added to the interval to next conception by acceptance strategy and monthly discontinuation rate $d'$

<table>
<thead>
<tr>
<th>Acceptance strategy</th>
<th>Monthly discontinuation rate $d'$</th>
<th>.0838</th>
<th>.0561</th>
<th>.0289</th>
<th>.0119</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postpartum ($T=1$)</td>
<td></td>
<td>2.18</td>
<td>5.12</td>
<td>15.41</td>
<td>43.68</td>
</tr>
<tr>
<td>Fixed duration ($T=6$)</td>
<td></td>
<td>3.35</td>
<td>6.80</td>
<td>17.80</td>
<td>46.29</td>
</tr>
<tr>
<td>Fixed duration ($T=18$)</td>
<td></td>
<td>5.81</td>
<td>9.54</td>
<td>19.96</td>
<td>44.74</td>
</tr>
<tr>
<td>Mixed ($T=18$)</td>
<td></td>
<td>5.81</td>
<td>9.54</td>
<td>19.96</td>
<td>44.74</td>
</tr>
<tr>
<td>Postamenorrheic</td>
<td></td>
<td>10.00</td>
<td>14.53</td>
<td>26.17</td>
<td>52.46</td>
</tr>
</tbody>
</table>

NOTE other assumptions: $e = .95; f = .10; \lambda = .70; \text{and} \ p < a_j >$ as described in text.

TABLE 3 Correlates of efficiency, by acceptance strategy

<table>
<thead>
<tr>
<th>Acceptance strategy</th>
<th>$P_f+P_x$</th>
<th>$P_c$</th>
<th>$P_{a^*}P_x$</th>
<th>$\Sigma a_j^*$</th>
<th>$\Delta^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postpartum ($T=1$)</td>
<td>.203</td>
<td>.000</td>
<td>.797</td>
<td>23.00</td>
<td>2.18</td>
</tr>
<tr>
<td>Fixed duration ($T=6$)</td>
<td></td>
<td>.311</td>
<td>.001</td>
<td>.325</td>
<td>23.02</td>
</tr>
<tr>
<td>Mixed ($T=6$)</td>
<td>.312</td>
<td>.001</td>
<td>.325</td>
<td>23.01</td>
<td>3.38</td>
</tr>
<tr>
<td>Fixed duration ($T=18$)</td>
<td></td>
<td>.541</td>
<td>.133</td>
<td>.326</td>
<td>24.83</td>
</tr>
<tr>
<td>Mixed ($T=18$)</td>
<td>.650</td>
<td>.024</td>
<td>.326</td>
<td>23.24</td>
<td>7.63</td>
</tr>
<tr>
<td>Postamenorrheic</td>
<td>.930</td>
<td>.070</td>
<td>.000</td>
<td>23.00</td>
<td>11.43</td>
</tr>
</tbody>
</table>

NOTE assumptions: $d' = .0838; f = .10; e = .95; \lambda = .70; \text{and} <a_j>$ as described in text.

$P_f+P_x$ = proportion "benefiting from contraception."

$P_c$ = proportion conceiving before prescribed time of acceptance.

$P_{a^*}P_x$ = proportion whose practice of contraception starts and ends during anovulation.

$\Sigma a_j^*$ = mean anovulation among acceptors.

$\Delta^*$ = months added to interval to next conception by contraception among acceptors.
ent, owing to so few women resuming menstruation and conceiving within six months of childbirth. However, the mixed 18 holds an appreciable advantage over the fixed duration 18 on account of the latter's high $P_c$ value.

Given a mean anovulation as long as 23 months in combination with a relatively low natural fecundability of .10, even a monthly discontinuation rate as low as .0119 is not enough to unseat the postamenorrheic as the optimal strategy.

Among acceptors, mean length of anovulation (fourth column of Table 3) is unchanged from 23.0 under the postamenorrheic strategy and also under the postpartum rule (the latter because every postnatal woman is accepting). The selection toward longer anovulation is small except for the fixed duration 18 strategy. The non-negative difference $\Delta^* - \Delta$ is positively correlated with $P_c$ and $\Sigma a_i^*$, both of which are largest in the case of the fixed duration 18 convention. Note that while the mixed 18 is superior in efficiency to the fixed duration 18 rule with respect to $\Delta$ (Table 2), it is inferior with respect to $\Delta^*$ (Table 3), indicating the extent of bias possible if only the experience of acceptors is consulted.

**DISCUSSION**

The present paper has reported on the progress of an on-going project. Further work can go in at least four directions.

First and most obviously, the three computer programs FIXEDT, MIXEDT, and POST may be applied to other cultural contexts which together would cover a wide range of fecundities and calibres of contraceptive practice. The finding of such an advantage for high $T$ acceptance strategies over low $T$ ones has depended very much on the rural Bangladesh population in question having unusually long anovulation, a relatively low natural fecundability, and contraception characterized by a very high monthly rate of discontinuation. It may be anticipated that low $T$ strategies, and in particular the postpartum acceptance rule with its strong administrative advantages, will appear in a relatively more favorable light when compared with other strategies in settings of shorter anovulation, higher natural fecundability, and stronger contraceptive continuation.

