Pharmacology Biochemistry and Behavior, Vol. 46, pp. 527-534, 1993
Printed in the U.S.A.

0091-3057/93 $6.00 + .00

Smoking-Related Subjective and Physiological Changes: Pre- to Postpuff and Pre- to Postcigarette

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Received 7 December 1992

HASENFRATZ, M., A. JACOBER AND K. BÄTTIG. *Smoking-related subjective and physiological changes: Pre- to postpuff and pre- to postcigarette.* PHARMACOL BIOCHEM BEHAV 46(3) 527-534, 1993.—Twenty-six female regular smokers participated in two sessions, smoking a cigarette and drinking for comparison a cup of coffee in each. Cardiovascular, electromyogram (EMG), motor activity, and electroencephalogram (EEG) parameters were assessed before and after smoking a cigarette or drinking a cup of coffee. The same variables were averaged for 5-s periods preceding, during, and following the first six puffs and sips. As the expected psychophysiological changes might be related to pleasure, the experimental design included both pleasant-tasting coffee and cigarettes and preparations manipulated to be unpleasant. Comparing pre/post consumption and pre/post puffing changes, heart rate increased as expected pre/post a cigarette but not pre/post puffing. On the other hand, there was no change in heart rate pre/post a cup of coffee but a transient increase pre/post sipping. The pre/post puffing and pre/post sipping changes in the EEG power distribution were similar for both drugs, occurred already in anticipation of puffing and sipping, and qualitatively suggested sedation as opposed to the pre/post cigarette arousing effects. These results might explain the observations of subjective tranquilizing effects during the consumption of a stimulant. Although the taste manipulations produced significant subjective effects, they did not influence the anticipatory effects.

Smoking   Coffee drinking   Pleasure   Puffing behavior

BY far, most of the evidence relating smoking motivation to the effects of nicotine is based upon experimental comparisons of different behavioral and physiological functions before and after smoking a cigarette. In general, such studies suggest that smoking may help in some way to enhance mental concentration (14,19), improve certain types of cognitive performance (20), or serve as a nonspecific help in coping with the daily challenges of life (2,5,10,12,17).

More diffuse reasons for smoking are usually obtained with systematic questionnaires or individual exploration of smokers' reasoning about the subjective benefits of their habit. In addition to stimulation or tranquilization, the immediate sensory rewards obtained through the act of puffing and the stimulation of taste and smell also play an important role.

A better understanding of such aspects of smoking motivation would require the analysis of subjective and physiological parameters in relation to single puffs. This has been done so far only in few studies.

Kochhar and Warburton (8) used analog scales presented on a computer screen to assess different attributes of three types of cigarettes in a puff-by-puff fashion. Two major components were extracted: The first involved sensory intensity, which increased during the smoking of a cigarette, and the second involved quality of flavor and satisfaction, which increased at the beginning of a cigarette but decreased thereafter. Knott (6,7), on the other hand, investigated the electroencephalogram (EEG) changes during cigarette smoking. The puff-by-puff analysis revealed that the profile characteristic for smoking emerged by the fourth puff. Finally, Revell (13) has shown that mental performance gradually improved when smokers were allowed to smoke while performing a visual rapid information processing task. Together, these experiments illustrate the gradual development of nicotine-induced changes in performance and EEG along the sequence of puffs, as well as the corresponding changes in subjective evaluation of puffing.

The possible attributes of the desire and expectation prior to puffing have been investigated only exceptionally. One such study, presented by Saumet and Dittmar (15), observed in a few heavy smokers that the well-known phenomenon of acrodermal vasoconstriction, which develops rapidly after single puffs (18), may appear even in expectation of smoking a cigarette. Further, it has been observed recently by averaging the pulse and physical activity changes accompanying ad lib

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smoking under field conditions that increases of activity and heart rate precede the lighting of a cigarette (1).

The present multiparametric study [EEG, electromyogram (EMG), activity, cardiovascular, and subjective parameters, etc.] was therefore aimed at a closer analysis of possible changes that may precede or immediately accompany cigarette puffing and at a comparison of such changes with the classical changes observed between the baseline periods preceding and following smoking an entire cigarette. Any changes immediately before and during single puffs are probably not a direct consequence of the pharmacological effects of nicotine intake but could be nonspecific anticipatory and rewarding components of the consummatory act in general. Therefore, the study was extended to observe such possible changes not only in relation to cigarette puffing but also in relation to taking single sips of coffee. In addition, the taste of smoke and coffee was either unaltered, and thus pleasant, or manipulated, so as to be unpleasant. Also, to verify possible effects of expectation subjects were required to signal the need for a puff/sip by pressing a button that in turn imposed on half the occasions a delay of a few seconds until the puff/sip was allowed. In order not to interfere with the development of their subjective needs, subjects were allowed to pace their puffs/sips freely, in contrast to the earlier studies (6-8), which relied upon fixed puffing regimes.

