Individual Taste Preferences Predict Cortical Taste Dynamics but Are Modified by Experience

Kathleen C. Maigler[1], Jian-You Lin[2], Ethan Crouse[1], Bradly T. Stone[1], Ainsley E. Craddock[1], and Donald B. Katz[1,2,3]

[1]Neuroscience Program, [2]Department of Psychology, [3]Volen National Center for Complex Systems, at Brandeis University, Waltham, MA, USA.

Affiliation Postal Code
Brandeis University
415 South Street
Waltham, MA 02453

Corresponding Author:
Dr. Donald B. Katz (dbkatz@brandeis.edu)

KCM and JYL share first authorship.

Conflict of Interest Statement:
The authors declare no competing financial interests.

Abstract

As is true in humans, no two rodents prefer precisely the same tastes, and no one rodent shows precisely the same taste preference pattern forever. Here, we make use of this between- and within-animal variability to generate and test novel insights about the stability and malleability of neural perceptual coding. We used a brief-access task (BAT) to reveal both between-rat individual differences in taste preferences and shifting preferences within individual rats (quantified in terms of lick bout lengths). We moved on to show that these phenomena are not simply random variation: first, we demonstrated that gustatory cortical (GC) taste response dynamics, the late part of which have been shown to reflect palatability, match that individual rat's BAT preferences (evaluated almost 2 weeks prior) better than canonical preference patterns, revealing that the individual differences reflect differences in neural taste processing; this enhanced correspondence, however, links neural taste processing only to the most recent BAT session—GC palatability processing does not reflect performance in earlier BAT sessions. The finding that rats' perceptual preferences shift across BAT sessions carries with it the implication that any tasting experience might change these preferences. We tested this implication by performing a second session of GC taste-response recordings—sessions in which tastes were delivered by intra-oral cannula to passive rats—and found that palatability-epoch taste responses in this later session no longer matched the most recent pre-recording BAT session. Together, these data demonstrate that every tasting experience (regardless of the method of taste delivery) changes the rat's perceptual/neural processing of those tastes.

Introduction

The basic task facing an animal's perceptual systems—processing input such that the animal can generate appropriate behavioral output—is of particular importance when said input is gustatory, because taste-guided consumption decisions are made when a potentially dangerous substance is already in the mouth. Palatability (the hedonic value associated with a taste) is the primary variable informing the selection of responses (swallowing or rejection) to such stimuli, and it is therefore unsurprising that a sweet (caloric) taste would be ubiquitously preferred, and a bitter (potentially toxic) taste ubiquitously shunned.

But despite the inescapability of the above logic, individual differences in palatability judgments abound. It is a given, in fact, that different human animals have different specific likes and dislikes when it comes to food; for any particular taste and flavor, there can be found people who love it and people who loathe it. And this is not just true for humans: rat taste preferences vary from strain to strain (Bachmanov et al., 1998; Grill & Bernstein, 1988) and even from individual to individual (Bacharach & Calu, 2019; Inui-Yamamoto et al., 2017; Kotlus & Blizard, 1998; Loney et al., 2012). While part of the explanation for these individual differences is no doubt genetic (Armitage et al., 2025; Bachmanov et al., 2016; Blizard, 1999; Keskitalo et al., 2007), a good deal of evidence supports the hypothesis that experience and eating history control individual taste preferences. Humans from different cultures and subcultures have notably different food preferences (Jamel, 1996), and experience—both social and non-social—is known to impact taste preferences (Herman & Higgs, 2015; Robinson & Higgs, 2012; Story et al., 2002). Social interactions can change the preferences of rodents as well (Galef & Wigmore, 1983; Posadas-Andrews & Roper, 1983), and even innocuous experience has an impact on rat taste coding that could conceivably change preferences (Flores et al., 2016; Flores et al., 2018).

The above work motivates the suggestion that neural taste processing should differ from animal to animal, and even from day to day within single animals, in concert with differences in preference patterns. But there has been very little work done on the relationship between individual differences and neural perceptual responses, and essentially none looking at the stability of this relationship through time. Here we perform this work, repeatedly evaluating rats' taste preferences using a brief-access task (BAT) that allows rigorous estimates of between-taste preference patterns in a single session, and comparing these perceptual behavioral data to assays of the rats' gustatory cortical (GC) responses to the same tastes—responses that have been reliably and repeatedly shown to reflect palatability in the "late response epoch" spanning the period between ~0.5s and ~1.5s following taste delivery (Katz et al., 2001; Mukherjee et al., 2019; Sadacca et al., 2016).

Individual rats' BAT preferences proved to be a specific match for those rats' "Late-epoch" GC responses, despite: 1) 2-week "empty stretches" between collection of behavioral and electrophysiological data; 2) a range of sampled taste batteries; and 3) vast differences in taste administration methods (licking in the BAT rig; passive intra-oral cannula delivery in electrophysiology sessions) for the two types of sessions. But this match was delicate, in that even single tasting experiences changed perception—palatability-related GC responses matched the most recent BAT preference assessment but not assessments from earlier days, and a second test of the rats' GC taste responses

one day after the first no longer matched the preference ranking from the most recent BAT preference test.

Together, these data demonstrate that: 1) palatability-related spiking in the late "epoch" of a rat's GC taste responses reflects that individual rat's taste preferences; 2) these preferences are relatively stable across multiple weeks, provided that the rat does not have intervening taste experience; and 3) the rat's perceptual preferences can quickly change with taste experience, regardless of whether the experience is self-acquired or experimenter-applied.

Results

Taste preferences vary between animals and across days

To measure each rat's taste preferences, we analyzed licking patterns from Brief-Access Task (BAT) data. This approach provides a rapid and reliable assessment of preferences across an entire taste battery; in particular, analysis of lick microstructure—most notably, calculation of the average size of lick clusters in 10-sec trials—has been shown to be an accurate assessment of the palatability of a proffered taste (Dwyer, 2009; Lin et al., 2012; Lin et al., 2025; Strickland et al., 2018), with smaller average cluster sizes equating to lower palatability. In the most rigorous test of preferences, comparison of cluster sizes provides an accurate picture of which tastes an animal likes more, and which tastes it likes less.

Figure 3A1 shows average sucrose, NaCl, and quinine lick cluster sizes for two representative rats' initial BAT sessions. While both rats produced very small lick clusters when offered the bitter quinine, and both produced large lick clusters when offered NaCl, they differed notably in their sucrose cluster sizes. A 2-way ANOVA of these data revealed a significant rat x taste interaction ($F(2,65)=13.44$, $p < 0.001$), with one of the two rats preferring sucrose to NaCl ($p < 0.05$) and the other barely preferring sucrose to quinine ($p > 0.05$).

