# INCOME ALTERS THE RELATIVE REINFORCING EFFECTS OF DRUG AND NONDRUG REINFORCERS

Marilyn E. Carroll

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**ABSTRACT**

Income is defined as the amount of funds, resources and/or time allowed to obtain goods over a specified period of time. This review discusses laboratory studies of income using methods of behavior analysis, behavioral pharmacology and behavioral economics. Initially, income was studied with respect to consumption of two types of the same good (e.g., food or drug), and later comparisons were made between food and nonfood rewards as well as drug and nondrug rewards. A consistent finding in these studies is that preferences between two goods change and often reverse as income is changed from low to high. Thus, reinforcing effects are not inherent in the goods, but they depend on the economic context (income, price of good, availability of substitutes). Another economic variable that has shown considerable impact on drug-reinforced behavior is the availability of nondrug alternative reinforcers which seem to function as economic substitutes. The present review also examines the interaction of income variables with price of drug (ethanol and phencyclidine) and availability of nondrug alternatives. It was concluded that price and availability of nondrug alternatives are major determinants of drug intake. Changes in income dramatically alter preference between drug and nondrug items; however, income has a greater effect on consumption of nondrug alternatives than on drug intake. It was concluded that the optimal formula for reducing/preventing drug intake would be low income, high drug price and availability of inexpensive alternative nondrug reinforcers.

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Income is an important factor to consider in evaluating demand for drugs. Income is defined as the amount of funds, resources, and or time (or number of opportunities) allowed to obtain goods over a specified time period. The income variable becomes especially interesting when considering how resources (income) are apportioned over various consumer choices. Income can change the choice between two reinforcers depending on the price of those goods (Lea et al., 1987). This paper will focus on how income affects choices between drug and alternative nondrug substances. Several assumptions are made; such as, 1) drugs function as reinforcers for operant behavior and can be studied by methods of behavior analysis, behavioral pharmacology and behavioral economics, 2) principles derived from these three methods of behavior analysis apply to animals and humans in similar ways (Carroll and Rodefer, 1993; Carroll et al., 1995; DeGrandpre et al., 1993; Johanson, 1978; Griffiths et al., 1981), 3) animal and human behavioral economic models have validity in epidemiological findings (Bickel and DeGrandpre, 1995), in human laboratory studies (Bickel and DeGrandpre, 1995,1996) and in treatment approaches (e.g., Higgins, 1997; Bickel and DeGrandpre, 1996), and 4) drug reinforcers are affected by income in the same way as nondrug reinforcers (e.g., food) indicating that income effects are guided by general principles.

A number of laboratory studies have demonstrated effects of income on food choice in animals. For example, Silberberg et al. (1987) allowed monkeys to work for food and varied income by changing the intertrial interval (ITI) from 60-70 sec for low income to 15 sec for high income. When monkeys were given a choice between large bitter food pellets and small standard food pellets, their choice was for large bitter pellets when income was low and it shifted to small standard pellets when income was high. The devaluation of the large bitter pellets (decreased consumption) as income increased indicated that they were an inferior good. In contrast, the small standard pellets would be considered a normal good because their consumption increases at the same percentage rate as income increases. The income elasticity would be equal to 1. This experiment was replicated in rats by Hastjarjo et al. (1990) extending the finding to another species. Hastjarjo and Silberberg (1992) also extended their results in rats from qualitative differences between different sized reinforcers to a choice between size and delay of reinforcer delivery, using the same type of food. Thus, the choice was between one food pellet presented immediately or three pellets presented after a delay (e.g., 10 sec). Income was varied by offering approximately 60 free-choice sessions in the low income condition and 100 free-choice sessions in the high income condition.

Parallel experiments have recently been conducted in human subjects given a choice between their own brand of higher-price cigarettes vs. a nonpreferred brand of lower-priced cigarettes (DeGrandpre et al., 1993). Income was varied by the amount of money ($1 - 15) allocated to the subjects to spend during the experimental session. As in the Silberberg et al. (1987) study, at low income conditions subjects preferred the less expensive other brand to their own brand. However, when income was high, the preference was reversed and the more expensive own brand was preferred. Thus, the own brand appeared to be a normal good and the other brand was functioning as an inferior good. Inferior goods' consumption falls as income rises. These studies illustrate that goods are not endowed with certain properties that are inherently reinforcing, but that the reinforcing effects of these goods are dependent upon the economic context in which they are presented (e.g., availability of other choices, income).

Shurtleff and coworkers (1987) examined the effects of income on choice between food and a noncaloric reinforcer (saccharin) in rats. Income was altered by changing the reinforcement rate from 36 to 240 per hour. When income was low, food was preferred to saccharin, and when income was high the preference was reversed to favor saccharin. They suggested that their results may be explained by the minimum needs hypothesis (Kagel et al., 1985) which states that goods are ranked based on how much they are needed for bodily functions. Satiation may occur at different rates for different goods. Thus, preference may have switched from food to saccharin because the nutritional need for food was satiated before the hedonic need for saccharin or a palatable taste was satiated.

Only a few studies have investigated the effect of income on choice between drug and a nondrug reinforcer. An early study by Elsmore et al. (1980) manipulated income by changing the ITI (2 to 12 min) and maintaining a constant session length. They offered baboons a choice between self-administered heroin injections and food, each presented at constant magnitudes. In this study there was a closed economy for food and heroin (i.e., the daily food and heroin supply were earned within the experimental session). The income elasticities for both drug and food were positive, but because the income elasticity for food was greater than that for heroin, under low income conditions there was a relative preference for food under low income conditions and for heroin under high income conditions.

The comparison of drug self-administration and consumption of nondrug reinforcers was continued in two studies in rhesus monkeys in which income was varied by changing session length (20, 60 and 180 min) (Carroll and Rodefer, 1993; Carroll et al., 1995). Either orally delivered phencyclidine (PCP), a dissociative anesthetic, (Carroll and Rodefer, 1993) or ethanol (Carroll et al., 1995) were available under concurrent fixed-ratio (FR) schedules with saccharin or water . A fixed ratio is the ratio of the number of required responses for one reinforcement. For example, a fixed number (4, 8, 16, 32, 64 or 128) lip-contact responses on solenoid-operated drinking spouts were required for the delivery of 0.6 ml of liquid. Variation of the FR allowed for price changes and construction of demand curves. Drug and saccharin concentrations were held constant. Table 1 summarizes the design of these experiments. Since drug and saccharin were available only during the experimental session, a closed economy was used for these goods; however, water was freely available during the intersession period or under an open economy; thus, the animals were not liquid deprived.

