Research Report

WHAT CAUSES HUMANS TO BEGIN AND END A MEAL? A Role for Memory for What Has Been Eaten, as Evidenced by a Study of Multiple Meal Eating in Amnesic Patients

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Abstract—*Although many factors have been proposed and studied as causes of onset and termination of meals by humans, little attention has been paid to memory for what has previously been eaten. We propose that a principal determinant of meal onset and cessation in humans is memory of when a last meal was eaten and how much was consumed. Knowledge that one has just eaten a culturally defined complete meal may be sufficient grounds for refusal of further food. This hypothesis was tested by studying two densely amnesic patients who had almost no explicit memory for events that occurred more than a minute ago, and who, in particular, usually failed to remember that they had just eaten a meal. Both patients (on three occasions each) readily consumed a second lunch when it was offered 10 to 30 min after completion of the first meal, and usually began to consume a third meal when it was offered 10 to 30 min after completion of the second meal. These findings suggest that memory for what has recently been eaten is a substantial contributor to the onset or cessation of eating of a meal.*

It has been presumed that at least some of the factors that regulate human and animal food intake are operative at the level of the meal. Because the meal is a much more tractable unit to analyze than intake over days to months, the focus of most research on regulation of food intake in both animals and humans has been the meal, a natural unit of analysis. Extensive research on the causes of meal onset and termination, in both humans and rats, has generated rather complex models of food intake from Stellar (1954) onwards (e.g., Birch & Johnson, 1994; Blundell & Rogers, 1990; Booth, 1978, 1994; and Bray, 1994). These models acknowledge multiple influences on meal initiation and termination and often include cognitive factors, but the focus has remained on physiological signals, with a secondary interest in palatability of foods. Herman and Polivy (1984) have suggested that psychological-cognitive factors may be critical in normal meal termination, with the traditional physiological signals of satiety functioning only in "boundary conditions" (cases of relatively extreme deprivation or surfeit). Memory for what has recently been eaten is not explicitly included in Herman and Polivy's or other researchers' psychological-cognitive factors. However, Polivy, Herman, Hackett, and Kuleshnyk (1986) have shown that in a number of conditions, if the amount consumed is made salient (by leaving the wrappers for pieces of candy being eaten in the view of the subject), there is a suppression of food intake.

There is evidence, in studies of both eating and drinking, that animals and humans keep some sort of record of the amount consumed (*oral metering*), and that this information influences food and water intake (e.g., Bellows, 1939; Mook, Bryner, Rainey, & Wall, 1980). This tracking may not be explicitly remembered. With respect to meals, there has been surprisingly little research on conscious monitoring in nondieting individuals. Yet it seems reasonable that for any particular meal, people stop either when they have finished what has been served or when they believe they have eaten a proper meal. On the other hand, people start eating when an appropriate occasion arises, as long as they do not remember having eaten very recently.

In humans, there are traditions and experiences that define a meal. For example, for many Americans, lunch is a sandwich, chips, and a beverage, and when that is completed, lunch is over. Alternatively, presentation of a meal implies that it is time to eat. It may be that memory for what has been eaten is a sufficient reason for meal termination, and that an appropriate stimulus for meal initiation is presentation of a meal in an appropriate context. One critical feature of such a context is the memory that one has not recently eaten.

In a study of perception of internal states after bilateral mediotemporal damage, Hebben, Corkin, Eichenbaum, and Shedlack (1985) reported that H.M., a well-studied, densely amnesic patient, ate a second full dinner (except for salad) 1 min after he had completed the first dinner. In a follow-up of the original report on H.M., Milner, Corkin, and Teuber (1968) stated that "H.M. rarely mentions being hungry even when his meals have been somewhat delayed; however, when food is put before him, he eats in a normal manner" (p. 216).

So far as we know, the report by Hebben et al. (1985) is the only observation of multiple meal eating in amnesics, and it involves one patient and one occasion. Our main purpose in this study was to verify this important observation, through multiple observations on two amnesic patients.

The two patients in this study had natural bilateral damage to the temporal areas. (In contrast, H.M.'s damage was primarily surgically produced.) There was extensive bilateral damage, in both patients, to the hippocampus and amygdala. The lesions in the three patients (H.M. and the two presented here) were somewhat different; what these patients had in common was dense amnesia with other mental functions well preserved. The two amnesic patients studied here had a much more severe recent memory deficit than patients typically studied in research on amnesia; both were comparable to H.M. in density of amnesia, a critical point because most patients described and studied as "amnesics" have some, if not substantial, memory of a very recent meal.