In even casual scrutiny of **Figure 3A2**, which presents lick cluster sizes to every taste across all 9 rats (the red dashed box delineates the rats used for **Figure 3A1**), it is clear that while few rats didn't like sucrose, individual variability was the rule across the entire sample of rats, and that individual preference orders often diverged from the canonical palatability ranking (sucrose > NaCl > citric acid > quinine). While we varied the precise battery offered from rat to rat (to ensure that results of our brain-behavior relationship tests were generalizable; see Methods), inspection of differences between sucrose and NaCl (typically the most palatable tastes) lick cluster sizes in every rat that sampled both (**Figure 3A3-top**) makes it clear that some rats prefer (this concentration of) NaCl over (this concentration of) sucrose, while others do not. Similarly, differences between citric acid and quinine (typically the most aversive tastes) lick cluster sizes (**Figure 3A3-bottom**) revealed individual differences in aversiveness: some rats disliked quinine more than citric acid whereas several did not. These impressions were statistically confirmed using one-sample t-tests against a null hypothesis of zero difference, with Bonferroni correction applied ($ps < 0.008$; see figure legends for exact *t*- and *p*-values).

Individual differences in taste preferences persisted across several days of testing, in that on the rats' final day of BAT testing (depending on the rat, this was either the 3rd

or 5th session), the results continued to reveal robust individual differences in taste preference (**Figures 3B1-3**; see figure legends for statistics and *p*-values, and note that one rat reliably shunned both quinine and citric acid after an initial lick bout, such that there was no error bar in the equivalent aversiveness of both tastes). These results support the suggestion that perceived palatability varies significantly from rat to rat, even after neophobia—a tendency to avoid novel tastes (Barnett, 1958; Domjan, 1977; Lin et al., 2012) that could possibly introduce rat-to-rat differences—has long since subsided.

Finally, a comparison of **Figures 3A3** and **3B3** makes it clear that rats' preferences changed with testing: 2-way ANOVAs revealed that the relative individual preference for either sucrose or NaCl was frequently different in the first and last tests ($F(5,116)=40.28$, $p < 0.001$), as was the relative aversiveness of quinine and citric acid ($F(5,116)=18.34$, $p < 0.001$; in both panels of **Figure 3B3**, "#" denotes significantly differences between the 1st and last session for that particular rat). That is, rats' taste preferences changed between testing sessions.

Individual rats' most recent taste preferences are specifically reflected in late-epoch GC taste responses

If the between-rat differences measured in the BAT test veridically reflect individual differences in perceptual preferences (as opposed to representing random variability in behavioral expression of population-general underlying preferences), then they should be reflected in that rat's neural taste responses. More precisely, the fact that gustatory cortex (GC) activity encodes taste palatability in the late taste-response epoch (Jones et al., 2007; Katz et al., 2001; Mukherjee et al., 2019; Sadacca et al., 2016) motivates the specific prediction that this activity should uniquely correlate with palatability rankings derived from each rat's own licking behavior (i.e., lick cluster size) during BAT testing.

To test this hypothesis, we recorded single-neuron spiking activity from GC in the same rats from which we collected preference data, while delivering tastants through pre-implanted intraoral cannulae (IOCs). A total of 230 GC neurons were recorded—25.5 ±12.1/rat. **Figure 4A** shows peri-stimulus time histograms (PSTHs) for a representative GC neuron's responses to the same tastes delivered in that rat's BAT sessions, overlain on one another. These responses replicate those observed in many previous investigations (Katz et al., 2001; Mukherjee et al., 2019; Sadacca et al., 2016): the firing caused by taste administration had little taste-specificity initially, becoming taste-specific only ~250 ms after delivery; the responses then came to reflect palatability only after the appearance of taste specificity, as indicated by the late appearance of significant correlations between firing rates and palatability after 500 ms of post-delivery time had elapsed (**Figure 4B**). Palatability-relatedness peaked (again consistent with previous reports) at approximately 1 second after taste administration, reaching a correlation of ~0.4 (i.e., r^2=0.16).

Note, however, that the correlation calculated from comparison of neuron firing to the "canonical" palatability rankings (green line) was, while significant, dwarfed by the much stronger correlations between GC late-epoch firing and palatability rankings estimated from the animal's own lick cluster sizes (NaCl > low NaCl > quinine > citric acid; **Figure 4B** inset) measured in the most recent BAT (orange line). That is, this rat's GC taste responses were specifically related to its own preferences. This neural expression of individually specific response tuning is particularly striking given the fact that: 1) the

BAT preference evaluation took place almost 2 weeks prior to the electrophysiology session; and 2) the method of taste administration was starkly different in the two sessions—rats obtained their own taste samples through licking in the BAT, and passively received IOC deliveries of tastes in electrophysiology sessions. We can therefore conclude that individual differences in taste preferences as measured in the BAT are real, robust to these variables (see Discussion), and stable across weeks of recovery, at least when those weeks contained no experience with strong basic tastes.

In contrast, sessions of taste experience had a significant impact on preferences. Closer inspection revealed that only the most recent BAT preferences were reflected in neural activity. **Figure 5A**, which presents the analysis for the entire sample of rats (N = 9), confirms that the magnitude of the late-response palatability-relatedness of firing evaluated using individual rats' final BAT data (orange curve) is more than twice as strong than when using canonical palatabilities (green curve; note that the small overall magnitude of r^2 values has to do with the lack of data selection—the fact that we did not restrict the analysis to those neurons with late-epoch palatability-related responses). This match to the rats' own data is entirely lost, however, when the first BAT session is used (blue curve). The robustness of this difference is underscored by the fact that only 1-3 days separated these different BAT sessions—1 to 3 days of tasting was enough to eliminate the effect. In fact, the peak neural correlation with palatability was slightly (but significantly) higher when canonical palatabilities were used than when earlier BAT sessions were used (we have no explanation for this small effect, but see Discussion for speculative consideration). Clearly, the repeated BAT sessions significantly altered the rats' preferences.

Figure 5B summarizes these results in an analysis comparing correlations between GC firing and preference patterns evaluated in different manners. The comparison was done separately for "early" (200–700 ms, a period during which GC responses largely reflect taste identity) and "late" (700–1200 ms, the time during which GC responses are coming to reflect palatability) epoch responses. As expected, effects were minimal during the early epoch, because responses at that time point were not palatability-related—the slight but significant difference between individual preferences measured in the most recent BAT and canonical preferences almost certainly reflects the onset of the Late epoch, a conclusion supported by the lack of significance in a comparison of the effect using first and last BAT rankings ($F(1,128) = 2.21$, $p > 0.05$).

Between-condition differences were pronounced, however, during the late epoch, when GC activity is known to reflect palatability. The brain-behavior correlation was significantly enhanced when using final BAT rankings (compared to when using canonical rankings; $t(128) = 5.71$, $p < 0.001$), and significantly poorer when using first BAT rankings ($t(128) = -3.20$, $p < 0.01$). The difference between these two effects was (of course) significant ($F(1,128) = 30.31$, $p < 0.001$). Palatability-related firing, which is restricted to the later aspects of GC taste responses, uniquely reflects the most recent assay of a rat's individual taste preferences.

Any tasting experience changes rat taste preferences.