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Table 1 here

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The results of these studies showed that PCP, ethanol and saccharin were functioning as reinforcers because behavior maintained by these substances greatly exceeded that maintained by the vehicle, water. Water data are not shown in succeeding figures because intake was very low and did not vary systematically with the experimental manipulations. The effect of saccharin on the demand for PCP is shown in the upper frames of Figure 1.

There was a reduction in PCP deliveries (left frames) at all FR and income conditions when saccharin (filled symbols) vs. water (open symbols) was concurrently available. This is consistent with previous studies of the effects of saccharin on PCP-reinforced behavior (Carroll, 1985; Carroll et al., 1991). These differences were more apparent when plotted as responses over the range of FR values (right frames). $P_{max}$ values were calculated as estimates of the price (FR) at which maximum responding occurred (Hursh, 1991). The equation for determining $P_{max}$ is stated in the logarithmic units of price (P) and consumption (Q): $\ln (Q) = \ln (L) + b [\ln (P)] - a (P)$. L is the initial level of demand at minimal price, b is the initial slope of the demand curve with increases in price. $P_{max}$, or price yielding maximal response output, is: $P_{max} = (1 + b)/a$. The $b$ parameter is usually negative and near zero, thus elasticity changes are expressed as changes in a. Level shifts or movements of the entire curve up or down on the y-axis are seen as changes in the L parameter. This equation accounts for 90-99% of the variance in consumption in studies analyzed thus far (Hursh, 1991; Hursh et al., 1988, 1989). Under the three income conditions $P_{max}$ was shifted to the left.

Table 2 indicates that $P_{max}$ increased only slightly but nonsignificantly with income, but the magnitude of the leftward shift was relatively constant regardless of income level. Overall, income had little interaction with saccharin's suppressant effects on PCP intake. Similar findings occurred when this experiment was replicated with ethanol and saccharin or water was concurrently available under the same FR and income conditions (Carroll et al., 1995, Figure 1, lower frame, Table 1). Figure 2 shows the same parallel shift downward of the ethanol demand curves and leftward shift of the $P_{max}$ values due to concurrent saccharin as were discussed for PCP.

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Figure 1 here

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Figure 2 here

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Table 2 here

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The effects of income are illustrated in Figure 3 represented in Engel curves (1972) in which consumption is plotted as a function of income. As income increased, consumption increased. The reduction in responding at low income became more pronounced as the FR increased. Table 3 shows the percent reductions in PCP and saccharin deliveries as income decreased from the highest (180 min) to the lowest (20 min) level. Saccharin intake was much more dramatically affected by income than PCP and ETOH intake under all FR values. In many cases the reduction in saccharin intake was nearly twice that of the drug. Reduction in drug intake due to reduced income did not vary consistently under the concurrent water vs. concurrent saccharin conditions. However, the consistent relationship between FR and income is apparent from the increased percent reductions in drug intake as FR increased.

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Figure 3 here

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Table 3 here

The effect of income on the relative preference for drug and saccharin is illustrated in Figure 4. Income elasticities for both drug and saccharin were positive, but since the slopes were different the curves crossed, revealing different relative preferences as a function of income. Data for all FRs are presented for the conditions in which either PCP (left panels) or ETOH (right panels) was concurrently available with saccharin. Saccharin was always available under FR 32. Data with concurrent water are not presented as water intake was negligible and did not change with income. At the FR 4 and 8 conditions (upper left) PCP (striped bars) and saccharin (open bars) were consumed in equal amounts under the 180-min income condition; however, as income was reduced to 20 min, PCP deliveries were almost four times as high as saccharin deliveries. At FRs 16 and 32 saccharin deliveries were nearly twice as high as PCP deliveries at the high income level, but this preference was completely reversed at the low income level (center left). At FRs 64 and 128 PCP deliveries were very low compared to saccharin deliveries, but the magnitude of the saccharin preference decreased substantially as income decreased (lower left).

The relationships between income and ETOH vs. saccharin preference were similar to those described for PCP. At FRs 4, 8 and 16 saccharin (open bars) was preferred to ethanol (striped bars) at the high income level, but the preference was reversed at the low income level. At FRs 32, 64 and 128 ethanol intake was low and saccharin was preferred at all income levels, although the magnitude of the saccharin preference diminished with decreased income. Overall, saccharin intake was lower in the ethanol study. This was not due to the effects of ethanol because at FR 128 there was little ethanol intake. It may have been due to intrasubject variabillity, although 5 of the 8 monkeys participated in both studies.

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Figure 4 here

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Individual monkey data that have been reported previously (Carroll et al., 1995, Figure 4) illustrate the time course of responding and development of preferences for ethanol or saccharin under different income levels. In general, there was a trend for the ethanol-reinforced responding to be completed during the first 20 minutes of the session regardless of session length. However, saccharin drinking continued at a fairly steady rate and did not begin to level off until about 120 min. Thus, the saccharin preference that emerged under most income conditions was due to sustained saccharin drinking for a longer time rather than more rapid saccharin drinking. Individual cumulative intake data for PCP and saccharin showed a similar pattern. These data suggest that the direct effects of PCP or ethanol on drug-maintained behavior were minimal, as monkeys were able to continue responding for saccharin long after drug intake had stopped

In Figure 5 PCP, ethanol and saccharin consumption are plotted (all under FR 32 conditions) as a function of income to determine whether drug and saccharin are normal or superior goods. As income increases, the percentage increase in intake of a superior good occurs at a rate that is greater than the percentage increase in income. Drug and saccharin consumption are plotted against the ideal curves (dotted lines) that would be expected if increases in intake were proportional to increases in income. With both PCP and ETOH under most FR conditions the drugs functioned as normal goods. Intake increased with income, but under many conditions increases in intake were proportionally less than increases in income. When saccharin was available with PCP it appeared to function as a slightly superior good, as increases in intake were proportionally greater than income.

