Increased Levels of Extracellular Dopamine in the Nucleus Accumbens and Amygdala of Rats by Ingesting a Low Concentration of a Long-Chain Fatty Acid

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Received March 19, 2013; Accepted July 25, 2013; Online Publication, November 7, 2013 [doi:10.1271/bbb.130234]

Changes in the extracellular concentration of dopamine (DA) in the nucleus accumbens (NAc) shell and the basolateral amygdala (BLA) resulting from the voluntary ingestion of either corn oil, mineral oil, or 1% linoleic acid diluted with mineral oil as a vehicle were measured in rats by using in vivo microdialysis after they had been trained to establish a preference for corn oil. Ingesting the mineral oil caused no significant change in DA level in the NAc shell, whereas corn oil ingestion significantly increased the DA level during 0–15 min of the test session, reaching the maximum level of 129.8 ± 6.2% compared with the baseline after 10 min. Ingesting linoleic acid also resulted in a significant increase in DA level during 0–20 min, reaching 125.9 ± 9.0% after 10 min. Similar results were obtained in the BLA. Despite its very low calorie content, a low concentration of non-esterified fatty acid increased the DA levels equivalent to those resulting from corn oil in the brain’s reward system.

Key words: dopaminergic nervous system; oil; fatty acid; palatability; reward system

Animals, including rodents and human beings, prefer fat-rich foods.1,2) The ingestion of corn oil has a strong reward effect on mice, and the involvement of dopaminergic pathways in the nervous system has been implicated in the manifestation of this effect.3,4) The mesolimbic system in the brain is thought to play a critical role in the reward effect, and the release of dopamine (DA) has been demonstrated when a natural or drug reward is acquired or its acquisition is anticipated.5,6) The midbrain dopaminergic circuits originate from the ventral tegmental area (VTA), and project to such sites as the nucleus accumbens (NAc), amygdala, and prefrontal area which are respectively related to motivation, palatability, and addiction.7–9) Since the extracellular concentration of DA in NAc has been increased dose-dependently by self-administering cocaine and ingesting sucrose in rats, the DA release in NAc could be considered as a kind of index of palatability or motivational drive.10,11) In fact, sham feeding corn oil or sucrose has been reported to increase the DA level in NAc of rats,12) and a similar increase in DA released by cocaine administration has also been reported to occur in the amygdala.13) However, which property of fat caused the increase in DA release has not been elucidated. Fat palatability could be explained by such factors as the unique texture of fat, odor, high caloric density per unit mass, and chemical reception of fatty acids on the tongue,14–16) all of which might result in increased DA release during fat ingestion.

We focused the present study on the chemoreception of fatty acids on the tongue. We have reported that when fat was introduced into the oral cavity of rats, a certain percentage of triacylglycerides was hydrolyzed to long-chain fatty acids (LCFAs) by lingual lipase.17) Gilbertson et al. have shown the regulation of K⁺ ion channels in type II taste cells by long-chain unsaturated fatty acids and suggested the presence of fatty acid chemoreceptors in taste cells.18) The protein candidates related to the recognition of LCFAs in the oral cavity are CD36 and G-protein-coupled receptor 120 (GPR120). We have found the expression of CD36 and GPR120 on the apical side of taste cells in the circumvallate papillae.19,20) In addition, CD36- or GPR120 gene-deficient mice have been reported to show a low taste preference for fat.21,22) These findings lead us to postulate that fat introduced into the oral cavity is hydrolyzed into LCFA by lingual lipase and that chemoreception of this LCFA by proteins such as CD36 and GPR120 expressed on the taste cells would function as energy sensors which transduce the presence of fat in the oral cavity. The purpose of the present study was to elucidate the involvement of LCFA, which is a component of fat, in the increased release of DA in NAc during corn oil ingestion. We studied the change in the extracellular concentration of DA in NAc by in vivo microdialysis when rats ingested a low concentration of LCFA. We used 1% linoleic acid diluted with mineral oil in the experiments. This concentration of fatty acid was in the range that could be released from fat by lingual lipase and had only a 1/100 caloric content when compared with the same weight of fat. Similar measurements were made in the basolateral amygdala (BLA), which is projected by the dopaminergic nerve system

Abbreviations: DA, dopamine; NAc, nucleus accumbens; VTA, ventral tegmental area; LCFA, long-chain fatty acid; GPCR, G-protein-coupled receptor

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Materials and Methods

Animals. This study was conducted in accordance with the ethical guidelines of the Kyoto University Animal Experimentation Committee and in complete compliance with the National Institutes of Health Guide for the Care and Use of Laboratory Animals, and was approved by the above-mentioned committee. Male Wistar rats (Japan SLC, Hamamatsu, Japan) at 8 weeks old were housed in stainless wire mesh cages in a room controlled by a 12-h light-dark cycle (dark phase of 18:00-6:00) and constant temperature (24 ± 1 °C). They were separately housed for a week for acclimatization to the environment. The animals were fed tap water and regular MF rat food (Oriental Yeast, Tokyo, Japan) ad libitum.