The above results demonstrate that individual differences in taste preferences reflect between-rat variability in neural taste processing, but also demonstrate that taste experience in the BAT changes those preferences such that the match between an

individual rat's palatability-related neural responses and earlier preference tests is lost. An obvious question regarding this result has to do with the specificity of the effect; it is important to ask whether it is only BAT-type taste experiences—experiences in which taste samples are acquired *via* licking, under the rat's control—that alter taste system function in such a way that preferences change. Alternatively, it is possible that any experience with strong concentrations of basic tastes will alter preferences (and neural processing).

This speculation engenders a specific novel hypothesis: if only self-administered experience with tastes licked from a source is sufficient to alter overall preference patterns, then electrophysiology sessions (which involve repeated administrations of each taste to passive rats *via* IOC) should have no such impact; if so, the palatability-related firing observed in a second electrophysiology session should continue to match the most recent prior BAT-based preference evaluation. We tested this novel hypothesis by conducting a second recording session 24 hours after the first to assess whether GC taste responses continued to correlate with licking-based individual preferences (note that between sessions, we advanced the chronically implanted electrodes by ~250 microns to ensure that the test was performed on a new set of neurons).

Figure 6 shows the result of this test. **Figure 6A**, which presents the same moving-window assessment of correlations between neural firing and palatability used in Figures 4 and 5 (and in many previous publications), once again replicated the late-epoch rise in palatability-relatedness of GC activity; this late-epoch coding of palatability was robust across different specific measures of taste preference. The neural responses in this second electrophysiology test no longer reflected the rats' recently-assayed individual preferences, however, as evidenced by the fact that the correlations with canonical taste preferences, first BAT taste preferences, and final BAT taste preferences were essentially identical—there was no evidence of an enhancement of the GC response correlation with the most recent BAT data when using neurons recorded in the second electrophysiology session.

This observation was confirmed by analyses showing no significant difference between correlations with canonical palatability ranks and correlations with ranks derived from either the first or last BAT sessions (*ps* > 0.05; **Figure 6B**). We therefore conclude that both lick-acquired and IOC-delivered taste experience quickly changes taste preferences.

Discussion

The fact that our BAT data revealed individual rats to have distinct taste preference patterns (i.e., their own ideas of what tastes better and worse) is perhaps not surprising, although the magnitude of those individual differences is almost certainly larger than many would have predicted (particularly given the homogeneity of our rats' genetics and environment). More surprising is our finding that, even with a surgery, almost 2 weeks of recovery, and a major change in stimulus delivery method interpolated between the BAT and electrophysiological assays, individual behavioral differences are reflected in ("late-epoch") GC palatability-related spiking. Most surprising, however, are the perceptual changes wrought by even a single tasting experience—whether lick-acquired or IOC-delivered, taste delivery changed preference patterns. Apparently, every new tasting experience changes what a rat thinks of a taste in its mouth; at least as far as gustation is concerned, Heraclitus was correct that "no [animal] ever steps in the same river twice."

These results validate the use of a brief-access task (BAT), and more specifically of lick cluster size, to measure a rodent's palatability judgments, suggesting that the apparent individual and between-session variability that these tests reveal is *bona fide*. The significantly enhanced match between a specific rat's measured preferences and their GC late-epoch neural responses (compared to canonical average preference rankings) makes it clear that between-rat variability in BAT performance is not noise but signal—each animal is genuinely different. This fact means that consumption averages calculated from BAT data should always have substantial confidence intervals around them. Furthermore, this brain-behavior match provides convergent evidence that the late-epoch GC response, which both predicts and drives the onset of consumption and rejection (Baas-Thomas et al., 2025; Li et al., 2016; Mukherjee et al., 2019; Sadacca et al., 2016), is deeply relevant to behavior; the transition to palatability-related ensemble firing reflects the reaching of a consumption decision, made on the basis of neural processing that is to some degree specific to the animal and session.

This processing turns out to be remarkably stable (note that this means that the relationships between responses are stable—it does not necessarily mean that the precise responses are themselves unchanging) across days and weeks in which no specific experience with the basic tastes is provided. We performed electrode implantation surgeries after the last BAT preference testing session and gave each rat approximately 11 days to recover prior to the beginning of adaptation to the electrophysiology acquisition setup, such that almost 2 weeks separated behavioral and neural evaluations of taste palatability overall. Despite this separation, brain-behavior correlations were heavily influenced by the individual rat's BAT performance, a relationship that persisted despite the fact that BAT and electrophysiology sessions differed with regard to: 1) whether the rat was engaged in active sensing (BAT) or passive acceptance (electrophysiology); 2) whether the taste was licked (BAT) or delivered directly into the mouth *via* IOC (electrophysiology); and 3) whether the tastant accumulated in the mouth bit by bit (BAT) or in a single aliquot (electrophysiology). In essence, our experiments constituted a highly conservative test, in that each of the variables discussed above (including the 2-week between-session interval) would be expected to reduce the brain-behavior correlation; the fact that our results were nonetheless highly significant stands in testament to the robustness of our test, and the strength of our conclusions.

Regardless, the stability of preferences proves delicate, and dependent upon a lack of experience with sapid tastants between the BAT and recording sessions (note that in their home cages, rats may choose to partake only of bland chow and highly familiar biological detritus, and have no access to any strong exemplars of the basic tastes). Rats showed robust changes in their preferences across multiple BAT sessions, and only the preference pattern from the final BAT session matched the palatability-related GC firing recorded during the subsequent IOC session. This surprising result motivated a further test involving a comparison between two successive recording sessions: we reasoned that, if any tasting experience changes preference patterns, only the first recording session would be a good match for the individual differences measured in the prior BAT session; this test revealed that even tastes passively sampled through the IOC change perception; either of the two (very different; see above) types of taste experience is sufficient to change a rat's taste preference structure enough that it no longer matches earlier tests.

We consider this last point to be of particular importance. It is already well known that a first experience with a particular taste can increase the palatability of that novel taste—a phenomenon known as the attenuation of neophobia (Lin et al., 2012; Menchén-Márquez et al., 2026). However, the phenomenon characterized in this current dataset is almost certainly not related to neophobia, in that: 1) these changes occur with each new session, even when the tastes can no longer be thought of as novel; and 2) these session-to-session changes cannot be described simply as an increase in each taste's palatability—if the palatabilities of all tastes increased together, preference ranks would have remained unchanged. Rather, our data suggest that aspects of taste processing that can otherwise remain stable across at least a 2-week period are altered by each and any taste experience, even after many taste experiences have already taken place.

By taking advantage of the naturally occurring individual differences in taste preference, the present findings demonstrate that both the stability and plasticity of these preferences are reflected in the aspect of GC activity that predicts and drives consummatory behavior. In the absence of taste stimulation, taste preferences remain largely stable. In contrast, whenever taste experience occurs, preferences change accordingly. This coordinated change between brain and behavior supports the idea that GC's role in taste processing extends beyond simple sensory representation: it also contributes to the modulation of consummatory decisions by integrating sensory input with contextual and experiential information. In other words, GC functions not merely as a sensory encoder or decoder, but as an integrative hub that links perception with consumption behavior.