Figure 5 here

When comparing the reinforcing effects of PCP or ETOH and saccharin, there are some data that suggest the drugs are more efficacious reinforcers than nondrug substances. For example, when income was decreased from 180 to 20 min the proportional (percent) reductions in drug intake were less than those found with saccharin intake. Also, although the saccharin FR was not manipulated in the income studies, it was changed across the same range of FRs in a previous study (using a 180 min session) with the ratio of price to quantity the same for each commodity. The negative slope of the demand curve for saccharin was greater (-7.8) than that for PCP (-3.6) (Carroll et al., 1991) or ethanol (-2.3) (Carroll and Rodefer, 1993) suggesting that saccharin was a more elastic and less efficacious reinforcer than the drugs. Finally, saccharin intake was more vulnerable than drug intake to decreases in income. When income was reduced from 180 to 20 min the relative preference for drug vs. saccharin was reversed, and drug intake exceeded saccharin intake at the low FRs. Silberberg et al. (1987), suggests that superior goods are like luxuries while normal goods tend to be necessities, and this is consistent with previous findings that elasticity of demand for luxury items is greater than for necessities.

In contrast, there are data that suggest that saccharin is the more efficacious reinforcer, such as higher intakes under the higher income conditions and equal FR (FR 32) conditions. It can also be argued that saccharin intake increased more readily with increases in income, and under some conditions saccharin functioned as a superior good. These differences may be related to different rates of satiation for a commodity that satisfies the need of a drug-dependent individual vs. a commodity that fulfills some hedonic need.

The clinical relevance of using alternative nondrug reinforcers for prevention and treatment of drug abuse is that they may substitute for drug reinforcers and maintain alternative lifestyle patterns that are incompatible with drug-taking. The drug-saccharin-income data also provide some quantitative evidence of substitution using behavioral economic measures. Substitution occurs when as the price of one good (e.g., drug) increases and consumption shows corresponding decreases, intake of another fixed-price good (e.g., saccharin) increases. Figure 6 shows saccharin deliveries as a function of increases in PCP or ETOH price (FR 4, 16, 64) for the three income levels.

Under all conditions there was a positive slope indicating substitution of saccharin for drug. Slopes are indicated in parentheses, and with both PCP and ethanol, the slopes increased with increases in income. However, with the exception of the 60 and 180 min income conditions with PCP, the slopes were less than 1. Thus, the substitution effect was relatively weak under most conditions.

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Figure 6 here

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Overall, it appeared that income is a major economic variable affecting drug-rewarded behavior. Decreasing income reduced intake of both drug and nondrug reinforcers. However the effect was much greater on the nondrug reinforcer. This differential response to lowered income resulted in a change in preference from the nondrug item to drug as income was reduced. Thus, income changes can reveal the relative reinforcing strength of drugs vs. nondrug substances. These results were consistent with a report of Shurtleff and coworkers (1987) who found a saccharin/food preference reversed to a food/saccharin preference at low income, and the data suggest that drug is functioning as a necessity like food. The results from the PCP and ETOH vs. saccharin studies described here were not in agreement with the Elsmore et al. (1980) data which showed preference for nondrug (food) at low income and drug at high income. This may have been due to the fact that in the Elsmore et al. (1980) study food was presented in a closed economy; and food was the necessity while heroin was the luxury. In the drug-saccharin studies food was available postsession or in an open economy while drugs were available only during session (closed).

Differences between these studies may have been due to the closed vs. open economies, dose levels, unit prices of food vs. drug or the specific pairs of commodities that were offered. Intake of the drugs (e.g., ETOH, heroin, PCP) as well as the dietary substance (food, saccharin) all increased as income increased indicating they were normal goods or in the case of saccharin, possibly a superior good. In contrast, in studies that used different forms of the same commodity such as food Hastjarjo et al., 1990; Hastjarjo and Silberberg, 1992; Silberberg et al., 1987) or cigarettes (DeGrandpre et al., 1993) one substance emerged as a normal good and the other as an inferior good (intake decreased as income increased). Further work is needed to determine the economic characteristics of the nondrug alternatives (e.g., inferior, normal, vs. superior, elasticity of demand) that are optimal for reducing drug self-administration.

Changing income also had effects on economic variables that were previously found to alter drug self-administration. For example, decreasing income reduced the intensity of demand for ethanol (Carroll and Rodefer, 1995) and PCP (Carroll et al., 1993). Another effect was the interaction of income with the unit price for drug. Lowering income produced a greater suppression in drug intake when the price of drug was high compared to when it was low. Income did not interact, however, with the suppressant effect of an alternative nondrug reinforcer (saccharin) on drug intake. Concurrent saccharin (vs. water) reduced the unit price at which maximum PCP- (Carroll et al., 1993) and ethanol- (Carroll and Rodefer, 1995) - reinforced responding occurred, but the magnitude of these shifts was similar at all income levels.

As shown previously (Carroll, 1985; Carroll et al., 1991) saccharin dramatically reduced drug intake, and this effect was proportionally greater at the higher FRs or unit prices. The overall effect of saccharin was to reduce the intensity of demand for drugs. As reported earlier (Carroll et al., 1991; Comer et al., 1994) saccharin appeared to function as an economic substitute for PCP. It should be noted that substitution effects have not been large in these studies possibly due to the fact that at the relatively low fixed-prices used for saccharin (e.g., FRs 16, 32) a ceiling effect occurred. Thus, alternative nondrug reinforcers as well as income manipulations are variables with considerable impact on drug-reinforced behavior; however, these variables appear to function independently. Income dramatically affects saccharin intake, reducing it by 80-90 percent when changes are made from high to low income. However, it should be noted that even when only small amounts of saccharin were consumed, the reduction in concurrent drug intake was similar to when greater amounts of saccharin were consumed when income was high. This finding is consistent with an earlier report in which the FRs for concurrent PCP and saccharin were both varied instead of keeping saccharin at a fixed price (Carroll et al., 1991). The resulting suppression of the PCP demand curve was the same regardless of whether saccharin intake was low due to FR increases or remained high at the fixed price.

In conclusion, the choice between a drug and nondrug reinforcer is highly dependent on the prevailing economic context. Choice will be affected by unit price of the different commodities. Changes in income may also dramatically alter the relative preference for drug and nondrug reinforcers, although income has a relatively small effect on total drug intake (Carroll et al., 1993; Carroll and Rodefer, 1995; DeGrandpre et al., 1993). The optimal economic conditions for reducing drug intake are: low income, high drug price, and most important, the availability of an alternative nondrug reinforcers.