Materials. Corn oil was purchased from Ajinomoto (Tokyo, Japan), and mineral oil was purchased from Kanesa Company (Tokyo, Japan). Linoleic acid from Sigma (St. Louis, MO, USA) was 99% pure, stored at −20 °C until needed and then diluted 1% with mineral oil for use in this experiment. The other reagents were purchased from Nacalai Tesque (Kyoto, Japan).

Training protocols for oil ingestion. To allow the rats to get accustomed to ingesting corn oil, mineral oil, and 1% linoleic acid, the rats were fed these liquids in their home cages before surgery and then in the microdialysis cage after recovery from surgery. The rats were deprived of water and food for 4 h and the liquids presented for 30 min. Before surgery, the rats were presented with corn oil and mineral oil at the same time on days 1 and 4, with mineral oil and 1% linoleic acid on days 2 and 5, and with 1% linoleic acid and corn oil on days 3 and 6.

To confirm the rats’ preference for corn oil versus mineral oil, the rats were subjected on day 7 to a 2-bottle preference test for corn oil vs. mineral oil. The bottle of each liquid was positioned randomly. After recovering from the surgery, the rats were presented one kind of liquid in the microdialysis cage as follows: corn oil on days 1 and 4, mineral oil on days 2 and 5, and 1% linoleic acid on days 3 and 6. The rats were then subjected to a microdialysis test on day 7.

Microdialysis. Surgery: The animals were anesthetized with pentobarbital sodium (Nembutal; Dainippon Pharmaceutical Co., Tokyo, Japan) and placed in a stereotaxic frame adapted for rat surgery. The skull was subsequently exposed, and holes for microdialysis were drilled. The respective coordinates for the NAc shell and in complete compliance with the National Institutes of Health Guide for the Care and Use of Laboratory Animals, and was approved by the above-mentioned committee. Male Wistar rats (Japan SLC, Hamamatsu, Japan) at 8 weeks old were housed in stainless wire mesh cages in a room controlled by a 12-h light-dark cycle (dark phase of 18:00-6:00) and constant temperature (24 ± 1 °C). They were separately housed for a week for acclimatization to the environment. The animals were fed tap water and regular MF rat food (Oriental Yeast, Tokyo, Japan) ad libitum.

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Microdialysis. Surgery: The animals were anesthetized with pentobarbital sodium (Nembutal; Dainippon Pharmaceutical Co., Tokyo, Japan) and placed in a stereotaxic frame adapted for rat surgery. The skull was subsequently exposed, and holes for microdialysis were drilled. The respective coordinates for the NAc shell and amygdala guide cannula (AG-10; Eicom, Kyoto, Japan) were AP, 1.7; ML, 0.2; and DV, 8.0; and AP, −2.8; ML, 5.0; and DV, 7.5 from the bregma. All coordinates were determined according to the stereotaxic atlas of Paxinos and Watson.25) The cannulas were secured to the skull with a LOCTITE 454 adhesive bond (Henkel Japan, Yokohama, Japan). A dummy AD-10 cannula (Eicom) was inserted into the guide cannula. The rats were anesthetized with sodium pentobarbital. The brain was removed from the skull, frozen and cut into 30-μm sections. The placement of the microdialysis probe was verified by thionine blue staining. Data obtained from the rats with inappropriate probe placement were excluded from the analysis.

Statistics. Data are expressed as the mean ± SEM. Data from the 2-bottle preference test were analyzed by a paired t-test. Changes in DA levels were compared with the corresponding baseline value by one-way ANOVA and Tukey’s multiple-comparison test as a post-hoc test. Mean differences among 3 groups at each time point were analyzed by two-way repeated-measures ANOVA and Bonferroni’s multiple-comparison test as a post-hoc test. The amounts of each fluid ingested during microdialysis were analyzed with one-way ANOVA and the Tukey–Kramer test as a post-hoc test. p values of 5% or less were considered statistically significant. Statistical analyses were conducted by using the Prism 4 software package (GraphPad, San Diego, CA, USA).