Materials and Methods

Subjects

Adult female Long Evans rats (N = 9; 250-375g at time of surgery) were acquired from Charles River Laboratories (Wilmington, MA), singly-housed in independently-ventilated cages on a 12h/12h light/dark schedule, and acclimated to the facility and handling for 1 week before the start of experimental procedures. Unless otherwise specified, animals in home cages had ad libitum access to lab chow and water. All

procedures were conducted in accordance with the guidelines established by the Brandeis University Institutional Animal Care and Use Committee.

Experimental Overview

Rats' taste preferences were assessed in the Brief-Access Task (BAT) for 3-5 days (**Figure 1A**). After BAT testing, the rats were implanted with a 32-channel electrode into primary gustatory cortex (GC; **Figure 2AB**). Following recovery, rats received passive taste deliveries *via* IOC while GC activity was recorded for two sessions (**Figure 1C**). There were ~11 days total (surgery recovery and rig habituation) between the last BAT and first electrophysiological testing session.

Brief Access Task (BAT) Preference Testing

The BAT rig (Davis MS-160 Lickometer apparatus, Med-Associates Instruments) assessed individual preferences for each taste in the battery. Before preference testing, rats underwent three days of 45-minute habituation to the experimental chamber, after which they were placed on water restriction and given two days of licking training—60 10s-trials in which water was available *via* a metal lick spout attached to glass bottles.

For the preference test assessment, rats were presented with a battery of tastes (in each rat, one of 3 different possible batteries of tastes were used to ensure that results were generalizable—see **Table 1**; as no differences in effects were observed between taste batteries, data was collapsed in our analyses) that spanned a putative range of palatabilities. One taste was offered per trial, in which rats were given 60s maximum to instigate licking, a maximum access time of 10s following the first lick, and a 30s inter-trial interval between trials. Tastes were presented in a pseudo-randomized order, such that two successive trials could neither offer identical tastants nor two aversive tastants (which would adversely impact willingness to participate). Each tastant was presented 8-10 times, depending on the specific taste battery. BAT testing persisted for 3 (taste set 1 & 2) or 5 (set 3) consecutive days.

Tastes, which were dissolved in deionized water (Millipore Milli-Q water purification system), were purchased from ThermoFisher Scientific at ACS Grade (with the exception of saccharin, which was FCC/USP Grade). A fan above the rig served to reduce any potential odor cues that might have accompanied taste presentation. The time of each lick was recorded for off-line preference analysis. All experiments were run between 10:00-16:00.

Surgical implantation of GC electrode and Intra-Oral Cannula

After the final BAT session, animals were removed from water deprivation and allowed to recover to full, pre-restriction weight for implantation surgery. Rats were anesthetized with an intraperitoneal injection of ketamine (100 mg/kg) and xylazine (5 mg/kg), and craniotomies were made to expose GC. The drivable electrode, consisting of a bundle of 32 nichrome wires (25 μm in diameter), was implanted just above GC (A/P = +1.4, M/L = ±5.0, D/V = -4.4), and secured in place with dental acrylic. Rats also received an intra-oral cannula (IOC)—a polyethylene cannula inserted behind the maxillary molars, through the left masseter muscle and through the opening of the scalp.

Rats recovered for 7 days; during the first day, meloxicam (Alloxate, 5mg/ml, Patterson) (1mg/kg) was injected for pain management.

Electrophysiological recording with passive tastant delivery

After recovery from surgery, rats habituated for 2 days (30-minute sessions) to the electrophysiological recording rig (plugged into their electrode harness in a plexiglass experimental chamber measuring 8.5 x 9.5 x 11.5 in), after which they were placed on water restriction in preparation for recording experiments. Experiments began with two days of habituation to liquids delivered through the IOC, during which 60 (day 1) and 120 (day 2) trials of water were delivered with inter-trial intervals of 22s. Twenty-four hours after, each rat received two consecutive recording days where 30 randomized presentations of each tastant (a total of four tastes selected from the same taste set received during the BAT preference testing; **Table 1**) were delivered.

Delivery of each taste was individually controlled by solenoid valves, pressurized by inert nitrogen. To ensure our ability to deliver precise amounts of fluid onto the tongue of each IOC delivery, we calibrated the rig to deliver 30 microliters in each aliquot at the beginning of each recording session, controlling the open time of valves *via* a Raspberry-Pi microcomputer.

Spiking data were collected *via* Intan RHD2132 analog-to-digital chip amplifier. Recordings were taken at a sampling rate of 30 kHz. Electrodes were driven down (~0.25mm) 24hr prior to each recording session to capture different populations of GC neurons for each session. The entire recording rig was enclosed in a faraday cage to reduce latent electromagnetic interference during recordings.

Electrophysiology data processing

Bandpass filtering and common average referencing were used to clean data and increase signal quality. Discriminable action potentials of no less than 3:1 signal-to-noise ratio were isolated online from each signal and saved digitally. Prior to analysis of taste-related activity, cells were clustered using 3-D cutting techniques alongside supervised verification of inter-spike interval plots. All spikes included in analysis had at least 2000 waveforms and met our criteria of < 0.5% 1ms violations and <2% 2ms inter-spike interval violations. For a comprehensive explanation of the protocol used for spike sorting, refer to Mukherjee et al. (2017). By driving down the mini-microdrive between sessions, new cells were captured each day, which was verified by comparing waveform shapes.

Semi-processed spiking arrays were then exported to an analysis framework built in python. After processing, each 7000ms (2s pre-stimulus, 5s post-stimulus) recording window was binned using a sliding window average with a window size of 250ms and a step size of 25ms.

Data analysis

Computational analysis of BAT data and preference ranks

Lick data was processed and analyzed in custom Python scripts. Libraries integral to the analysis included: pandas, numpy, pingouin, matplotlib, and seaborn. Several lick parameters were measured for each tastant presentation; we used the inter-lick interval (ILI; ~125msec) to determine lick cluster size—the number of licks produced prior to a 500ms pause (**Figure 1A**). Individual taste preferences were estimated using averaged lick cluster sizes obtained from a BAT session.

Palatability correlation

The method of calculating correlation between GC activity and palatability has been described previously (Katz et al., 2001; Sadacca et al., 2016): a vector of firing rates in each taste response at each 25-ms timepoint in a moving average is Spearman correlated (to control for nonhomogeneity) with the vector of preferences. For the "canonical" palatabilities, the data are first averaged across animals. To incorporate individual preferences here, we also correlated neural activity to animal-matched mean cluster values over all BAT sessions and in the first or most recent BAT session (First BAT, Final BAT).

Histology

Following the experimental sessions, subjects were deeply anesthetized with ketamine/xylazine mix (200, 20 mg/kg respectively, delivered *via* intraperitoneal injection) and perfused *via* intra-ventricular perfusion of saline, followed by 10% formalin. Brains were then extracted for histological verification of electrode placement. Electrode cannulae were painted with a fluorescent cell-labeling dye (Vybrant DiI, invitrogen) upon insertion to verify electrode location and regional markers were used to confirm the cannula track is above and the electrode tip sits in GC as confirmed by another independent experimenter. Following histological examination, one of the 10 experimental rats was removed from the experiment due to electrode misplacement, which left a total of 9 rats in the dataset (**Figure 2**)

Data availability

The data within this study can be made available from the corresponding author upon reasonable request. Spike sorting code used here as described above is available at https://github.com/narendramukherjee/blech_clust. This study's design and analyses were not pre-registered.