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**Table 1. Income Study Design**

| | | FR Value | | | | | |
|---|---|---|---|---|---|---|---|
| Low Income (20 min) | PCP or ETOH | 4 | 8 | 16 | 32 | 64 | 128 |
| | vs. | | | | | | |
| | Water | 32 | 32 | 32 | 32 | 32 | 32 |
| | PCP or ETOH | 4 | 8 | 16 | 32 | 64 | 128 |
| | vs. | | | | | | |
| | Sacc | 32 | 32 | 32 | 32 | 32 | 32 |
| Medium Income (60 min) | PCP or ETOH | 4 | 8 | 16 | 32 | 64 | 128 |
| | vs | | | | | | |
| | Water | 32 | 32 | 32 | 32 | 32 | 32 |
| | PCP or ETOH | 4 | 8 | 16 | 32 | 64 | 128 |
| | vs | | | | | | |
| | Sacc | 32 | 32 | 32 | 32 | 32 | 32 |
| High Income (180 min) | PCP or ETOH | 4 | 8 | 16 | 32 | 64 | 128 |
| | vs | | | | | | |
| | Water | 32 | 32 | 32 | 32 | 32 | 32 |
| | PCP or ETOH | 4 | 8 | 16 | 32 | 64 | 128 |
| | vs | | | | | | |
| | Sacc | 32 | 32 | 32 | 32 | 32 | 32 |

Saccharin (Sacc) vs. water counterbalanced

FR given in mixed order

PCP study preceded ETOH study

**Table 2. $P_{max}$ Values Under Conditions of Concurrent Saccharin or Water Availability and Income Level.**

| | Income Level (min) | $P_{max}$* | |
|---|---|---|---|
| | | with saccharin | with water |
| PCP | 20 | 23.55 | 34.25 |
| | 60 | 26.32 | 58.29 |
| | 180 | 40.07 | 61.6 |
| ETOH | 20 | 32.52 | 52.26 |
| | 60 | 37.66 | 66.5 |
| | 180 | 40.51 | 50.38 |

*$P_{max}$ is the FR value at which maximum response output occurs (Hursh, 1991).

**Table 3. Percent Reductions in PCP or ETOH and Saccharin Deliveries as Income Decreased from 180 to 20 min.**

| FR | Sacc | PCP w/Sacc | PCP w/Water | Sacc | ETOH w/Sacc | ETOH w/Water |
|---|---|---|---|---|---|---|
| 4 | 89.0 | 39.9 | 51.0 | 72.2 | 35.0 | 38.9 |
| 8 | 92.9 | 40.2 | 44.8 | 83.1 | 46.3 | 50.0 |
| 16 | 92.8 | 51.7 | 49.5 | 81.1 | 41.1 | 49.0 |
| 32 | 92.7 | 60.0 | 56.7 | 82.4 | 59.3 | 54.8 |
| 64 | 90.1 | 71.7 | 65.9 | 79.6 | 77.9 | 61.7 |
| 128 | 88.4 | 78.6 | 78.0 | 76.0 | ---* | ---* |

*Intake too low and variable to calculate

**Figure Legend**

**Figure 1.** Mean (± S.E.) PCP deliveries (left frames) and lip contact responses (right frames) are shown as a function of drug price or FR requirement for drug deliveries (4, 8, 16, 32, 64 and 128). Saccharin or water deliveries were concurrently available under an FR 32 schedule. Filled symbols refer to PCP deliveries or responses when saccharin was concurrently available and open symbols refer to PCP deliveries or responses when water was concurrently available. In the right frames the vertical lines that intersect the x-axis refer to $P_{max}$ values (see Table 2) which are estimates of the unit price at which maximum responding occurred (Hursh, 1991). Broken lines refer to the concurrent water conditions and solid vertical lines refer to the concurrent saccharin condition. Each point represents a mean for 6 monkeys over the last 5 days of stable behavior. Standard errors of the mean were calculated for the 5-day means of each group of monkeys.

**Figure 2.** Mean (± S.E.) ethanol deliveries (left frames) and lip contact responses (right frames) are shown as a function of drug price or FR requirement for drug deliveries (4, 8, 16, 32, 64 and 128). Saccharin or water deliveries were concurrently available under an FR 32 schedule. Filled symbols refer to ethanol deliveries or responses when saccharin was concurrently available and open symbols refer to ethanol deliveries or responses when water was concurrently available. In the right frames the vertical lines that intersect the x-axis refer to $P_{max}$ values (see Table 2) which are estimates of

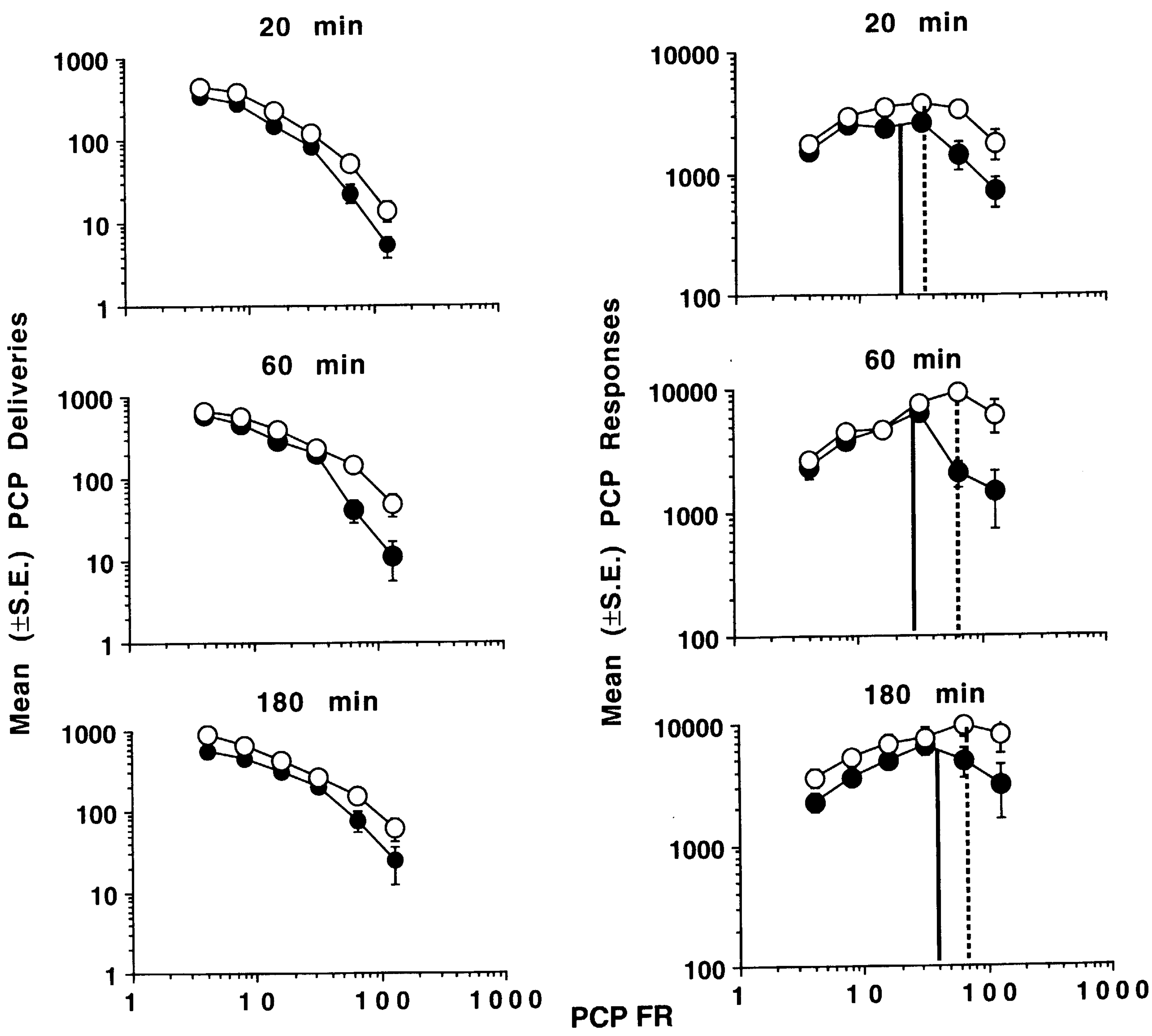
the unit price at which maximum responding occurred (Hursh, 1991). Broken lines refer to the concurrent water conditions and solid vertical lines refer to the concurrent saccharin condition. Each point represents a mean for 8 monkeys over the last 5 days of stable behavior. Standard errors of the mean were calculated for the 5-day means of each group of monkeys.