METHOD

Two densely amnesic, otherwise quite intact patients were studied, along with two control patients who had previously experienced brain damage, but had reasonably intact memories..

R.H. was a 48-year-old, black American male. He died of lung cancer a year after these studies were completed. R.H. held a B.S. degree and began a master's program, but his progress was interrupted by

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seizures and a gradual loss of explicit memory function. At the time of testing, he had suffered a dense amnesic syndrome, of uncertain etiology, for more than 20 years. Remarkably, he lived alone, in an apartment and neighborhood that were familiar to him before the onset of symptoms.

R.H. was aware that he had a very poor memory. He was highly intelligent, with a full-scale IQ of 126 on the Wechsler Adult Intelligence Scale (WAIS; Verbal: 126, Performance: 123), and he appeared normal in casual conversation. R.H. was of normal weight for his height (120 lb; 5 ft, 6 in.) and showed a strong interest in food and eating. His olfactory sensitivity was measured with an odor identification test (University of Pennsylvania Smell Identification Test, UPSIT; Doty, Shaman, & Dann, 1984). His performance was poor: He scored 12 correct out of 40; the median for his age is in the high 30s, with 10 correct being a random score.

R.H.'s short-term memory, as gauged from the continuity of his conversation or his digit span (7 forward, 5 backward), was normal. However, he had a dense and virtually complete amnesia for recent events. His score on the Wechsler Memory Scale was 86; on the test of logical memory, he answered 4 out of 23 questions correctly when his immediate recall was tested and none of the 23 questions correctly when his delayed recall was tested. He did not remember anything about the experimenters after about 12 hr of experimental sessions, nor did he remember the experimental room and area where he had been interviewed weekly for more than a year. He was unaware of the calendar year. Given the usually effective mnemonic image for the word pair "locomotive–dish towel" (a dish towel wrapped around a locomotive), he showed normal immediate recall of this pair (when prompted with "locomotive"), but no memory for it minutes later.

Magnetic resonance imaging (MRI) results indicated severe damage, bilaterally, to the hippocampus, hippocampal gyri, and amygdala. The posterior portion of the hippocampi was partially preserved.

B.R. (alive and well at this writing) was a 59-year-old white Canadian male at the time of testing. He was perfectly normal until an acute episode of Herpes encephalitis on July 29, 1992. In a period of a few days, he developed a dense and permanent amnesia. Since the onset of symptoms, approximately 1 year prior to the tests carried out in this study, he had spent most of his time in a neurological inpatient unit. He had some seizures, which were controlled with appropriate medication. B.R. had a partial gastrectomy some 20 years ago. He was 6 ft, 1 in., tall and weighed 199 lb. He was close to anosmic (UPSIT score of 8/20 on the first half of the UPSIT test, less than half of what we expected of someone at his age, with 5/20 being a random score).

B.R. was of low-average intelligence and a cooperative and articulate person who worked as a sales manager for a number of corporations. His WAIS full-scale IQ was 88 (Verbal: 93, Performance: 84). He showed a normal digit span (scaled score of 9 on the WAIS) and normal vocabulary and arithmetic performance. He could carry on a normal conversation, and, as with R.H., the presence of a severe deficit was not obvious on casual conversation. On the Wechsler Memory Scale—Revised, his scores for the various indexes were as follows: General Memory, 50; Verbal Memory, 67; Pictorial Memory, 57; Delayed Memory, < 50; and Attention/Concentration, 109.

Like R.H., B.R. showed a dense amnesia for explicit recent memories, with the same total inability to remember mnemonically pictured word pairs. He showed no recognition of the experimenters after 9 hr of contact, no awareness of a memory problem, and no familiarity with the hospital environment and room that he had lived in for most of a year.

An MRI revealed bilateral damage to the medial temporal lobes, including hippocampus and amygdala, and some damage to the inferior frontal areas.

Neither R.H. nor B.R. showed any specific recall of meals or other salient events that had happened more than a minute prior to their being probed, so long as there was a distraction in that interval.

Two control patients from the same region as B.R. were studied according to the same protocol as R.H. and B.R. One, J.C., was a 54-year-old woman who had a WAIS IQ of 118 (Verbal: 121, Performance: 112). She scored in the third percentile on the California Verbal Learning Test, suggesting some memory problems. She was 5 ft, 2 in., tall and weighed 140 lb. This patient had a closed-head injury 2.5 years before testing, and continues to visit the hospital for evaluations as an outpatient because of problems in sustaining attention.

T.A., a 57-year-old male, suffered a right-hemisphere stroke in 1995, with principal symptoms of left-side neglect and weakness. He was 5 ft, 7 in., tall and weighed 190 lb. Psychometric data on this patient are not available. He is currently an outpatient being treated for an attentional disorder.