Acknowledgements

This work has been supported by National Institute on Deafness and Other Communication Disorders Grants R01- DC006666 & DC007703 to DBK and F31 - DC019863 to KCM.

	BAT Sessions	Electrophysiology Sessions
Set 1	NaCl (0.1M) NaCl (0.05M) Citric Acid (0.009M) QHCl (7.8E-5M) Citric Acid (0.00625M) QHCl (0.00156M) Water	NaCl (0.1M) NaCl (0.05M) Citric Acid (0.009M) QHCl (7.8E-5M)
Set 2	Sucrose (0.3M) NaCl (0.1M) Citric Acid (0.1M) QHCl (0.001M) Water	Sucrose (0.3M) NaCl (0.1M) Citric Acid (0.1M) QHCl (0.001M)
Set 3	Sucrose (0.3M) Saccharin (0.005M) NaCl (0.1M) Citric Acid (0.1M) QHCl (0.001M) Water	Sucrose (0.3M) Saccharin (0.005M) NaCl (0.1M) Citric Acid (0.1M)

Table 1. Summary of taste stimuli used in brief-access tests (BATs) and electrophysiological recording sessions. QHCl: quinine hydrochloride.

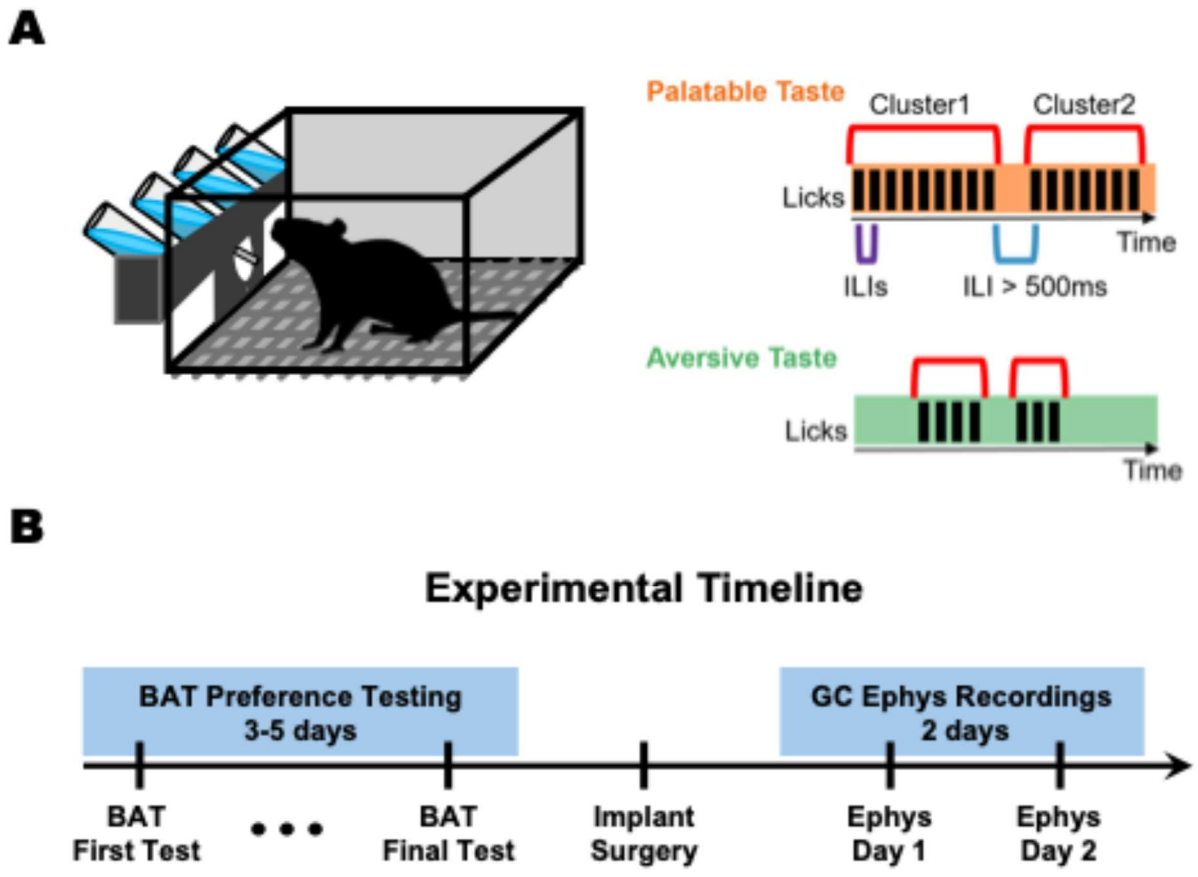

Figure 1. Brief-access rigs and experimental timeline. (A) The brief-access rig—multiple bottles, each made available periodically. To the right are example data schematizing the analysis of rhythmic licking to pull out lick numbers and "clusters," both of which reflect palatability. **(B)** The experimental timeline, showing preference testing sessions and the delay (for surgery and recovery) between the final BAT day and Electrophysiology recording/passive tastant deliveries.

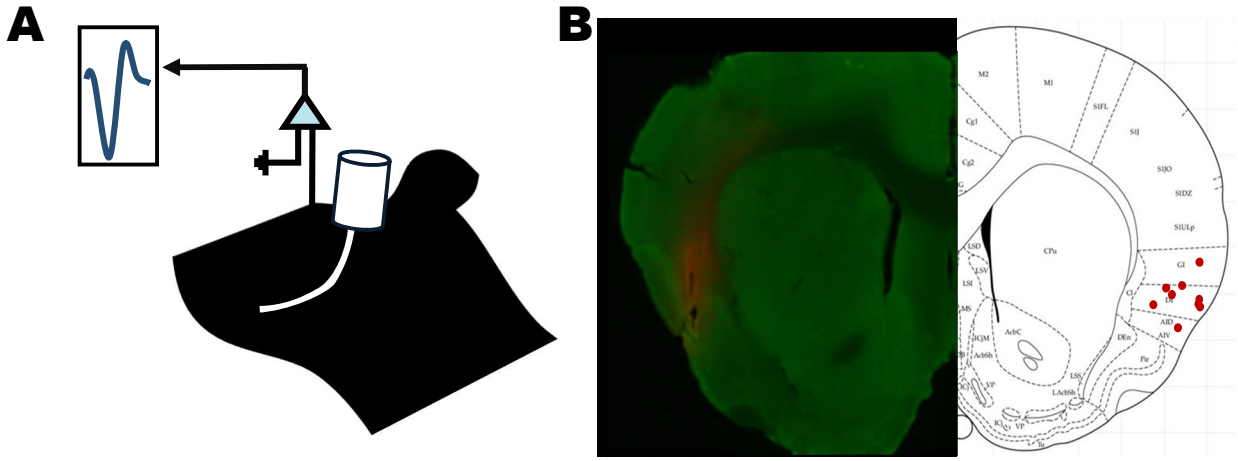

Figure 2. Passive taste delivery and electrophysiology recording and histological verification. **(A)** A schematic of *in vivo* GC recordings with taste delivery *via* a pre-implanted intra-oral cannula. **(B)** Histological verification of a representative electrode implant site (left) with dye marking the recording site in gustatory cortex. On the right is the schematic of the coronal slice through central GC, with the positions of electrode tips for all animals (N=9) denoted with red circles.