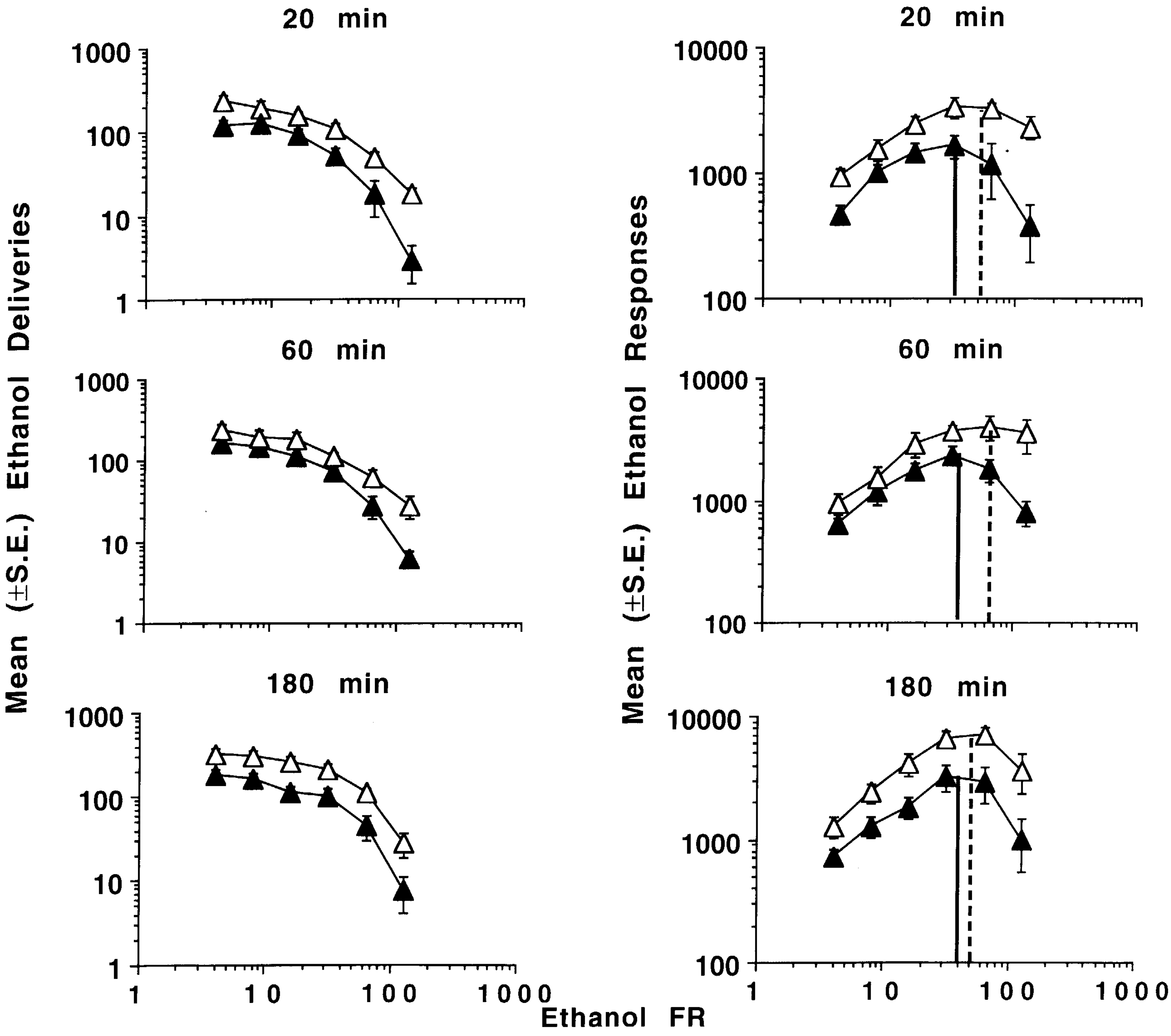
**Figure 3.** Engel curves are presented for the PCP (upper frames) and ethanol (lower frames) income studies. Drug consumption is plotted as a function of income (session length) when water (left frames) or saccharin (right frames) were concurrently available. Each line represents a different FR condition: Open circles - FR 4, filled circles - FR 8, open triangles - FR 16, filled triangles - FR 32, open squares - FR 64, filled squares - FR 128. Each point represents a mean of 6 (upper frames) or 8 (lower frames) monkeys over the last 5 days of stable behavior. Standard errors of the mean were calculated for the 5-day means of each group of monkeys.

