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Pharmacological Versus Sensory Factors in the Satiation of Chocolate Craving

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MICHENER, W. AND P. ROZIN. *Pharmacological versus sensory factors in the satiation of chocolate craving*. *PHYSIOL BEHAV* 56(3) 419–422, 1994. — This is the first experimental study directed at differentiating between physiological or sensory accounts of the satiation of nondrug cravings, using chocolate craving, the most common craving in North America. At the onset of craving, chocolate cravers consumed a chocolate bar, the caloric equivalent in “white chocolate” (containing none of the pharmacological components of chocolate), the pharmacological equivalent in cocoa capsules, placebo capsules, nothing, or white chocolate plus cocoa capsules. Chocolate reduced self-rated craving. The cocoa capsules, placebo, and no treatment conditions had virtually no effect. White chocolate produced partial abatement, unchanged by the addition of all the pharmacological factors in cocoa. This result indicates no role for pharmacological effects in the satisfaction of chocolate craving. It also suggests a role for aroma independent of sweetness, texture, and calories.

Addiction	Aroma	Biogenic amines	Chocolate	Caffeine	Cocoa	Food craving	Magnesium
Methylxanthines		Phenylethylamine	Sweet	Theobromine	Tyramine		

CRAVING is an extremely common occurrence, and yet there is almost no literature exploring the basis for cravings or their satisfaction. The only generally accepted account identifies craving as a component of the response to withdrawal from addictive drugs [see (22)]. Yet cravings occur for many substances and activities that are not linked in any obvious way to addictive drugs. In this study we explore the basis for satisfaction of craving using chocolate, which is not clearly established as an addictive substance and is also the most commonly craved substance in North America (30). Where craving is defined as “a strong desire, so strong that it will cause a person to go far out of his or her way to satisfy the craving,” chocolate craving is present in 40% of females and 15% of males (21).

Chocolate craving has been attributed to rewarding effects of phenylethylamine (13) or magnesium (1,2,29). It is clear that chocolate can have neurologic effects because it will induce migraine in susceptible individuals, as will phenylethylamine (23). However, claims for a physiological basis for the causation or satiation of chocolate craving have been criticized on the ground that they are not adequately supported by evidence (31).

Chocolate cravers themselves usually account for their craving simply as a desire for the experience of chocolate. Correlational data suggest that they seek other foods that share sensory rather than pharmacological properties with chocolate when chocolate is not available (21). Still, three-fourths of chocolate cravers claim that there is no substitute that will satisfy a chocolate craving (30).

There is reason to believe in a physiological basis for the initiation (as opposed to satiation) of chocolate craving, because in many females, the craving occurs almost entirely in the period around the onset of menstruation (21,27). This craving is, to at least some extent, specific to chocolate, as opposed to sweets in general (21). In the perimenstruum, ratings of craving for chocolate increase relative to ratings of craving for comparable non-chocolate sweets (27). Perimenstrual chocolate cravings are sufficient to account for the greater prevalence of chocolate craving among women compared to men, as well as the higher hedonic rating that women give to chocolate (21). Sensitivity to phenylethylamine could be the critical factor, because monoamine oxidase B may be reduced during the perimenstruum (18).

A full account of craving would identify those events that cause the craving to be acquired, those that initiate individual episodes of craving, and those that terminate them. This study addresses directly only the problem of termination, but it has implications for the problem of initiation as well. Three hypotheses that might account for the initiation and termination of cravings are: 1) Cravings are initiated by a desire for the sensory properties of chocolate and are terminated by same. 2) Cravings are initiated by some internal physiological factor (e.g., a deficiency of endogenous phenylethylamine) and terminated by post-ingestional consequences of chocolate that correct or compensate for the original surplus or deficit. [For example, steady administration of nicotine tends to prevent cigarette cravings from arising, suggesting that nicotine deficit initiates the craving, and

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acute administration of nicotine tends to reduce a craving that has already occurred, suggesting that nicotine terminates the craving (5,16). Some researchers also find craving for the conditioned sensorimotor cues of smoking, however (20). 3) Cravings are initiated by some internal physiological factor (other than desire for the sensory properties of chocolate), but nevertheless, postingestional consequences of chocolate consumption play no role in terminating the craving. A finding that pharmacological factors reduce craving would support hypothesis 2 and oppose 1 and 3. The opposite finding would oppose 2 but would be consistent with either 1 or 3.