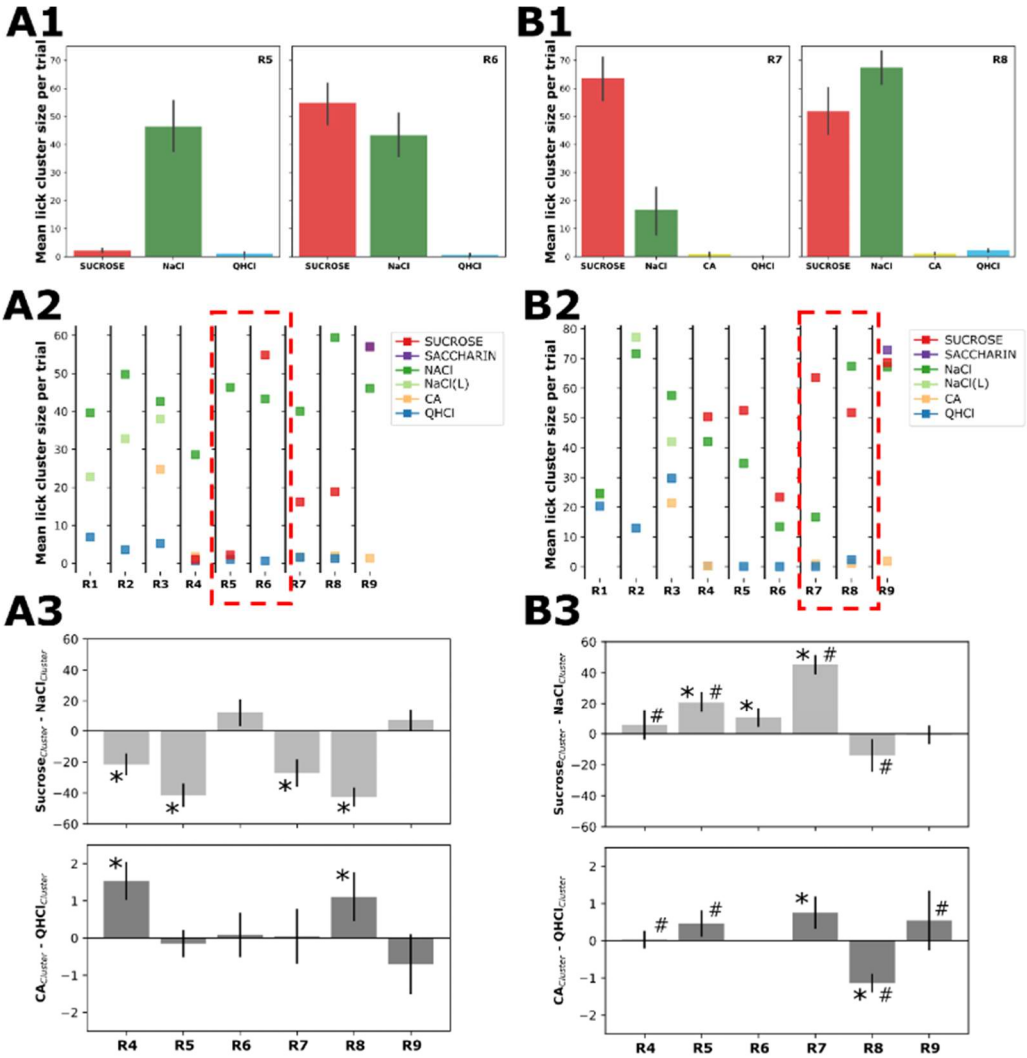

Figure 3. Individual and between-session differences in perceived taste palatability. **(A1)** Mean lick cluster sizes for two representative rats during the first BAT test illustrate clear individual differences in preference for sucrose, NaCl, and QHCl. A two-way ANOVA revealed a significant Taste × Animal interaction ($F(2,65) = 13.44$, $p < 0.05$). Post hoc Tukey tests further showed that sucrose, while highly preferred by the rat on the left, was perceived similarly to QHCl by the rat on the right ($p < 0.05$). **(A2)** Mean lick cluster sizes for each taste across all animals during the first BAT test (N = 9). The two rats shown in panel **(A1)** are outlined for reference. **(A3)** Differences in lick cluster sizes comparing sucrose and NaCl (top) and comparing citric acid (CA) and quinine (QHCl; bottom) during the first BAT test. One-sample *t*-tests (against a population mean of zero) revealed individual differences in the preferences for the two palatable and the two aversive tastes ($p < 0.05$). **(B1-3)** The same analyses as in A1-3, but for each rat's final BAT session (depending on the rat, sessions 3 or 5). In **(B3)**, we also show an analysis of whether individual rats changed their relative preferences between BAT sessions—two-way ANOVAs with variables Animal and Session, comparing the data shown in panels **(A3)** and **(B3)**. The majority of rats exhibited significant changes in relative preference for tastes of the same valence across sessions (# *ps* < 0.05). The labels R1–R9 denote the rats included in the data analysis.