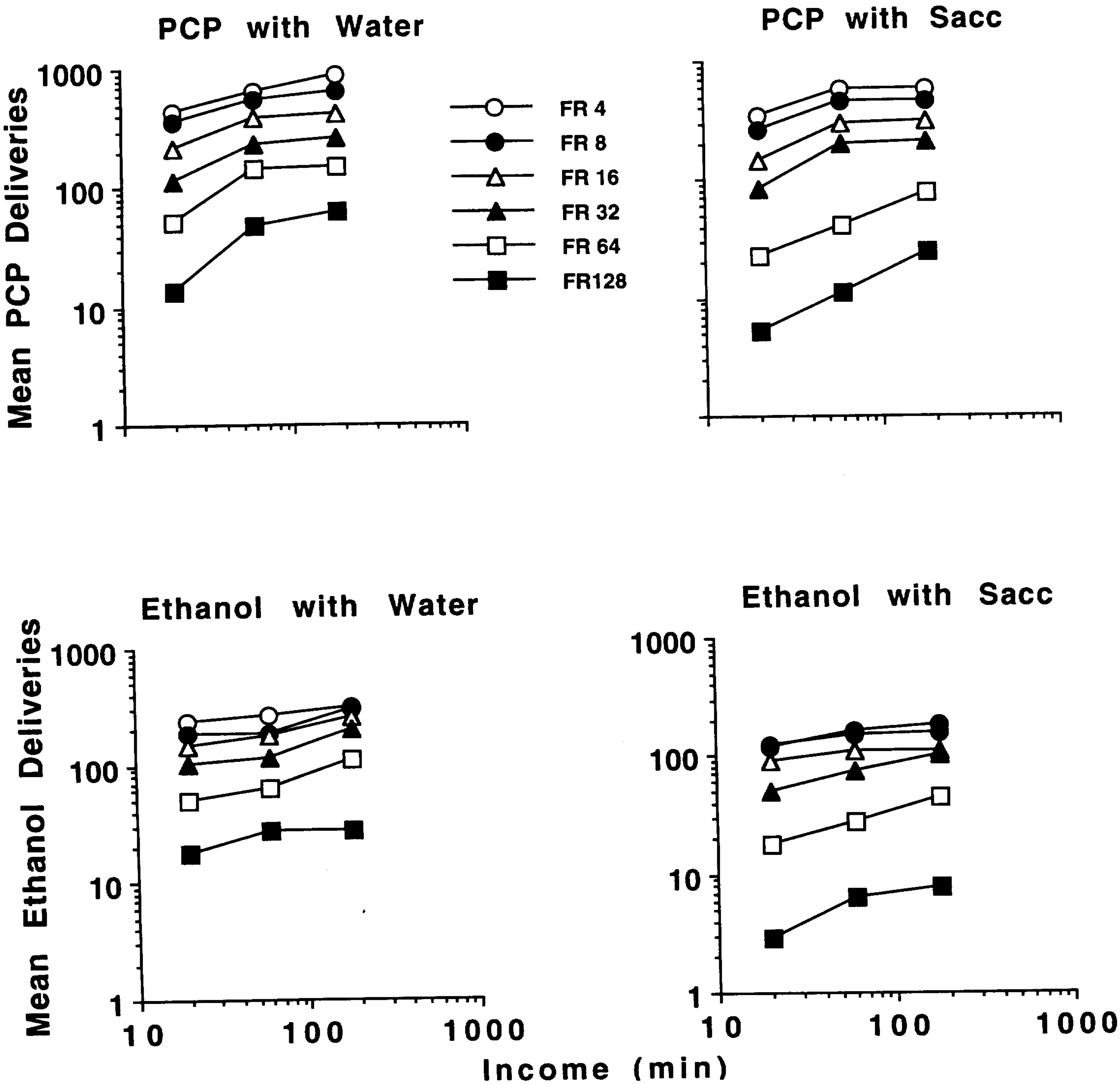
**Figure 4.** Mean (± S.E.) liquid deliveries are presented as a function of income level (20, 60 and 180 min) for all 6 drug FR conditions. Saccharin was available under an FR 32 schedule. Left frames represent PCP data; right frames refer to ethanol. Striped bars indicate drug deliveries, and open bars refer to saccharin deliveries. Water deliveries are not shown as they were negligible and did not vary as a function of FR or income. Each bar represents a mean for 6 (left frames) or 8 (right frames) monkeys over the last 5 days of stable behavior. Standard errors of the mean were calculated for the 5-day means of each group of monkeys.