Examination of all patients took place in an office room in a hospital (the same room for all but R.H.). Data collection for each occurred in two or three sessions. A full meal was introduced, always between 11:30 a.m. and 1:00 p.m. The meal was placed in front of the subject (introduced by "Here's lunch"), and he or she was invited to eat it. Hunger ratings were obtained before and after each meal. Ratings were on a 9-point scale (1 = *extremely full*, 2 = *very full*, 3 = *moderately full*, 4 = *slightly full*, 5 = *neither hungry nor satiated*, 6 = *slightly hungry*, 7 = *moderately hungry*, 8 = *very hungry*, 9 = *extremely hungry*) that was visually displayed in front of the subject.

During meal consumption, if about 1 min elapsed without the subject eating, we asked if he or she was finished. We removed the plate if the answer was affirmative; if the answer was negative, we left the food available for another minute. After the subject completed the meal, the plate was removed, a hunger rating was obtained, and for a period of 10 to 30 min, the subject was engaged in conversation. During this period, if the subject did not spontaneously drink water, he or she was asked to drink some (to clear away any oral food residues). Then, using an identical meal and an identical procedure, we introduced a second meal. In all but one of the six sessions with the amnesic patients, a third meal, again after a 10- to 30-min break, was introduced.

Meals offered to R.H. were selected on the basis of interviews with him about foods that he liked. The first two meals during the first session were Swanson turkey "TV dinners" (turkey, peas, potatoes, and applesauce; 300–340 Cal). Subsequently, the meals offered were Swanson TV dinners of veal parmigiana (veal, pasta, string beans, and apple crumb cake; 410 Cal). An 8-oz glass of apple juice was also provided, and was refilled when empty. Each meal was heated in a microwave oven before presentation.

B.R. was an inpatient and was offered multiple, identical versions of the hospital lunch that was served on the day of each session. On Day 1 (March 9), the meal included soup (onion, macaroni, vegetable), cheese-rice casserole, bread and butter, salad, peas, applesauce, and tea (537 Cal); on Day 2 (July 4), the meal was vegetable barley soup, meatloaf, bread and butter, tomatoes, potatoes, beans, peaches, and tea (703 Cal); and on Day 3 (July 5), the meal consisted of lentil soup, apple-glazed chicken, bread and butter, beets, mashed potatoes, salad, prunes, and tea (672 Cal).

Control subject J.C. was observed in two sessions, 2 weeks apart, in the same hospital room as B.R. On the first occasion, the meal was glazed chicken, with wild rice and string beans (Stouffer's Lean Cuisine, 216 Cal). On the second occasion, at the patient's request, the meal was vegetable lasagna (President's Choice, 295 Cal). J.C.'s preferred beverage was water, which was provided.

Control subject T.A. was offered two identical meals on each of two occasions, 1 week apart. The meal was seasoned boneless chicken with potatoes, corn, and apple-cranberry crumb (Swanson, 420 Cal). The beverage provided was water, as the patient requested.

RESULTS

All patients were extremely amicable and cooperative, and showed considerable interest in interacting with the experimenters and eating. In all the tasks presented, they had no trouble understanding instructions and using scales. Both amnesic patients showed some vague and uncertain memory, on some occasions, of having eaten recently, but never had further information on when, or what they had eaten. R.H. never commented that he had just eaten when presented with second or third meals. Indeed, at the end of his first session, 20 min after eating much of the third meal, R.H. announced that he would "go for a walk and get a good meal." We asked him what he would like to eat. His answer was "veal parmigiana."

B.R. had six opportunities to note that he had just eaten, on the presentation of second and third meals on each of 3 testing days. He made some comment indicating that he had recently eaten on five of these occasions. On Day 1, he commented that he had just eaten supper (it was actually lunch) when the second and third meals were presented. Other interviews with B.R. indicate strongly that he had no memory at all of the content of a recent meal or snack. When he responded to a presented meal by saying something indicating that he had recently eaten, we said: "Eat what you feel like eating."

A summary of the results from the eating sessions (three for each amnesic patient and two for each control patient) is presented in Table 1.

The most critical observations involve the acceptance and consumption of successive meals. R.H. never completed a meal, though he typically completed the meat course. He readily accepted all three of the second and third meals, consuming well in excess of 1,000 Cal in two of the three sessions. Across all six second or third meals, he consumed between 81% and 87% of all of the food offered (by weight), always completing the meat course. Only during the 3rd day was there any indication of a drop in consumption from first to third meals (Table 1). Given that R.H. failed to completely consume any meal, and that the TV dinners were rather small, we allowed him to eat to the point of rejection on the third meal. Indeed, on two occasions, we offered him a fourth meal. He refused it in both cases, claiming in one case that his "stomach was a little tight."