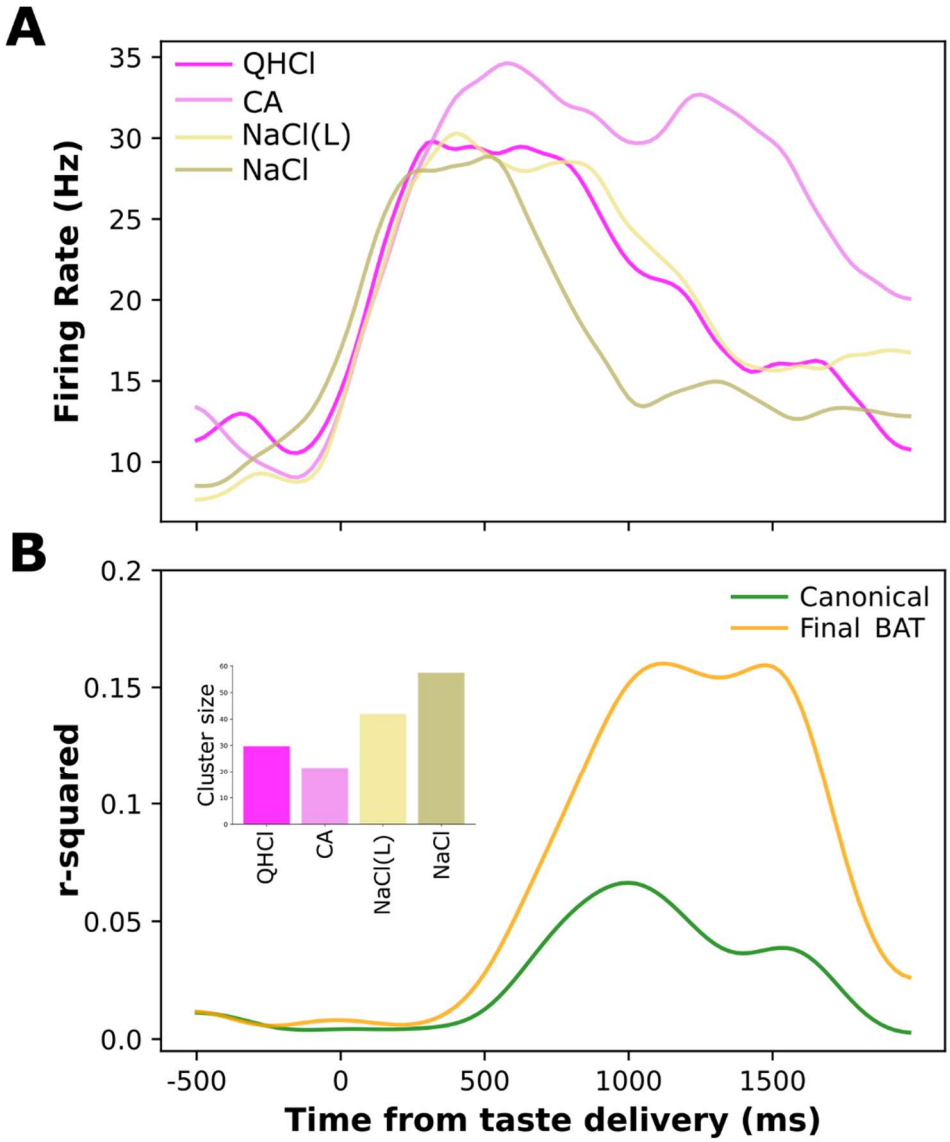

Figure 4. Palatability-relatedness of Late-epoch taste responses match the individuals' preferences. **(A)** Peristimulus time histogram of 4 passively delivered tastes for a representative cortical neuron, showing typical response dynamics including correlation (r-squared, dotted line and right y-axis) to palatability peaking around 1 second from taste delivery. **(B)** Palatability correlations from the GC unit **(A)** calculated based on the canonical ranking or the ranks estimated from either first or final BAT test. **Inset**: Bar plot showing the average lick cluster sizes for each taste obtained during the final BAT testing session. Concentrations for each taste were as follows: QHCl, 7.8×10^{-5} M; CA (Citric Acid), 0.009 M; NaCl(L), 0.05 M; and NaCl, 0.1 M.

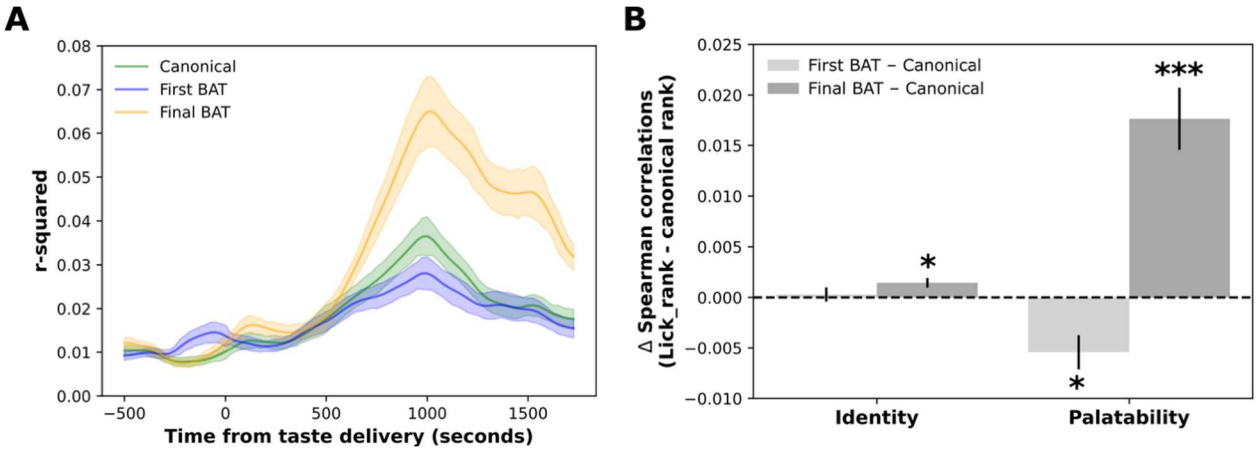

Figure 5. The correlation between Late-Epoch GC firing and an individual rat's taste preferences is specific to the most recent BAT assay. **(A)**. The palatability correlation over time from all of the (n=129) recorded neurons, using canonical palatability (green), lick cluster data from the first BAT session (blue), and lick cluster data from the final BAT session (orange). **(B)** The difference in correlation calculated from canonical palatability and data from the animal's individual preferences (First BAT or Final BAT), separated into the Identity epoch (200-7000ms) and the Palatability epoch (700-1200ms). * $p < 0.01$, *** < 0.001.

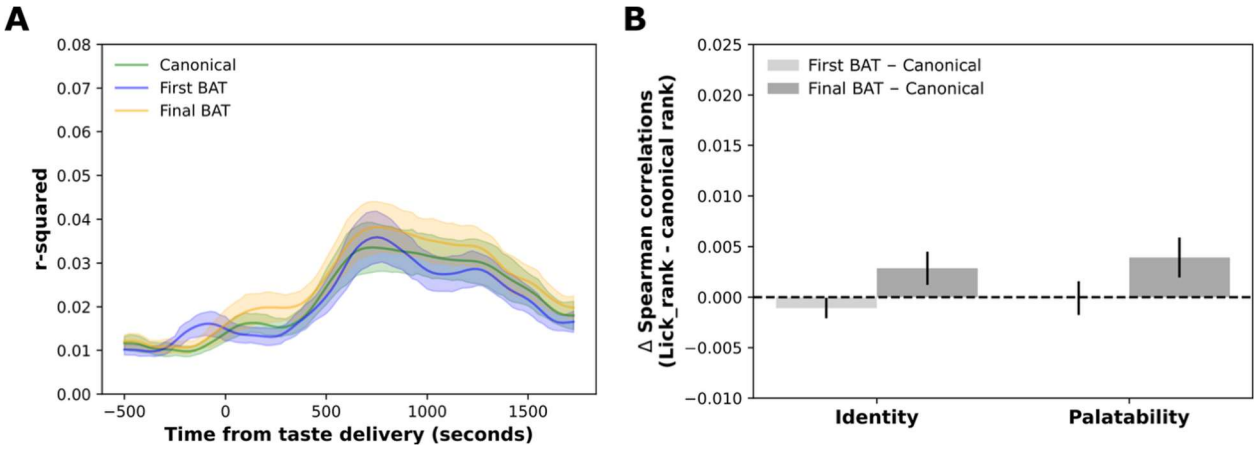

Figure 6. A single session of IOC taste delivery to passive rats nullifies the correlation with palatability calculated from the most recent BAT assay. **(A)** Cortical coding no longer matches rats' individual preferences when using neurons (n=101) from electrophysiology session 2 (same conventions used in Figure 5A. **(B)** A summary of the data in **(A)**, showing there is no longer a significant difference using preference rankings estimated from BAT performance.