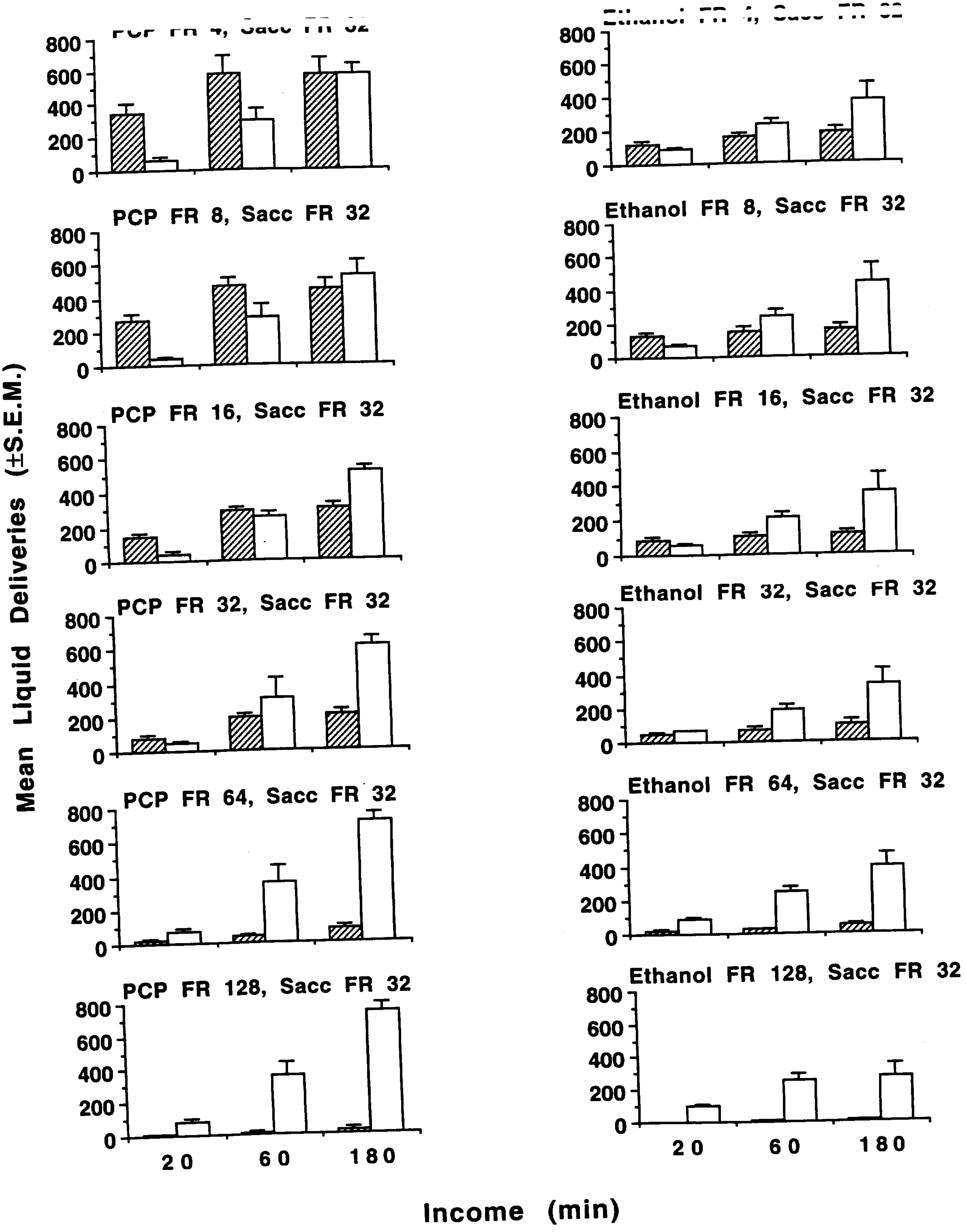
**Figure 5.** Mean (±S.E) PCP (left frame) and ethanol (right frame) deliveries are plotted as a function of income (20-, 60-, 180- min sessions. The upper frames illustrate drug intake when water was concurrently available, middle frames indicate drug intake with concurrent saccharin and lower frames represent saccharin intake. All data are for the FR 32 condition. Dotted lines represent hypothetical curves that would represent normal goods. Each point represents a mean of 6 (PCP) or 8 (ethanol) monkeys over the last 5 sessions of stable behavior. Standard errors of the mean were calculated for the 5-day means across the number of monkeys in each group.

**Figure 6.** Mean (±S.E.) saccharin consumption is plotted as a function of the PCP (left frame) and ethanol (right frame) FR schedule value (4, 16, 64) for the 3 income conditions. Circles - 20 min, triangles - 60 min and squares - 180 min. Numbers in parentheses refer to the slopes of each line. Each point represents a mean of 6 (PCP) or 8 (ethanol) monkeys for the last 5 sessions of stable behavior. Standard errors of the mean were calculated for the 5-day means across the number of monkeys in each group.

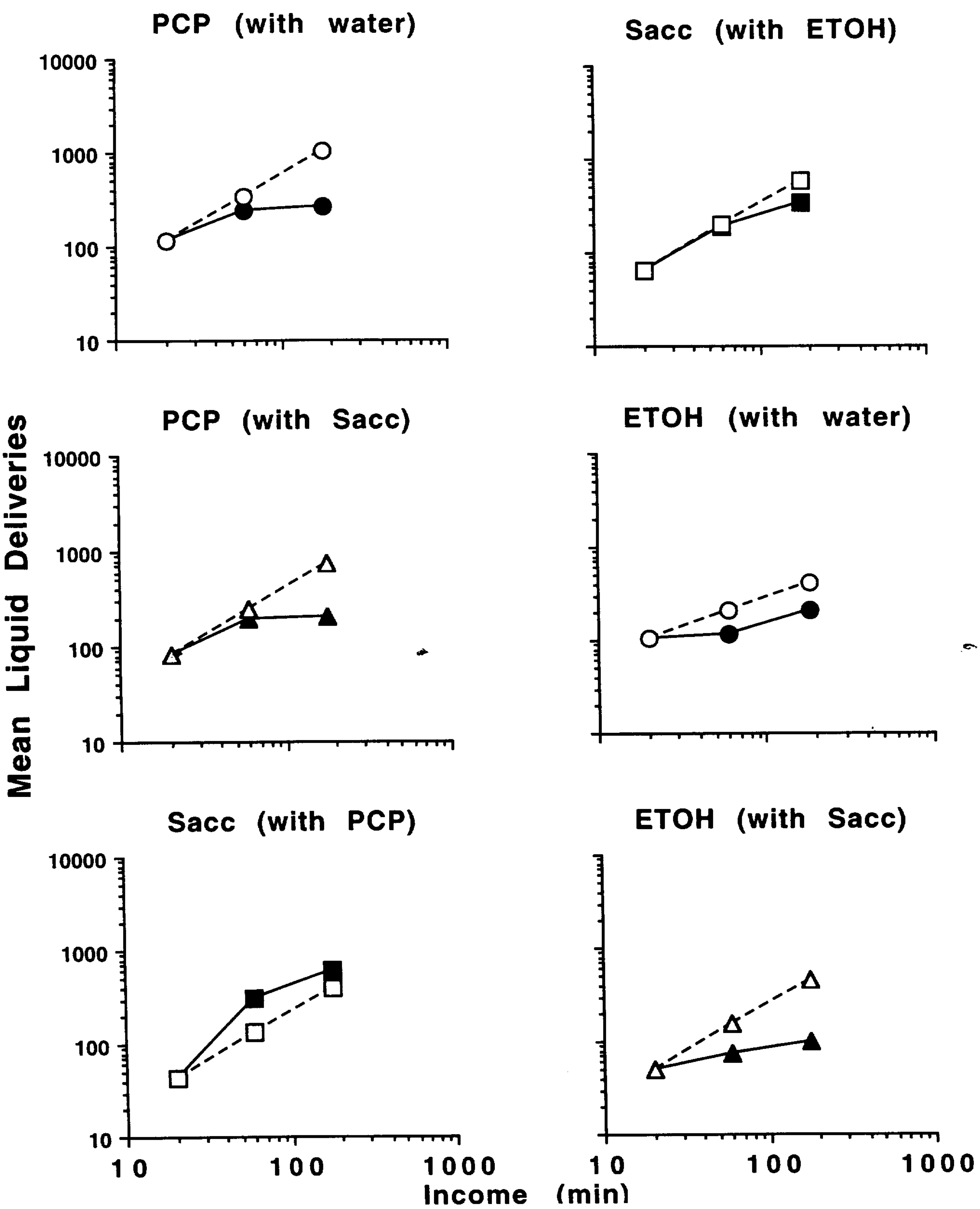

20 min
60 min
180 min
Mean (±S.E.) PCP Deliveries
Mean (±S.E.) PCP Responses
1
10
100
1000
10000
PCP FR