METHOD

Subjects

Twenty-six female regular smokers with a mean age of 28 years (range 20-36) participated in the study. They reported being in good health and smoking 18.7 cigarettes/day (range 10-35). They weighed 57.8 kg (range 46-75) and had a mean height of 168.3 cm (range 160-182). Preceding the experiment, they were required to abstain from alcoholic beverages on the morning of the test day and from coffee after noon. There was no restriction concerning cigarette smoking. Subjects were selected responders to an advertisement in a local newspaper and received 120 sFr after completing the entire experiment.

Design

A 2 × 2 crossover design was used to investigate cigarette smoking and coffee drinking in a pleasant as well as in an unpleasant version. In each session, subjects smoked one cigarette and drank one cup of coffee. One cigarette and one cup of coffee was pleasant, the other unpleasant. The order of drinking and smoking and of the taste manipulations was balanced.

Treatments

In both sessions, subjects smoked cigarettes of their habitual brand. Whereas one was untreated (pleasant taste), the filter of the other one was impregnated with 0.5 ml vinegar and then dried for 5 h (unpleasant taste). This method was used previously by Leventhal and Avis (9) to study the influence of taste on smoking rate. Filter coffee (150 ml; Mövenpick Café Qualité Premium, Zurich, Switzerland) was prepared according to the subject's preferences (with respect to milk, cream, sugar, artificial sweetener). In one session, subjects received 100% pure coffee (pleasant taste) while in the other session 80% coffee substitute (roasted chicory, "Franck Arome," Thomi + Franck AG, Basel, Switzerland) as a taste adulterant and only 20% coffee was used (unpleasant taste). To compensate the caffeine deficit in this manipulated coffee, 80 mg caffeine were added. Both the manipulated cigarettes and the manipulated coffee were rated as distinctly unpleasant but not as totally obnoxious.

Physiological Recordings

Blood pressure. Blood pressure was measured at the nondominant upper arm (arm cuff; Tonomed Electronic, Speidel & Keller AG, Jungingen, Germany) immediately before and after each rest phase.

The following parameters were measured and recorded with an AT-compatible microcomputer and stored on streamer tape for later offline analysis.

ECG. The electrocardiagram signal was recorded with two Ag/AgCl electrodes fixed below the middle of the right clavicle and below the last rib on the left. A third electrode below the last rib on the right served as ground. This signal passed an ECG cardiometer device that detected the R-wave peaks, thus monitoring heart rate (HR) continuously during the experiment.

Finger and ear pulse amplitudes and arrival times. Finger (FPAs) and ear pulse amplitudes (EPAs) were recorded with miniature photosensors placed at the palmar surface of the distal phalanx of the left ring finger and at the left ear lobe. The finger (FPATs) and ear pulse arrival times (EPATs) were computed as the time between the R-peak of the ECG and the foot point of the following pulse amplitude at the finger or the ear.

EMG. The electromyogram of the musculus frontalis was recorded with three Ag/AgCl electrodes arranged in a horizontal line in the middle of the forehead.

Respiration. Respiratory amplitude and frequency were registered with a Pneumotrace respiration transducer (Model 1130, Morro Bay, CA).

Activity. Body movements were measured with four piezoelectrical crystals, centrally installed under the seat. The impulses of the three dimensions were recorded as sum vector.

EEG and EOG. EEG activity was recorded with goldcup electrodes from C_z, P_3, and P_4 (international 10-20 system). Combined ear references with resistances between them were used and a midforehead electrode served as ground. The electrode impedances were kept below 5 kOhm. The signals were amplified with bandpasses from 0.2 to 25 Hz. Electrooculogram (EOG) activity was monitored with Beckman Ag/AgCl electrodes (Beckman Instruments, Fullerton, CA) placed below the left infraorbital ridge and above the left supraorbital ridge. The signal was monitored with a bandpass setting of 0.5-25 Hz.

Subjective Parameters

After each puff from the cigarette and after each sip of coffee, subjects had to answer four questions presented one after the other on a computer screen. The questions appeared at the top of the screen and subjects answered by operating a trackball with their dominant hand to adjust a pointer on a 100-mm long, horizontal analog scale in the middle of the screen. The four questions after each of the cigarette puffs and each of the sips of coffee were the following: "How strong was the smoke of the last puff?" "How strong is the coffee?" [left end (0 mm) labeled with very weak; right end (100 mm) labeled with very strong]. "How good was the taste of the last puff/sip?" (very bad-very good). "How relaxed do you feel now?" (not relaxed at all-totally relaxed). "How much would you like to continue to smoke/to drink coffee?" (not at all–with pleasure).