We compare the effect of six treatments on craving: a milk chocolate bar; white chocolate candy providing the sweetness, calories, and texture of true chocolate without the pharmacological components; cocoa capsules containing the minerals and pharmacologically active agents of a bar of chocolate; placebo capsules; nothing; and white chocolate plus cocoa capsules, providing all of the ingredients of chocolate without the flavor. Table 1 presents the pattern of results predicted by each of four theories (to be elaborated below) of satiation of chocolate craving on the assumption that the named substance or effect is necessary and sufficient to terminate a chocolate craving.

White chocolate is a confection made from a cocoa butter base. Cocoa butter is the fat removed from chocolate liquor. When sufficient fat has been removed, what remains is cocoa powder. There is no third product (3).

White chocolate does not contain significant amounts of any of the known pharmacological agents in chocolate. The biogenic amines are not fat soluble, and thus are absent from cocoa butter when it is removed from chocolate liquor. Theobromine is present in white chocolate but at less than 2% the level found in milk chocolate (8). Magnesium is present in white chocolate at a level of 4 mg/100 g, compared to 60 mg/100 g for milk chocolate (28).

If sensory experience is the ultimate object of chocolate craving, then only the chocolate bar would totally satisfy the craving. White chocolate might partially satisfy the craving, as it has the texture and sweetness of chocolate, without the unique aroma. No other treatments should be effective.

Craving for the nutritional effects of chocolate could be for the rapid glycemic effect, for the bolus of calories, or for a specific nutrient. Magnesium is a possible candidate, because chocolate is high in magnesium, though nuts are as well (24). There is a report of magnesium supplementation preventing the occurrence of chocolate cravings (29). Sugar is not a likely candidate, because this cannot explain why chocolate is craved in preference to other sweets (21,27,30). For the caloric theory, chocolate and white chocolate should be about equally effective. For the magnesium theory, chocolate and cocoa capsules should be equally effective.

The ultimate object of chocolate craving may be some positive pharmacological effect. The sympathomimetic amines and methylxanthines of chocolate have arousing and hence potentially positive effects.

Phenylethylamine (PEA) has been measured at from 0.4–6.6 $\mu\text{g/g}$ in milk chocolate (11). This is high compared to most foods (10), though it is exceeded in some cheeses and sausage (12,26). Phenylethylamine resembles amphetamine in its structure, and in its effects (including reinforcement) at pharmacological levels. Phenylethylamine is found normally in the CNS, probably colocalized with dopamine. At physiological doses it may serve to potentiate dopaminergic and noradrenergic neurotransmission (15). There is a clinical report that the antidepressant bupropion, also structurally similar to PEA, abolishes craving for chocolate (14).

TABLE 1
THEORIES OF CRAVING AND THEIR PREDICTIONS

Theory	MCHOC	W	CC	Plac.	W + C	Empty
Sensory	++	+	0	0	+	0
Nutritive						
Calories	++	++	0	0	++	0
Magnesium	++	0	++	0	++	0
Pharmacological	++	0	++	0	++	0
Result	++	+	0	0	+	0

++ = full effect, + = partial effect, 0 = no effect; MCHOC = milk chocolate, W = white chocolate, CC = cocoa capsules, Plac. = placebo capsules, W + CC = white chocolate plus cocoa capsules, empty = no treatment.

Tyramine has been measured at 3.8–12 $\mu\text{g/g}$ in milk chocolate (11) but at 0–625 $\mu\text{g/g}$ in cheese (26). The effect of tyramine varies with the menstrual cycle, with sensitivity higher in the perimenstrum (6).

Quantities of the methylxanthines caffeine and theobromine in chocolate are variable even within a brand, but finished milk chocolate products average about 0.2 mg/g caffeine and 2 mg/g of theobromine (25) (or about 9 mg caffeine and 88 mg theobromine in a 44-g bar). Because caffeine may have addictive properties (9), the related methylxanthine theobromine (17) may as well. Craving could represent an attempt to alleviate symptoms of withdrawal from either methylxanthine.