20 min
60 min
180 min
Mean (±S.E.) Ethanol Deliveries
Mean (±S.E.) Ethanol Responses
1000
100
10
1
10000
1000
100
1
10
100
1000
Ethanol FR

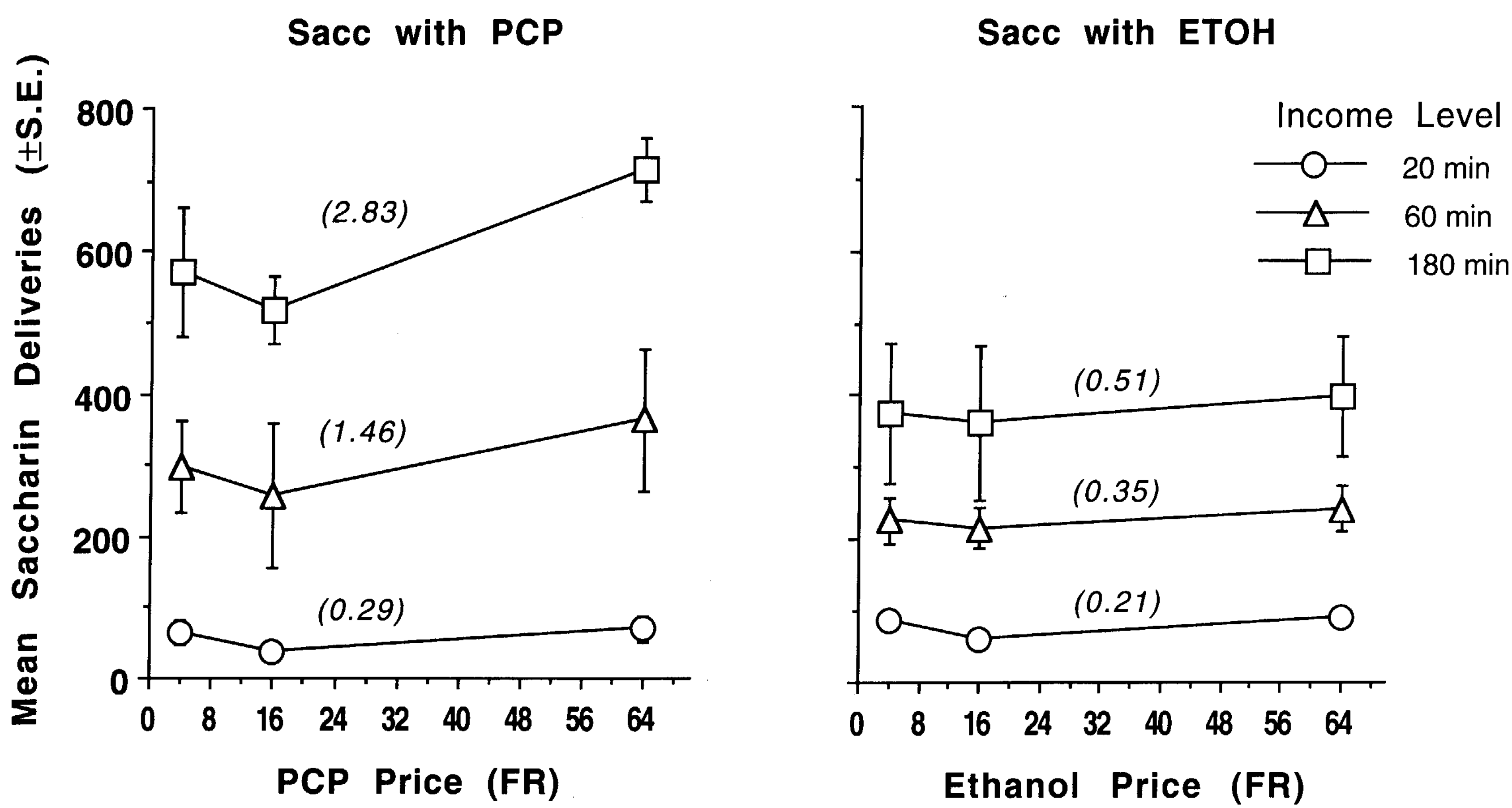

PCP with Water
PCP with Sacc
Mean PCP Deliveries
1000
100
10
1
FR 4
FR 8
FR 16
FR 32
FR 64
FR128
Ethanol with Water
Ethanol with Sacc
Mean Ethanol Deliveries
1000
100
10
1
10
100
1000
Income (min)



PCP FR 8, Sacc FR 32
PCP FR 16, Sacc FR 32
PCP FR 32, Sacc FR 32
PCP FR 64, Sacc FR 32
PCP FR 128, Sacc FR 32
Ethanol FR 8, Sacc FR 32
Ethanol FR 16, Sacc FR 32
Ethanol FR 32, Sacc FR 32
Ethanol FR 64, Sacc FR 32
Ethanol FR 128, Sacc FR 32
Mean Liquid Deliveries (±S.E.M.)
Income (min)
20
60
180



PCP (with water)
Sacc (with ETOH)
PCP (with Sacc)
ETOH (with water)
Sacc (with PCP)
ETOH (with Sacc)
Mean Liquid Deliveries
10000
1000
100
10
1 0
1 0 0
1 0 0 0
Income (min)



Sacc with PCP
Sacc with ETOH
Mean Saccharin Deliveries (±S.E.)
800
600
400
200
0
(2.83)
(1.46)
(0.29)
(0.51)
(0.35)
(0.21)
0 8 16 24 32 40 48 56 64
PCP Price (FR)
Ethanol Price (FR)
Income Level
20 min
60 min
180 min