Procedure

The sessions, which lasted about 2 h, started in the afternoon between 1:30 and 2:30 p.m. and took place in a separate chamber immediately adjacent to the control room housing the recording and steering computers. At the beginning of a session, all subjects had to answer questions about their drug consumption (illegal drugs, medicaments, coffee, alcohol, cigarettes) in the preceding 24 h. A short training program was run at the beginning of the first session to familiarize subjects with the handling of the trackball, and a brief general instruction about the experimental procedure was given. Each session consisted of two measuring blocks with a 10-min break between them, and each measuring block consisted of a first 5-min rest phase, a smoking or coffee drinking phase, and a second 5-min rest phase. Blood pressure was measured before and after each rest phase. Subjects were instructed to sit quietly with closed eyes during all the rest phases. During the smoking and coffee drinking phases, subjects had to press the trackball button when they wished to take the next puff or sip but were allowed to smoke or drink only after an acoustic signal. This signal appeared in a pseudorandom order either immediately after the subject pressed the button or 5 s later. The exact time of taking a puff (when the tip of the cigarette started to glow) or taking a sip (when the cup touched the subject's lips) was observed by the experimenter on a video screen and recorded using a marker button. Subjects were required to finish the cigarette and coffee they received, but no time limit was imposed.

Data Treatment and Statistics

All continuously recorded physiological data were analyzed offline. For the 5-min rest phases preceding and following the drinking/puffing intervals, the mean values and SDs for each successive 10-s period were computed. After a visual artefact control carried out under blind conditions, the 10-s averages were aggregated to means for each rest phase (5-min means). From the EEG data, the relative power of the delta (1.0–3.9 Hz), theta (4.0–7.8 Hz), alpha (7.9–11.7 Hz), and beta (11.8–24.7 Hz) bands as well as the peak frequencies of the alpha and beta bands were determined for each 5-min rest period and for each lead separately.

For the smoking and drinking phases, the means of five 5-s intervals were computed as follows: a) before the subject pressed the button to indicate that she wished to take a puff/sip; b) between the subject's button press and the acoustic signal (these data were available for only half of the puffs of a cigarette/sips of a cup of coffee); and c)–e) the three successive 5-s after the subject began to puff/drink. These 5-s inter-