Results

Validation of the preference for oil after ingestion training

The 2-bottle preference test on day 7 before surgery demonstrated that the rats significantly preferred corn oil to mineral oil (Fig. 1, p < 0.05 by the paired t-test).

Effect of oil intake on the extracellular DA level in the NAc shell

The intake of 1% linoleic acid was greater than that of mineral oil during the microdialysis test (Fig. 2B; p < 0.05 by the Tukey–Kramer test). No significant difference was apparent between other combinations of liquids. Figure 2A shows the time-course changes to the DA level in the NAc shell of rats that had ingested each liquid. There was no difference in the baseline extracellular DA concentrations in NAc among those rats respectively ingesting corn oil, 1% linoleic acid, and mineral oil (0.49 ± 0.16 pg/μL, 0.76 ± 0.22 pg/μL, and 0.52 ± 0.11 pg/μL). There was no significant change to dialysate, samples were analyzed by reversed-phase HPLC with an electrochemical detector, using an Eicompp PPD-ODS column (4.6 i.d. × 30 mm long; Eicom). The applied voltage was set at 450 mV (relative to an Ag/AgCl reference electrode). The mobile phase at a flow rate of 500 μL/min consisted of a 99% (v/v) 0.1 M phosphate buffer at pH 6.0, 1% (v/v) methanol, 500 mg/L of sodium decane sulfate, and 50 mg/L of 2Na-EDTA. The mean value obtained from 3 samples from −20 to −5 min was set as the 100% baseline level, and all subsequent sample values were expressed as a percentage of the baseline value.

Histological analysis. After completing the experiment, the rats were deeply anesthetized with sodium pentobarbital. The brain was removed from the skull, frozen and cut into 30-μm sections. The placement of the microdialysis probe was verified by thionine blue staining. Data obtained from the rats with inappropriate probe placement were excluded from the analysis.

Fig. 1. Preference for Corn Oil before Surgery.

The rats (n = 35) were subjected to a 2-bottle choice test with the presentation of 100% corn oil and 100% mineral oil at the same time for 30 min, the amount of each liquid ingested being recorded. Data are presented as the mean intake ± SEM summed for 30 min per rat (p < 0.0001, corn oil vs. mineral oil intake by a paired t-test).
DA level in the rats ingesting mineral oil; however, the DA level in the rats ingesting corn oil was significantly higher than the baseline value at times of 0–15 min (vs. baseline by Tukey’s multiple-comparison test: 123.4 ± 3.8% at 0 min, \( p < 0.01 \); 128.1 ± 4.6% at 5 min, \( p < 0.001 \); 129.8 ± 6.2% at 10 min, \( p < 0.001 \); and 120.4 ± 5.0% at 15 min, \( p < 0.05 \)). The DA level in the rats ingesting 1% linoleic acid was significantly higher than the baseline value at times of 0–20, 40, and 45 min (vs. baseline: 121.9 ± 4.3% at 0 min, 124.8 ± 5.5% at 5 min, 125.9 ± 9.0% at 10 min, 120.1 ± 3.6% at 15 min, 117.1 ± 5.8% at 20 min, 112.5 ± 3.1% at 40 min, and 113.8 ± 5.0% at 45 min). The \( p \) values at these times were as follows: \( p < 0.001 \) at 0, 5, 10, 15 min, \( p < 0.01 \) at 20 min, \( p < 0.05 \) at 40 and 45 min. The DA levels in the rats ingesting corn oil and 1% linoleic acid were significantly higher than those in the rats ingesting mineral oil at 5 and 10 min by Bonferroni’s multiple-comparison test (vs. mineral oil: \( p < 0.01 \) at 5 min and \( p < 0.001 \) at 10 min for corn oil; \( p < 0.05 \) at 5 min and 10 min for 1% linoleic acid). Figure 2 shows the typical position of the microdialysis probe inserted into the NAc shell.