B.R. was offered a more substantial lunch than R.H., and had a different meal on each day (but three identical meals on any given day). B.R. completed every first and second meal. He also readily began eating a third meal on Days 2 and 3. On Day 1, a third meal was not available. We offered him apple pie (a liked food) instead, but he refused it. It is of interest that for both amnesics, the number of bites went up within each session, indicating that smaller amounts were taken in each bite on the later meals.

The 2 control subjects completed all of their initial meals. In all four cases (2 subjects, each offered a second meal during two sessions), these subjects absolutely refused to eat any of the second meal. On both occasions, J.C. was surprised and amused (laughed), indicated puzzlement at the offer of a second meal, and said she was not hungry. T.A. seemed to consider the offering of the second meal a generous rather than unusual move, and responded on both occasions with "no, no, no, thank you." A second prompt to eat each of the second meals was also rejected by each subject.

Hunger ratings showed minimal changes for R.H. (Table 1); in seven of the nine cases, his rating dropped slightly (usually 1 point) after a meal, and his rating always returned to the original level before the subsequent meal. For B.R., data are available only for the first two meals because we did not allow him to complete the third meal. His hunger ratings generally decreased across meals, but the pattern was irregular (Table 1). The control subjects reported substantially declining hunger after eating; their ratings remained stable or decreased from the end of the first meal to the time when the second meal was offered (Table 1).

DISCUSSION

We have shown that in the absence of conscious memory of having recently eaten, two densely amnesic people consumed multiple meals. This observation suggests that, at least under certain circumstances, memory for eating and the current eating situation are more predictive of consumption than physiological signals resulting from recent meals.

The hunger ratings of amnesics covered a narrower range than did the ratings of control subjects, and did not show reliable reduction after eating. For R.H., the hunger rating prior to a second or third meal typically returned to the level of the original rating, before any meal consumption. This return to prior reported hunger levels is surprising because nutrient absorption should reduce hunger. Control subjects showed the expected postabsorptive decline in reported hunger, as did B.R. on at least some occasions.

Until B.R. was massively overloaded with food, his food intake seemed to be determined primarily by the palatability of the food and his memory for recent meals. He maintained an enthusiasm for eating well into his second meal, and sometimes into the third meal. His wife informed us that on one home visit, he "overdosed" on bananas and vomited.

We believe that this study makes a case that memory of recent eating plays an important, but previously unappreciated, role in the onset and termination of meals by humans. This memory factor, if not controlled, may be a confounding factor in studies that seek to uncover other controls of food intake.

Although our results are clearly evidence that conscious memory has a major role in normal meal onset and termination, problems in interpretation remain. One is simply that our evidence is based on amnesic, not normal, individuals. We believe that the amnesics in our study showed surprisingly normal relations to food, and that they can be considered reasonably normal with respect to food attitudes, except for the absence of recent conscious memory. A second concern is the fact that B.R. may not have had total amnesia for all of the recent meals. However, his memories were uncertain and vague, and he provided no other embellishing information about the prior meal (such as any of its contents). In any event, there is no way that residual memories could explain continued meal ingestion; on the contrary, residual memory of prior meals could be used to explain refusal of multiple meals.

Table 1. *Summary of multiple-meal sessions for each subject*

	Amnesic patients						Control patients					
	B.R.			R.H.			J.C.			T.A.		
Meal	Kilocalories consumed	Status	Hunger rating[a]	Kilocalories consumed[b]	Status	Hunger rating[a]	Kilocalories consumed	Status	Hunger rating[a]	Kilocalories consumed	Status	Hunger rating[a]
Session 1												
1	537	Finished	7/8	236	Partially eaten	7/6	216	Finished	5/2	420	Finished	5/4
2	537	Finished	2/5	255	Partially eaten	7/7	0	Rejected	1	0	Rejected	3
3	0[c]	Rejected[c]	3[c]	333	Partially eaten	7/7						
Session 2												
1	703	Finished	6/5	356	Partially eaten	7/6	295	Finished	7/2	420	Finished	7/3
2	703	Finished	5/3	356	Partially eaten	7/6	0	Rejected	1	0	Rejected	3
3	—[d]	Partially eaten[d]	5	354	Partially eaten	7/6						
Session 3												
1	672	Finished	7/3	354	Partially eaten	7/6						
2	672	Finished	2/3	345	Partially eaten	7/6.5						
3	—[d]	Partially eaten[d]	5/3	330	Partially eaten	7/5						