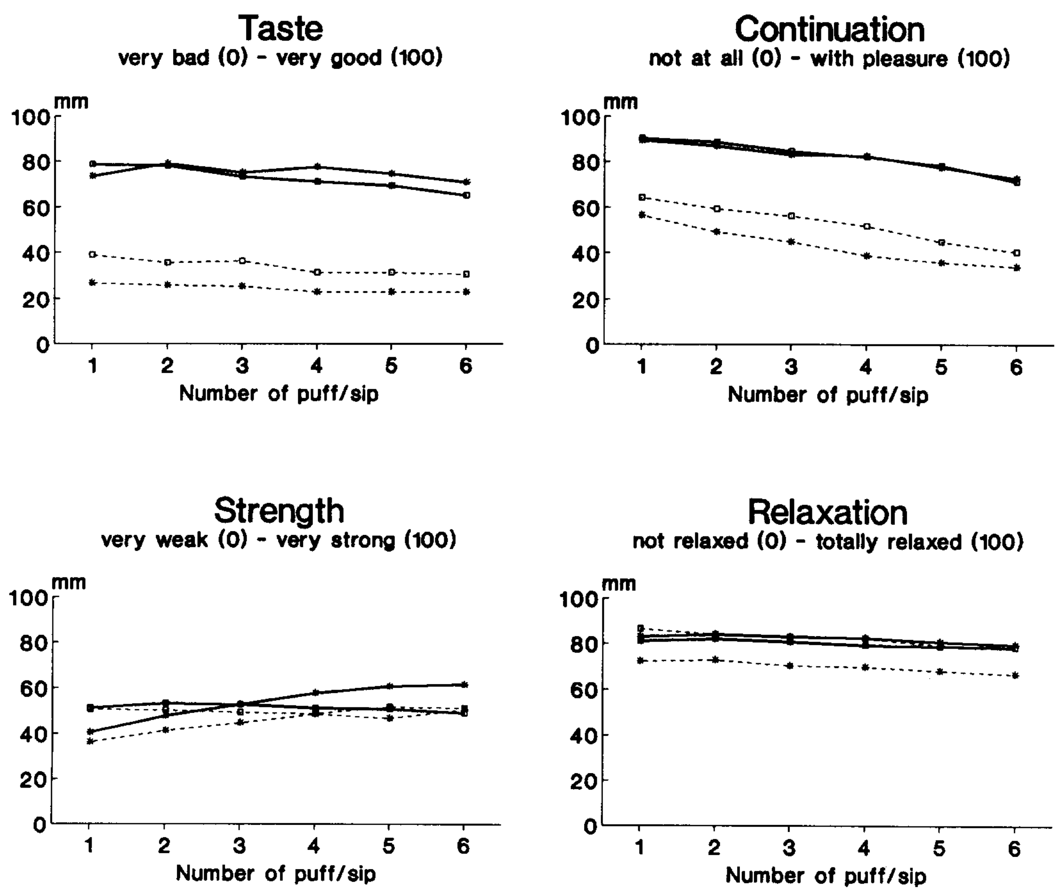

FIG. 1. Development of the subjective parameters over the first six puffs of a cigarette/sips of coffee. (*), cigarette; (□), coffee; (—), pleasant taste; (---), unpleasant taste.

vals were aggregated separately over the first six puffs of a cigarette and the first six sips of coffee.

These reduced data sets were then statistically analyzed using the appropriate software programs of the SPSS and BMDP packages available on a mainframe computer. For all significance levels of the analyses of variances (ANOVAs, BMDP2V) Greenhouse-Geisser probabilities were considered where appropriate.

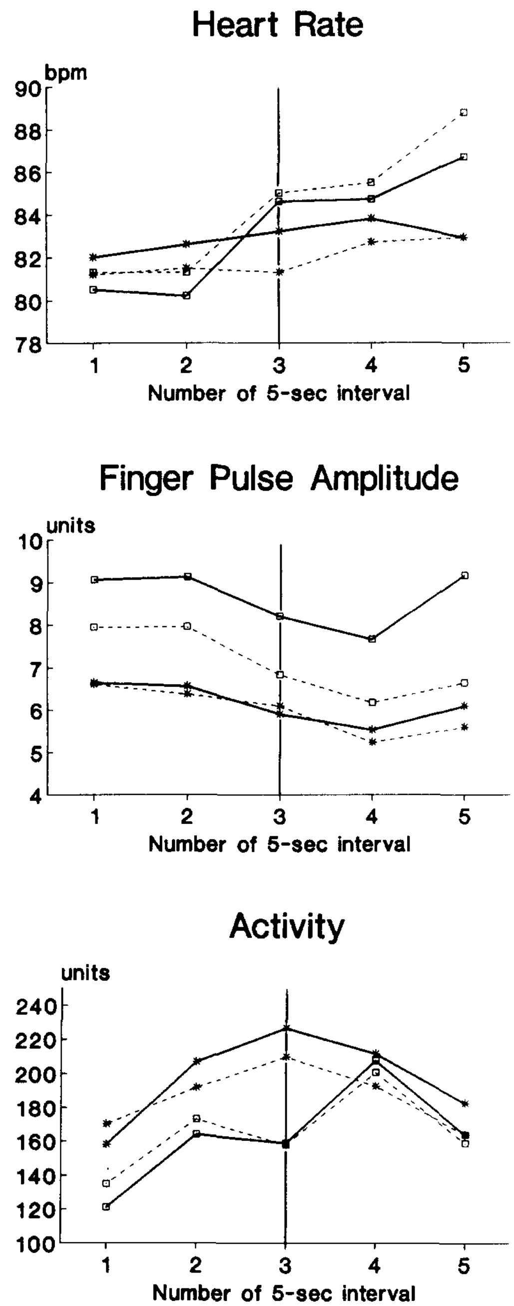

FIG. 2. Development of physiological parameters over the five 5-s intervals around a puff/sip. The intervals were recorded as follows: (1), immediately before the button press with which the subject indicated her wish to take another puff/sip; (2), between the button press and the acoustic signal that allowed the subject to puff/drink (only half of all puffs/sips); (3)-(5), three 5-s intervals immediately after the beginning of a puff/sip. See Fig. 1 legend for definition of symbols and rules. The vertical line indicates lip contact.

RESULTS

Subjective Ratings

The average postpuff/postsip subjective ratings across the first six puffs/sips are shown in Fig. 1. ANOVAs with the factors drug (D: cigarette vs. coffee), taste (T: pleasant vs. unpleasant), and ordinal puff/sip number (N) all revealed ordinal effects and, in part, also effects of taste and drug. Taste clearly affected the ratings "How good was the taste of the last puff/sip?" [T, $F(1, 22) = 95.74$, $p < 0.001$] and "How much would you like to continue to smoke/to drink coffee?" $F(1, 22) = 47.38$, $p < 0.001$. The gradual decreases of the taste ratings produced significance for the ordinal number both with taste [N, $F(5, 110) = 6.05$, $p < 0.01$] and the wish to continue, $F(5, 110) = 21.32$, $p < 0.001$. An additional D × T interaction, obtained with the taste ratings, $F(1, 22) = 4.95$, $p < 0.05$, further suggests that the unpleasant cigarette was perceived as more disagreeable than the unpleasant coffee.