Effect of oil intake on the extracellular DA level in the amygdala

The intake of 1% linoleic acid was greater than that of mineral oil during the microdialysis test (Fig. 3B; \( p < 0.05 \) by the Tukey–Kramer test). There was no significant difference in intake between the other combinations of liquids. Figure 3A shows the time-course changes in the extracellular level of DA in the amygdala of rats ingesting each liquid. There was no difference among the baseline extracellular DA concentrations of the rats respectively ingesting corn oil, 1% linoleic acid, and mineral oil (0.58 ± 0.18 pg/μL, 0.67 ± 0.57 pg/μL, and 0.75 ± 0.18 pg/μL). There were small but significant increases in the DA level of the rats ingesting mineral oil at 0–10 min (vs. the baseline by Tukey’s multiple-comparison test: 109.8 ± 0.6% at 0 min, \( p < 0.05 \); 110.5 ± 0.7% at 5 min, \( p < 0.01 \); 110.5 ± 0.9% at 10 min, \( p < 0.01 \)). The DA levels in the rats ingesting corn oil were significantly higher than the baseline values at time points 0–20 min (vs. baseline by Tukey’s multiple-comparison test: 129.9 ± 4.9% at 0 min, 129.0 ± 3.0% at 5 min, 128.3 ± 4.5% at 10 min, 125.5 ± 2.5% at 15 min, 119.0 ± 3.4% at 20 min, and 122.4 ± 3.6% at 25 min; \( p < 0.001 \) at 0, 5, 10, 15, and 25 min, \( p < 0.01 \) at 20 min). Significantly higher levels of extracellular DA were also observed in the rats ingesting 1% linoleic acid at time points 0–25 min (vs. baseline: 127.9 ± 3.4% at 0 min, 125.2 ± 3.1% at 5 min, 125.1 ± 6.2% at 10 min, 125.2 ± 5.7% at 15 min, 124.0 ± 4.4% at 20 min, and 121.5 ± 5.3% at 25 min; \( p < 0.001 \) at 0, 5, 10, 15, and 20 min, \( p < 0.01 \) at 25 min). There was no significant difference among the DA levels of the 3 groups at corresponding time points. Figure 3C shows the typical position of the microdialysis probe inserted into the amygdala.

Discussion

Previous reports have shown that the higher the concentration of sucrose(10) or cocaine(11) ingested or self-administered by rats, the greater the increase in DA level in their NAc shell. These reports indicate the possibility
that the increased DA level in NAc might be correlated with the degree of pleasantness and palatability, and could be considered an index of the reward value or motivational state of the animal. In respect of oil ingestion, sham feeding of corn oil (the rats were operated on to drain out the ingested solution before it had reached the stomach) has been reported to increase the DA level in NAc of rats, this finding suggesting that information from the oral cavity was sufficient for increasing the DA level and that feedback from the digestive tract was not necessary. We have reported in a previous study that the licking ratio for a low concentration of LCFA was similar to that for 100% corn oil administration of a D1-receptor antagonist to the amygdala, as well as to the NAc shell, and the amygdala has been more strongly activated by high-fat food ingestion than by low-fat food ingestion. Moreover, the amygdala has been more strongly activated by high-fat food ingestion than by low-fat food ingestion. We also observed that there was an increase in extracellular DA level in the amygdala of rats exposed to handling stress. Furthermore, Yokoyama et al. have reported that a conditioned stimulus, in addition to an unconditioned stimulus (foot shock), caused the DA level to rise in the amygdala of rats in a conditioned-fear experiment involving foot shock. However, some recent studies have reported the involvement of the amygdala in both negative emotions and in positive ones. For example, Polston et al. have reported an increased DA level in the amygdala in response to a reward stimulus such as methamphetamine, and See et al. have shown that the administration of a D1-receptor antagonist to the amygdala inhibited the reinstatement of cocaine self-administration. Food addiction scores have been reported to be correlated with activation of the amygdala in fMRI measurements on young women, and the activity of the amygdala observed during food intake (also with fMRI) increased more in response to an increase in taste intensity than to taste affective valence. Moreover, the amygdala has been more strongly activated by high-fat food ingestion than by low-fat food ingestion. In our experiment, more palatable food clearly resulted in an increased DA level in the amygdala, the extracellular DA level there increasing after the ingestion of corn oil and 1% linoleic acid, these liquids being consumed by rats in preference to mineral oil.

Mineral oil was clearly preferred to water by rat pups aged 12–15 d, and had similar acceptability to corn oil by adult rats. We also observed that mineral oil was preferentially consumed and that the ingested volume of mineral oil was more than that of water by mice (Taka and Fushiki, unpublished data). Although the method for administration was different via an oral cannula, mineral oil has a similar texture to corn oil but does not contain LCFA and is not digestible. Consequently, it cannot be utilized by animals and has very little reward value, based on the increase in DA level in the NAc shell observed in this study.