[a]Hunger ratings are on a scale from 1 (*extremely full*) to 9 (*extremely hungry*). If the subject ate all or part of the meal, two ratings are given (before/after).
[b]This is the only subject who did not complete meals, and he never completed a meal. He always consumed the main dish (turkey or veal parmigiana), and most of the other food. We estimated calories by multiplying the percentage of total weight eaten by the total calories. This is an underestimate because the subject did not eat all the vegetables, and always completely consumed the more calorie-dense main course.
[c]Only apple pie was offered for the third meal.
[d]The subject began eating the third meal, but was stopped by the experimenter after eating a few spoonfuls of soup.

A third concern is demand characteristics. Perhaps the subjects ate the offered meals only to comply. Doing so might not be unreasonable, as they found themselves in an odd setting with people they did not know. However, the results from the control subjects speak against this interpretation. In addition, the caloric load of the meal was much smaller for the control subjects than for one of the experimental subjects (B.R.), so that this explanation would lead to the expectation that if there were any difference between amnesic and control subjects, the difference would be that the control subjects would be more inclined to continue eating. No pressure was put on the subjects to consume a meal. Furthermore, on other occasions during the sessions, both R.H. and B.R. refused to answer some question or engage in some activity, and both (R.H. often) refused to eat particular things.

A fourth concern is that brain damage outside the hippocampus may have caused disorders of regulation of food intake in our subjects. The amygdala has inputs from the chemical senses and viscera, and outputs to the hypothalamus and brain-stem, so that it might well play a role in the regulation of food intake. Amygdala damage in animals has been associated with changes in sodium appetite (Schulkin, Marini, & Epstein, 1989) and in sham feeding (e.g., Siegel, Joyner, & Smith, 1988). The Kluver-Bucy syndrome, which includes mouthing of objects inappropriate as foods, has been linked to amygdala damage. Hebben et al. (1985) suspected that, in light of the bilateral amygdala damage in H.M., there might be a deficit in perception of internal states. They reported a few observations indicating that H.M.'s rated hunger declined very little after he ate a meal. The amnesics in our study also had smaller than expected changes in hunger following a meal. This small decline could be indicative of some attenuation or distortion of internal-state registration, but it could also be that the normal drop in hunger upon eating (and before most of the food has entered the bloodstream) reflects some cognitive influences related to knowledge of having just eaten.

The following observations argue against accessory damage to food-regulation structures as a satisfactory explanation of our results: First, R.H., B.R., and H.M. had different but overlapping brain damage; what they had in common was a dense amnesic syndrome, extremely poor or no memory for recent meals, and ingestion of an additional meal within a short time after completing a prior meal. Second, there was no evidence in any subject of damage to the hypothalamic structures believed to be central to regulation of food intake. Third, although all three of the amnesic patients had damage to the amygdala, they showed no symptoms of such damage (e.g., eating

inappropriate foods). Furthermore, amygdala damage, judging from the animal literature reviewed in the introduction, would not be expected to eliminate satiety.

This study is presented primarily to highlight a potentially important aspect of the regulation of food intake at the level of the meal. It also serves to alert investigators of human (and perhaps animal) food intake that awareness of recent eating experiences may confound measures of food intake in experimental situations. Our results are, in general, compatible with the boundary model of Herman and Polivy (1984), in that outside of the extreme condition of truly excessive food intake, nonphysiological factors seem to be of major importance in the onset and cessation of normal eating. The results suggest that one of the principal nonphysiological factors is memory for what has recently been eaten.

Amnesic patients may be valuable in exploring other aspects of appetite. For example, one could use such patients to evaluate the role of signs of having eaten (e.g., the visual residues of eaten food) in controlling intake and the role of memory for what has recently been eaten in guiding food choices. One could ask whether sensory-specific satiety or priming requires explicit memory of what has recently been eaten.

This study exemplifies the possibility of using densely amnesic patients to explore a wide range of issues in psychology in which recent explicit memory figures as either a cause or a contaminant of the behaviors under discussion. Amnesic patients serve as perfect within-subject controls, so that repeated measurements can be made without concern about interference from explicit memories about past performances. In this respect, dense but otherwise intact amnesic patients are even better controls than identical twins, because they include controls for past experience as well as common genetics. We hope this investigation opens up possibilities for investigating the role of recent memory in many areas of interest to psychologists, including aesthetic judgments, attitude change, conversational continuity, and a variety of social judgments and encounters.

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