All of the pharmacological accounts would predict that the cocoa capsules and chocolate bar should be about equally effective in satisfying craving. White chocolate should have no effect, but white chocolate plus cocoa capsules should have the full effect.

METHOD

A screening questionnaire identifying chocolate cravers and willingness to participate in a craving study was distributed to undergraduate psychology classes at the University of Pennsylvania, and to 4000 undergraduates at M.I.T. Subjects were admitted to the experiment if they reported having a craving for chocolate at least once a week, where craving was defined as "a strong desire for something, such that you would go far out of your way to get it." Each subject swallowed a sample capsule before beginning the experiment, to make sure that he or she would have no difficulty with the capsules later on.

Subjects were given opaque boxes numbered one to six. On the occurrence of each craving (so long as it was not within 60 min of a meal), they were to open the next box in the sequence and follow instructions. Each box contained three visual analog scales, 100-mm lines anchored with the words "just noticeable" on the left and "uncontrollable" on the extreme right, with the midpoint defined as "I would go out of my way to obtain chocolate." Subjects were instructed to rate their current craving, consume what was in the box, rate their craving again, and rate it again 90 min later. In 90 min theobromine is near its peak level in plasma (19) and biogenic amines have been absorbed as well (4). Subjects were instructed to eat nothing, and drink only water during this 90-min period.

For subjects who typically ate one chocolate bar on the occasion of a craving, the boxes presented the following treatments in random order:

1. one Hershey 44-g milk chocolate bar (240 calories),

2. six opaque capsules containing 3.8 g of Hershey's cocoa powder, approximately equal in pharmacological content to the chocolate bar according to average figures provided by the manufacturer (7) (16 calories),
3. six opaque capsules containing 4.5 g white flour (16 calories),
4. 42.7 g of white chocolate, a confection of sugar, cocoa butter, milk, vanilla, and artificial flavoring (240 calories),
5. 39.9 g of white chocolate plus six opaque capsules containing 3.8 g of Hershey's cocoa powder (240 calories), or
6. nothing.

When the box did not contain capsules, instructions were added directing subjects to consume as much water as they would have needed to swallow six capsules. For the eight subjects who typically ate more than one chocolate bar when they craved chocolate, all quantities were doubled. Subjects who completed all six conditions were asked to repeat the experiment.

RESULTS

Thirty-four subjects (29 females and five males) provided at least one observation for each condition. Of these, 17 provided two observations for each condition; their scores were averaged across conditions. An additional 11 subjects turned in only partial data. Twenty-seven more turned in no data, or no useable data. Two gave as their reason that they could not control their desire to eat chocolate (the protocol required fasting for 90 min after the contents of the box had been consumed, even when the box did not contain chocolate candy). There may have been others with this problem, as many gave no reason for quitting. Others deviated from instructions. One gave up chocolate for Lent.

Figure 1 displays the decrease in self-rated craving 90 min after each treatment.

The milk chocolate bar(s), the standard for craving relief, reduced self-rated craving from a mean of 74 before ingestion to 16 just after, and 13 at 90 min. Thus, the mean drop in craving at 90 min was 61 points. In the control (nothing) group, craving was rated 70 before, and 70 after the empty box was opened, and 58 at 90 min later. The mean reduction in craving was 12 points, significantly smaller than the effect for the chocolate bar, $t(33) = 10$, $p < 0.001$ (all the positive tests of significance survive the Bonferonni correction for multiple comparisons). These two values, 61 and 12, establish the limits between a full and no effect.

White chocolate produced an intermediate effect, a drop of a mean of 42 points at 90 min, significantly less than chocolate, $t(33) = 6$, $p < 0.001$, and significantly more than nothing, $t(33) = 5.5$, $p < 0.001$. Craving was rated 70 before, 33 just after, and 28 at 90 min. The difference from chocolate supports either a sensory effect of chocolate aroma or a pharmacological effect of chocolate. The superiority to nothing indicates a role for either sensory effects (sweetness and texture) or energy.