Dopaminergic neurons in the VTA project to the amygdala, as well as to the NAc shell, and the amygdala is thought to be involved in the manifestation of negative emotions like fear and in the evaluation of a negative reward value. Inglis and Moghaddam have reported that there was an increase in extracellular DA level in the amygdala of rats exposed to handling stress. Furthermore, Yokoyama et al. have reported that a conditioned stimulus, in addition to an unconditioned stimulus (foot shock), caused the DA level to rise in the amygdala of rats in a conditioned-fear experiment involving foot shock. However, some recent studies have reported the involvement of the amygdala in both negative emotions and in positive ones. For example, Polston et al. have reported an increased DA level in the amygdala in response to a reward stimulus such as methamphetamine, and See et al. have shown that the administration of a D1-receptor antagonist to the amygdala inhibited the reinstatement of cocaine self-administration. Food addiction scores have been reported to be correlated with activation of the amygdala in fMRI measurements on young women, and the activity of the amygdala observed during food intake (also with fMRI) increased more in response to an increase in taste intensity than to taste affective valence. Moreover, the amygdala has been more strongly activated by high-fat food ingestion than by low-fat food ingestion. In our experiment, more palatable food clearly resulted in an increased DA level in the amygdala, the extracellular DA level there increasing after the ingestion of corn oil and 1% linoleic acid, these liquids being consumed by rats in preference to mineral oil.

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oil ingestion resulted in a low but significant increase in the extracellular concentration of DA in the NAc shell of rats (Adachi et al., manuscript in preparation). However, the reward value of mineral oil would be lower than that of corn oil, and the level of the DA increase in NAc might not have been captured by unknown factor in this experiment. The different response to mineral oil ingestion between the two brain nuclei should be further studied.

A main ingredient of cooking oil is triacylglyceride that consists of esterified glycerol with LCFA. Kawai and Fushiki have demonstrated that a few percent of triacylglycerol administered into the oral cavity was hydrolyzed into LCFA by lingual lipase secreted by von Ebner’s glands present in the circumvallate papillae of rats.17) Gilberston et al. have elucidated the regulation of K⁺ channels in type II taste cells by long-chain unsaturated fatty acids and suggested a chemical receptor for fatty acids in taste cells.18) Fukuwatari et al. have demonstrated the expression of CD36, which is a translocator of LCFA, on the apical surface of taste cells of the circumvallate papillae in rats.19) and Laugerette et al. and Martin et al. have found no preference for fatty acids in CD36-deficient mice. These findings suggest the chemoreception of dietary fat via CD36 in the oral cavity. In addition, Matsumura et al. have studied the expression of GPR120 on the tongue,20,21) and reported a decrease in preference for fat by GPR120-deficient mice.22) Moreover, Yoneda et al. have demonstrated that mice preferred about a 1% concentration of LCFA and that a low concentration of LCFA manifested similar palatability to that of corn oil in the oral cavity. These reports indicate that chemoreception of LCFA via fatty acid receptors like CD36 and GPR120, which are expressed on the tongue, was involved in fat palatability.

Liu et al. have reported that information on fatty acid reception was intracellularly transduced via transient receptor potential channel type M5 (TRPM5). Taste cells from TRPM5-deficient mice showed no intracellular increase in the calcium ion concentration by stimulation with linoleic acid. They have indicated that certain GPCRs were present upstream of this transduction mechanism. Additionally, Shah et al. have demonstrated that, although not present in taste cells but in STC-1, an enteroendocrine cell line, TRPM5 played a critical role in cholecystokinin (CCK) release by linoleic acid, which has a very low calorie level, these levels being comparable to those of full caloric 100% corn oil. These data support the notion that the chemoreception of LCFA released from fat by lingual lipase plays a critical part in the detection of fat in the oral cavity and the manifestation of a reward effect.

To summarize, the results of the present study corroborate the increase in extracellular DA levels in the NAc shell and BLA of rats after ingesting 1% linoleic acid, which has a very low calorie level, these levels being comparable to those of full caloric 100% corn oil. These data support the notion that the chemoreception of LCFA released from fat by lingual lipase plays a critical part in the detection of fat in the oral cavity and the manifestation of a reward effect.

Acknowledgment

This study was supported by the Program for Promotion of Basic and Applied Researches for Innovations in Bio-oriented Industry.

References

8) Vucetic Z and Reyes TM, Wiley Interdisciplinary Reviews: Systems Biology and Medicine, 2, 577–593 (2010).