Perception of strength increased gradually across the puffs on the cigarettes but not with the sips of coffee [interaction D × N, $F(5, 110) = 6.49$, $p < 0.01$] and remained unaffected by the taste manipulations. Relaxation was perceived to be greater with both coffee conditions and the pleasant cigarette than with the unpleasant cigarette [interaction D × T, $F(1, 22) = 8.34$, $p < 0.001$], and the ratings decreased gradually for all conditions [N, $F(5, 110) = 4.00$, $p < 0.05$].

Puffing and Sipping Parameters

Whereas the mean number of puffs (10.2 ± 2.4) was significantly higher than the number of sips (8.0 ± 2.0), $F(1, 22) = 18.71$, $p < 0.001$, there was no significant difference for taste. On the other hand, the mean interval between two puffs (41.2 ± 8.0 s) or sips (42.8 ± 8.1 s) did not differ between the two drugs nor between the two tastes.

Development of the Physiological Parameters Across Successive 5-s Periods

According to the experimental design, the physiological variables were averaged across the first six puffs/sips for the 5 s preceding the wish to puff/sip, for the following 5 s, when the subjects had to wait, and finally for the subsequent three 5-s periods after the cup touched the lips or the cigarette started to glow. These data were submitted to ANOVAs with the factors drug (D), taste (T) and 5-s phase (P). The development of heart rate, finger pulse amplitude, and motor activity across these 5-s periods is shown in Fig. 2. The other parameters did not show any relevant significance.

Heart rate developed differentially for puffs and sips [interaction D × P, $F(4, 88) = 14.30$, $p < 0.001$], remaining relatively stable for the puffs but increasing for the sips. The finger pulse amplitudes were significantly smaller with puffing than sipping [D, $F(1, 22) = 7.53$, $p < 0.05$]. Motor activity was also smaller with sipping than puffing, $F(1, 22) = 14.10$, $p < 0.01$, particularly for the first three 5-s intervals [interaction D × P, $F(4, 88) = 3.94$, $p < 0.05$]. A further, remarkable, result was that the increase in motor activity appeared already in the second 5-s interval, when subjects had to wait for puffing or sipping. This was confirmed by separate

ANOVAs limited to the first two 5-s intervals, $F(1, 22) = 24.80, p < 0.001$.

The development of EEG power is shown for C_z in Fig. 3. The analogous developments of the recording sites P_3 and P_4 were qualitatively similar, and the F-values for the factor phase were significant for all EEG frequency bands and all three leads. Significant effects, independent of drug and taste, as seen similarly after puffing and sipping (i.e., for intervals 4 and 5), were already present during the second interval, when subjects had to wait for puffing or sipping. This was confirmed by separate ANOVAs limited to the first two 5-s intervals, which revealed significance for all parameters and leads except for theta power at P_4. The different effects in interval 3 can be attributed to motor artifacts in the EEG signal because subjects puffed and sipped during this interval.

Pre- to Postsmoking/Drinking Effects

The means of the pre- and postconsummatory rest phases were submitted to ANOVAs with the factors drug (D), taste (T), and pre- vs. posttreatment phase (P). As was expected after this short absorption period, there were some significant effects of smoking but not of coffee drinking. As shown in Fig. 4, smoking increased heart rate by about 6-8 bpm [interaction D × P, $F(1, 25) = 45.99, p < 0.001$], systolic blood pressure by 3-5 mm Hg, $F(1, 25) = 9.46, p < 0.01$, and diastolic blood pressure by 3-6 mm Hg, $F(1, 25) = 6.86, p < 0.05$, and decreased finger pulse amplitude by about 40%, $F(1, 25) = 24.96, p < 0.001$. The smoking-induced increase in activity, as seen in Fig. 4, failed to reach significance, $F(1, 25) = 4.22, p = 0.0505$. Further, a significant triple interaction D × T × P for heart rate, $F(1, 25) = 4.25, p < 0.05$, suggested that the smoking of the pleasant cigarette led to a greater heart rate increase than the smoking of the unpleasant cigarette. The remaining peripheral physiological parameters did not show any relevant significance.

The cell means of the EEG data revealed pre/post smoking decreases of delta and theta power and increases of beta power and the dominant alpha frequency and pre/post coffee drinking increases of alpha power (Fig. 5). The resulting F-values for the prepost × drug interaction are shown in Table 1.

DISCUSSION

The aim of this study was to investigate the psychophysiological changes occurring in anticipation of and concomitant with cigarette puffing and compare them with the changes pre/post smoking an entire cigarette. The sipping of a cup of coffee served as a control condition. The microanalyses around each puff and each sip revealed that a) the differences between puffing and sipping are few, b) the EEG parameters showed more effects than the peripheral physiological parameters, and c) some effects already occurred before a puff or a sip was taken and can therefore be seen as anticipatory effects.