Second, it is important to assess the short-range efficiencies of the various contraceptive acceptance strategies—that is, their cumulative pregnancy rates over the initial 12 or 18 months following childbirth—and not to confine attention, as has been done so far, to just the long-range efficiency that is measured by the expected mean duration to
next conception. The family planning administrator, concerned with lowering population birth and growth rates, might be chiefly concerned with long-run efficiency; but the field staff responsible for distributing the contraceptive will be sensitive to the incidences of early unwanted pregnancies. The algebra necessary to consider both aspects already exists (Potter, Kobrin, and Langsten, 1979). In rural Bangladesh, owing to such lengthy anovulation and low natural fecundability, the high \( T \) strategies suffer little disadvantage during the initial few months post partum and acquire an appreciable advantage by the end of 18 months. Given a setting of short anovulation and medium natural fecundability, the short-run advantage almost certainly would lie with low \( T \) strategies, whatever might be their comparative showing in the longer run.

Third, results obtained so far have depended on strong simplifying assumptions: (a) exact compliance with the prescribed acceptance times (i.e., no anticipation or procrastination); (b) homogeneous natural fecundability and homogeneous monthly discontinuation risks among couples; (c) no truncation effects from onset of secondary sterility; (d) no reacceptance of contraception before next conception after once discontinuing; and (e) no infant mortality or mixing of breastfeeding and bottle-feeding practices to yield a bimodal distribution of anovulation. An essential remaining task is to consider how well findings to date remain intact as various simplifying assumptions are relaxed. For instance, from preliminary work, it is hypothesized that the performance of the postpartum strategy relative to other contraceptive acceptance rules will be changed only insignificantly, or perhaps slightly improved, when assumptions (b) through (e) are relaxed.

Fourth, for family limiters, all further pregnancies are unwanted and may be usefully classified into three categories of failure according to their timing: “acceptance failure” (conception before prescribed start of contraception), “method failure” (conception during practice of contraception), and “client failure” (conception after discontinuing contraception). A clinic administrator may feel more responsibility to provide an abortion back-up in connection with acceptance and method failures than in relation to client failures. The present computerized models could be usefully extended to permit tracing the relative frequencies of the three types of failure as they vary among acceptance strategies and to permit assessments of the associated potential abortion loads. To implement this latter assessment would require an additional assumption about the time flow of new clients at risk of failure.
APPENDIX

The six generalizations enumerated in the text may be justified by several formulas taken from Potter, Kobrin, and Langsten (1979), which are given here without proof. The basic formula for $\Delta$, applicable to all three sets of strategies, is

$$
\Delta = (P_f + P_x) \left( \frac{1}{d+p} - \frac{p}{d+p} \left( \frac{1}{f} \right) \right) = (P_f + P_x) C.
$$

(1)

Clearly, with $0 < P_f + P_x < 1.0$, $\Delta$ can be large only if $C$ is large, which requires that $e$ be close to 1.0, thereby assuring a small $p$, and that $d'$, and therefore $d = (1-p)d'$, be small. In confirmation of generalization 1.a, months subtracted from $\Delta$ as a result of contraceptive failures, or

$$
L = (P_f + P_x) \left( \frac{p}{d+p} \right) \left( \frac{1-d'}{d'} + \frac{1}{f} \right),
$$

(2)

can be sizable only when $d'$ is small and $e$ low enough to raise $p = (1-e)f$ to the same order of magnitude as $d$.

Corroborating generalization 2, formula (1) makes explicit the proportionality between $\Delta$ and the proportion $P_f + P_x$ benefiting from contraception.

Respecting generalization 3, it is convenient to evaluate the complement of $P_f + P_x$, namely,

$$
1 - (P_f + P_x) = P_c + (P_\alpha - P_x).
$$

(3)

Here $P_c$ signifies the proportion of women who conceive before the time prescribed for acceptance; $P_\alpha - P_x$ denotes the proportion of postnatal women who accept during anovulation and discontinue before its end. Explicit expressions are

$$
(P_\alpha - P_x) + P_c = \lambda f,
$$

(4)

$$
= \sum_{j=T+1}^{\infty} a_j [1 - (1-d')^{j - T}] + \sum_{j=1}^{T-1} a_j [1 - (1-f)^{T-j}] + \sum_{j=1}^{T-1} a_j \left( \frac{T-1}{j+1} \right) - \sum_{j=T+1}^{\infty} a_j [1 - (1-d')^{j - T}] + \lambda f \sum_{j=1}^{T-1} a_j;
$$

(5)

respectively for the postamenorrheic, the fixed duration $T$, and the mixed $T$ rules. Note that none of the expressions (4) to (6) involves
the parameter $e$, proving the independence of $P_f + P_x$ from effectiveness of contraception.