The data are very clear in indicating no role for pharmacological effects in satisfying craving. For cocoa the values were 67 before, 66 just after, and 51 at 90 min. For placebo they were 71 before, 65 just after, and 52 at 90 min. There was no significant difference in reduction in craving at 90 min following cocoa [16] compared to placebo [19], $t(33) = 6$, $p = 0.5$. Further, for the subjects who repeated the placebo and cocoa capsule conditions, superiority of cocoa on one iteration was not predictive of superiority over placebo on the other. The nothing condition was not significantly lower than the cocoa capsule condition, $t(33) = 1$, $p = 0.3$. Furthermore, the white chocolate with cocoa capsule treatment [43] was not sufficient to reduce chocolate craving more than white chocolate alone [42], $t(33) = 0.3$, $p = 0.8$. For white chocolate plus cocoa capsules, self-rated cravings averaged 72 before, 32 just after, and 29 at 90 min after ingestion. Thus,

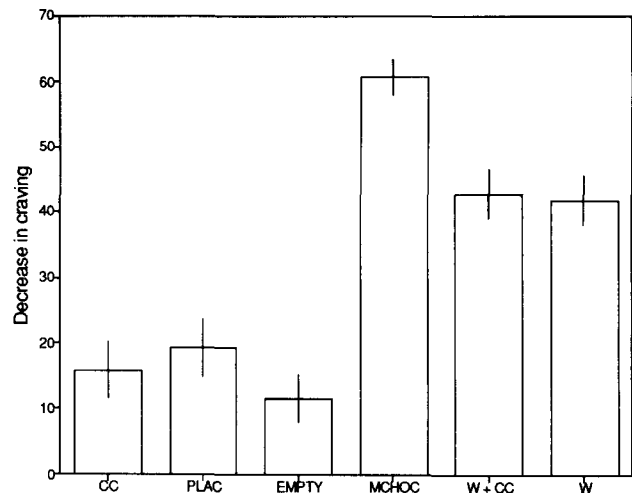


FIG. 1. Reduction in craving for chocolate. Values shown are the difference between craving rated on a 100-mm VAS before and 90 min after treatment; bars represent the SEM. EMPTY = no treatment, PLAC = placebo, CC = cocoa capsules, W = white chocolate, W + CC = white chocolate plus cocoa capsules, MCHOC = milk chocolate.

the pharmacology of chocolate was not sufficient to abate a chocolate craving. Whether it is necessary was not tested directly, because we lacked a treatment that would provide the flavor of chocolate without the pharmacological factors. However, it would be surprising if pharmacological factors account for part of the difference between true chocolate and white chocolate and yet the cocoa pills add nothing to the effectiveness of white chocolate.

Immediately after treatment the average reduction in craving was near zero for the cocoa capsule, placebo, and nothing conditions, as expected. The immediate reductions in craving for the milk chocolate [57], white chocolate [37], and white chocolate plus cocoa capsule [40] conditions were quite similar to the 90-min values.

The results do not differ by gender, nor do the findings we report change if the 11 subjects who completed only part of the sequence are included.

DISCUSSION

This study was unavoidably biased by the requirement that cravers control their desire to eat chocolate. Persons with especially strong chocolate cravings may have excluded themselves, and two subjects gave their inability to control themselves as a reason for withdrawing. In this regard the absence of even a trend in favor of a pharmacological effect is reassuring.

Another problem arises from the fact that flavor cannot be delivered blind. Because subjects knew when they were receiving true chocolate this knowledge may have biased their self-reports.

Within these limitations, our observations suggest that chocolate cravings are satisfied by sensory experience. The critical elements probably include both aroma (accounting for the superiority of chocolate over white chocolate) and sweetness and texture (accounting for the superiority of white chocolate over placebo), though calories may also play a role. A more definitive conclusion on the sufficiency of sensory properties would depend on a further breakdown of treatments, and in particular, inclusion

of an as yet unavailable sensory mimic of chocolate that had neither pharmacological nor nutritional/caloric effects.

These findings suggest that the most common American craving is satisfied by sensory experience. They neither support nor oppose the hypothesis that the effectiveness of the sensory properties is due to conditioning by a pharmacological effect, though they do oppose the hypothesis that the pharmacological effect itself terminates the craving (the nicotine model). They lend force to the suggestion that some or most

other cravings may also be satisfied by specific sensory experiences (21,31).

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