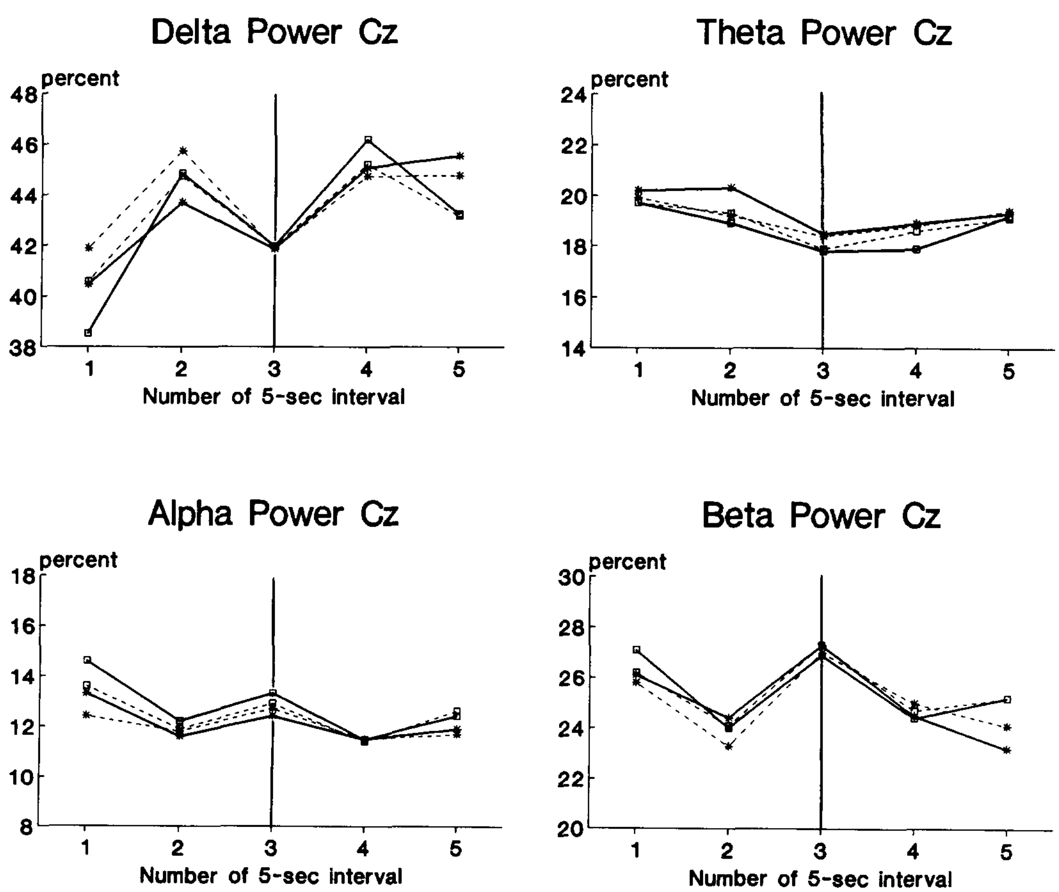

FIG. 3. Development of the electroencephalogram (EEG) parameters over the five 5-s intervals around a puff/sip (see Fig. 2 legend). See Fig. 1 legend for definition of symbols and rules. The vertical line indicates lip contact.