Let that value of $T$ which maximizes $P_f + P_x$ for the class of fixed duration strategies be denoted $F_{T_{\text{MAX}}}$. $F_{T_{\text{MAX}}}$ varies as a function of parameters $d', f$, and $<a>$, though not $e$ or $\lambda$. $M_{T_{\text{MAX}}}$, signifying that $T$ value maximizing $P_f + P_x$ for the class of mixed $T$ strategies, is a function of $d', f$, $<a>$, and also $\lambda$. A very high $M_{T_{\text{MAX}}}$ value is implied whenever the postamenorrheic is found to be optimal policy.

It follows from equation (4) that for the postamenorrheic rule, $P_f + P_x$ is raised only through a lower $f$ or lower $\lambda$.

The behavior of $P_f + P_x = 1 - P_c - (P_\alpha - P_x)$ is not quite so simple for the fixed duration and mixed $T$ rules. Suppose $T$ is incremented in steps of one month starting with $T=1$. Then as $T$ rises to a high value, $P_c$ climbs from 0 to 1.0; meanwhile $P_\alpha - P_x$ declines from some initial maximal value of $1 - P_x$ at $T=1$ to 0. Any condition that decelerates the rise of $P_c$ conduces to a higher $F_{T_{\text{MAX}}}$ or $M_{T_{\text{MAX}}}$. Correspondingly, any condition increasing the initial level of $1 - P_x$ and therefore the amount that $P_\alpha - P_x$ may fall, has the same effect. Favoring a slower climb of $P_c$ is a lower $f$, lower $\lambda$, and longer anovulation. Augmenting the value of $1 - P_x$ at $T=1$ is longer anovulation and a higher discontinuation rate $d'$. Actually, study of formulas (4) to (6) indicates that for the above assertions to be rigorous it is necessary to impose restrictions on the $a_j$ terms that are operating as weights. A sufficient set of restrictions is that $<a>$ be unimodal and have a rising hazard function, by which is meant that the conditional probability of resuming ovulation during a month if still anovulatory at its start must be rising with increasing duration $j$. One such distribution is the modified Pascal, utilized above.

The lesser efficiency of fixed duration $T$ strategies as compared with mixed $T$ counterparts depends on the difference

$$FP_c - MP_c = \sum_{j=1}^{T-1} a_j [(f + (1-f)f + ... + (1-f)^{T-j-1}f) - \lambda f] ,$$

the $P_\alpha - P_x$ terms being identical for the two strategies. Evidently the gap between $P_c$ values increases with higher $f$ or higher $T$ or, fixing $T$, with shorter anovulation. It may also be argued that $M_{T_{\text{MAX}}} \geq F_{T_{\text{MAX}}}$. While the mixed and fixed duration strategies share the same $P_\alpha - P_x$ term as a function of $T$, $P_c$ as a function of $T$ rises less rapidly for the mixed strategy than for the fixed duration and therefore $M_{T_{\text{MAX}}}$ should be at least as large as $F_{T_{\text{MAX}}}$.

In the case of the postamenorrheic strategy, $P_\alpha - P_x = 0$, though
$P_c = \lambda f$. In order for the mixed $T$ to be more efficient than the post­amenorrheic, the disadvantage reflected in its nonzero $P_a - P_x$ term must be less than its advantage with respect to the proportion $P_c$. That is, it is required that

$$\sum_{j=T+1}^{\infty} a_j (1 - (1 - d')^{j-T}) < \lambda f (1 - \sum_{j=1}^{T-1} a_j),$$

equivalent to

$$\lambda f > \frac{\sum_{j=T+1}^{\infty} a_j (1 - (1 - d')^{j-T})}{\sum_{j=T}^{\infty} a_j},$$

an inequality most likely to be satisfied under conditions favoring low $T$ strategies, namely, high $\lambda$, high $f$, short anovulation, and low $d'$. No selection toward longer than average anovulation occurs among acceptors under the postamenorrheic rule because the probability of conceiving before acceptance, $\lambda f$, is the same for all anovulatory lengths. Under the fixed duration $T$ rule, the probability distribution, $<a_j^*>$, of anovulation among acceptors is

$$a_j^* = (1-f)^{T-j} a_j / P_a \quad j = 1, 2, ..., T-1$$

$$= a_j / P_a \quad j = T, T+1, ...$$

with $P_a = 1 - P_c$

and $P_c = \sum_{j=1}^{T-1} a_j (1 - (1-f)^{T-j})$.

Clearly, the selection toward longer anovulation is enhanced by either a higher $T$ or higher $f$. The corresponding probability distribution for the mixed $T$ rule, betokening a much weaker selectivity, is

$$a_j^* = (1 - \lambda f) a_j / P_a \quad j = 1, 2, ..., T-1$$

$$= a_j / P_a \quad j = T, T+1, ...$$

with $P_a = 1 - P_c = 1 - \lambda \sum_{j=2}^{T-1} a_j$. 
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