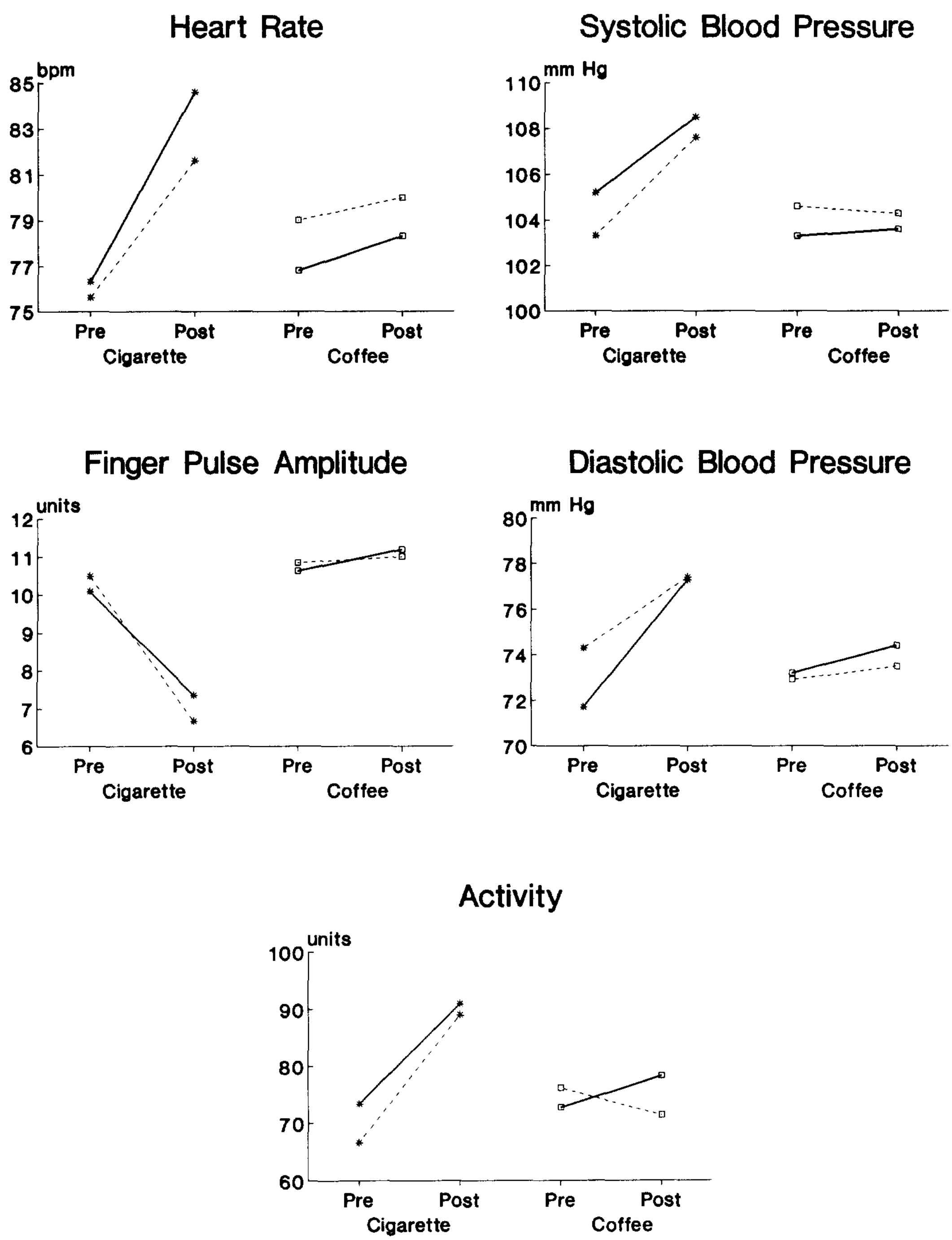

FIG. 4. Phase means of the physiological parameters during the rest phases pre- and postsmoking/drinking. See Fig. 1 legend for definition of symbols and rules.

The most obvious difference between smoking and coffee drinking was found for heart rate. While it increased pre/post cigarette, there was no change pre/post puffing. On the other hand, there was no change in heart rate pre/post a cup of coffee but an increase pre/post sipping. This transient postsip cardioacceleration might be a reaction to swallowing and/or the heat stimulation of the pharynx and esophagus. The averaging procedure (over the first six puffs of cigarette) does not allow the assessment of the gradual increase of heart rate caused by nicotinic stimulation, so this can be assessed only in the pre/post cigarette comparison.

Probably the most interesting results, however, are the anticipatory effects that were found for motor activity and for the EEG power data of all frequency bands. The increase of motor activity immediately before puffing and drinking is in line with a similar increase of motor activity immediately be-

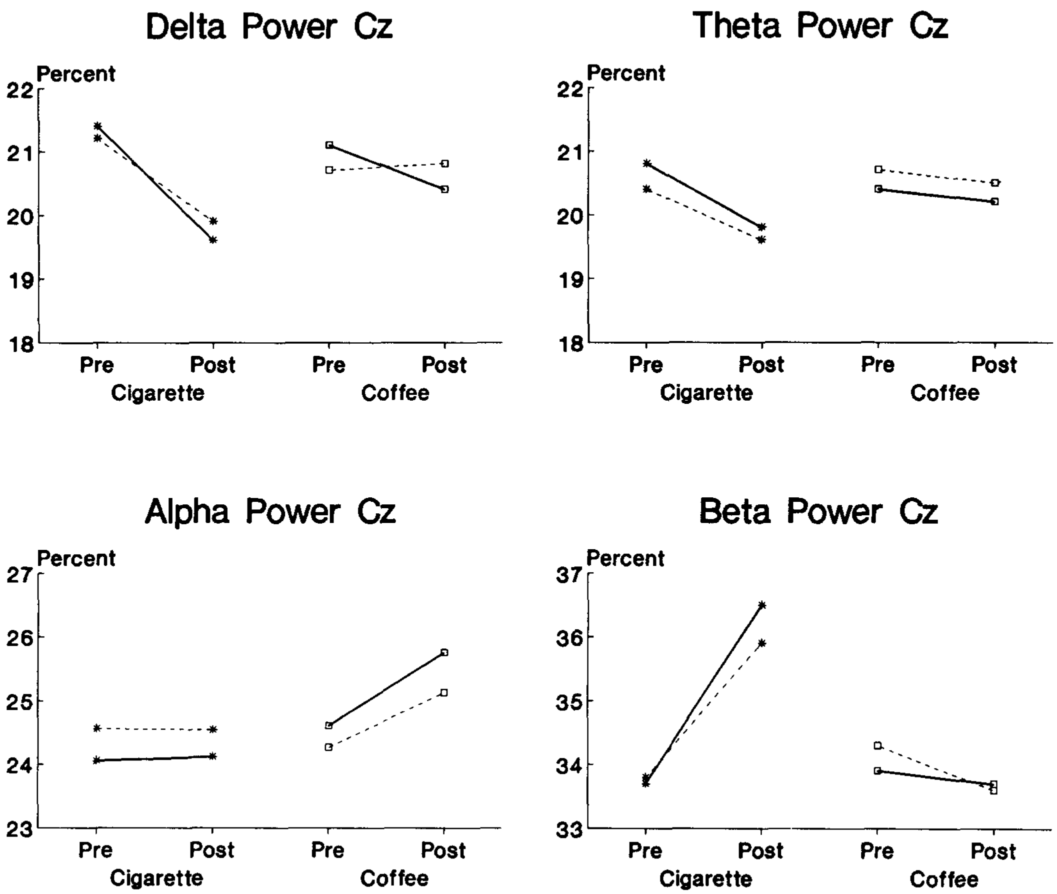

FIG. 5. Phase means of the electroencephalogram (EEG) data during the rest phases pre- and postsmoking/drinking. See Fig. 1 legend for definition of symbols and rules.

fore the lighting of a cigarette observed under field conditions (1). This appears to be an expression of an unconscious, generally anticipatory unrest before lighting, puffing, or sipping and to constitute a conditioned phenomenon.

The anticipatory effects on the EEG parameters were surprisingly the inverse of the pre/post cigarette arousing effects of smoking, which were similar to those found earlier (3,4, 6,7). The decreases in the alpha and beta bands and the increase in the delta band immediately before a puff/sip to values similar to those seen after puffing/sipping suggest a sedative correlate of the anticipation of puffing or sipping independent of the arousing pharmacological effects, which were observed only when comparing the pre- and postsmoking/drinking states. Such a sedative state seems to be experi-

TABLE 1

F-VALUES OBTAINED FOR THE DRUG × PREPOST INTERACTION WITH THE DRUG × TASTE × PREPOST ANOVAs OF THE EEG PARAMETERS DURING THE REST PHASES FOR THE THREE LEADS P_3, C_z, AND P_4

Parameter	*df*	P_3	C_z	P_4
Delta power	1, 25		8.78*	7.88*
Theta power	1, 25		6.16†	
Alpha power	1, 25	4.59†		3.43‡
Beta power	1, 25	16.39§	32.60§	41.79§
Dominant alpha	1, 25	11.15*	4.08‡	10.89*
Dominant beta	1, 25		3.29‡	

*$p < 0.01$.
†$p < 0.05$.
‡$p < 0.1$.
§$p < 0.001$.

enced by smokers and might explain the findings of subjectively tranquilizing but physiologically arousing effects of smoking (11,16,21). However, it should be considered that the EEG analyses differed between the rest and consummatory phases in that the eyes were closed during the former but open during the latter.

The lack of anticipatory effects on finger pulse amplitude in the present study is not contradictory to the anticipatory effect of smoking observed by Saumet and Dittmar (15) because the data were analyzed differently. Whereas they compared presmoking, smoking, and postsmoking states, we analyzed prepuffing, puffing, and postpuffing periods. Thus, the anticipatory effects on finger pulse amplitude may be related to the lighting of a cigarette rather than to a single puff.

A further aim of the study was to test whether these effects might be influenced by differences in taste and whether physiological correlates of "pleasure" can be assessed as the difference between a pleasant- and an unpleasant-tasting substance. Surprisingly, although there were highly significant differences in taste ratings, the intersip and interpuff intervals remained highly similar for pleasant and unpleasant taste and no effects of taste on physiological parameters could be detected under the conditions of the present experiment.

ACKNOWLEDGEMENTS

The authors thank B. Kohler and P. Schmid for technical and B. Strehler for editorial assistance and the Swiss Association of Cigarette Manufacturers for financial support.

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