References

Armitage, R. M., Iatridi, V., Gaysina, D., Tuorila, H., Yeomans, M. R., Kaprio, J., & Zellers, S. (2025). Genetic and Environmental Influences on Sweet Taste Liking and Related Traits: New Insights from Twin Cohorts. *Behavior genetics, 55*(5), 407-421. doi:10.1007/s10519-025-10232-2.

Baas-Thomas, N., Mahmood, A., Mukherjee, N., Maigler, K. C., Wang, Y., & Katz, D. B. (2025). The Ingestive Response Reflects Neural Dynamics in Gustatory Cortex. bioRxiv, 2025-10.

Bacharach, S. Z., & Calu, D. J. (2019). Stability of individual differences in sucralose taste preference. *PLoS One, 14*(5). doi:https://doi.org/10.1371/journal.pone.0216431

Bachmanov, A. A., Bosak, N. P., Glendinning, J. I., Inoue, M., Li, X., Manita, S., . . . Beauchamp, G. K. (2016). Genetics of Amino Acid Taste and Appetite. *Advances in nutrition (Bethesda, Md.), 7*(4), 806S-822S. doi:10.3945/an.115.011270

Bachmanov, A. A., Tordoff, M. G., & Beauchamp, G. K. (1998). Voluntary Sodium Chloride Consumption by Mice: Differences Among Five Inbred Strains. *Behavior genetics, 28*(2), 117-124. doi:10.1023/A:1021471924143

Barnett, S. A. (1958). Experiments on 'neophobia' in wild and laboratory rats. *British Journal of Psychology, 49*(3), 195-201. doi:https://doi.org/10.1111/j.2044-8295.1958.tb00657.x

Blizard, D. A. (1999). Quantitative Trait Loci Associated with Short-term Intake of Sucrose, Saccharin and Quinine Solutions in Laboratory Mice. *Chemical senses, 24*(4), 373-385. doi:10.1093/chemse/24.4.373

Domjan, M. (1977). Attenuation and enhancement of neophobia for edible substances. *Learning mechanisms in food selection*, 151-179.

Dwyer, D. M. (2009). Microstructural analysis of ingestive behaviour reveals no contribution of palatability to the incomplete extinction of a conditioned taste aversion. *Quarterly journal of experimental psychology (2006), 62*(1), 9-17. doi:10.1080/17470210802215152

Flores, V. L., Moran, A., Bernstein, M., & Katz, D. B. (2016). Preexposure to salty and sour taste enhances conditioned taste aversion to novel sucrose. *Learning & memory (Cold Spring Harbor, N.Y.), 23*(5), 221-228. doi:10.1101/lm.040360.115

Flores, V. L., Parmet, T., Mukherjee, N., Nelson, S., Katz, D. B., & Levitan, D. (2018). The role of the gustatory cortex in incidental experience-evoked enhancement of later taste learning. *Learning & memory (Cold Spring Harbor, N.Y.), 25*(11), 587-600. doi:10.1101/lm.048181.118

Galef, B. G., & Wigmore, S. W. (1983). Transfer of information concerning distant foods: A laboratory investigation of the 'information-centre' hypothesis. *Animal behaviour, 31*(3), 748-758. doi:10.1016/S0003-3472(83)80232-2

Grill, H. J., & Bernstein, I. L. (1988). Strain differences in taste reactivity to NaCl. *American journal of physiology. Regulatory, integrative and comparative physiology, 24*(3), R424-R430.

Herman, C. P., & Higgs, S. (2015). Social influences on eating. An introduction to the special issue. Appetite, 86, 1-2.

Inui-Yamamoto, C., Yamamoto, T., Ueda, K., Nakatsuka, M., Kumabe, S., Inui, T., & Iwai, Y. (2017). Taste preference changes throughout different life stages in male rats. *PLoS ONE, 12*(7), e0181650. doi:10.1371/journal.pone.0181650

Jamel, H. A., Sheiham, A., Cowell, C. R., & Watt, R. G. (1996). Taste preference for sweetness in urban and rural populations in Iraq. *Journal of Dental Research, 75*(11), 1879-1884. Retrieved from https://www.proquest.com/scholarly-journals/taste-preference-sweetness-urban-rural/docview/209476143/se-2?accountid=9703

Jones, L. M., Fontanini, A., Sadacca, B. F., Miller, P., & Katz, D. B. (2007). Natural stimuli evoke dynamic sequences of states in sensory cortical ensembles. *Proceedings of the National Academy of Sciences*, *104*(47), 18772-18777.

Katz, D. B., Simon, S., & Nicolelis, M. (2001). Dynamic and multimodal responses of gustatory cortical neurons in awake rats. . *The Journal of neuroscience, 21*(12), 4478-4489.

Keskitalo, K., Tuorila, H., Spector, T. D., Cherkas, L. F., Knaapila, A., Silventoinen, K., & Perola, M. (2007). Same genetic components underlie different measures of sweet taste preference. *The American journal of clinical nutrition, 86*(6), 1663-1669. doi:10.1093/ajcn/86.5.1663

Kotlus, B. S., & Blizard, D. A. (1998). Measuring Gustatory Variation in Mice: A Short-term Fluid-Intake Test. *Physiology & Behavior, 64*(1), 37-47. doi:https://doi.org/10.1016/S0031-9384(98)00016-X

Li, J. X., Maier, J. X., Reid, E. E., & Katz, D. B. (2016). Sensory cortical activity is related to the selection of a rhythmic motor action pattern. Journal of Neuroscience, 36(20), 5596-5607.

Lin, J.-Y., Amodeo, L. R., Arthurs, J., & Reilly, S. (2012). Taste neophobia and palatability: The pleasure of drinking. *Physiology & Behavior, 106*(4), 515-519. doi:10.1016/j.physbeh.2012.03.029

Lin, J.-Y., & Stone, B. T., Rahamim, O. M., Craddock, A. C. & Katz, D. B. Changes in palatability processing across the estrous cycle are modulated by hypothalamic estradiol signaling. in revision.

Loney, G. C., Blonde, G. D., Eckel, L. A., & Spector, A. C. (2012a). Determinants of Taste Preference and Acceptability: Quality versus Hedonics. *The Journal of neuroscience, 32*(29), 10086-10092. doi:10.1523/JNEUROSCI.6036-11.2012

Loney, G. C., Blonde, G. D., Eckel, L. A., & Spector, A. C. (2012b). Determinants of taste preference and acceptability: quality versus hedonics. *J Neurosci, 32*(29), 10086-10092. doi:10.1523/JNEUROSCI.6036-11.2012

Menchén-Márquez, S., Valero, M., Gasalla, P., Gámiz, F., Gallo, M., & Dwyer, D. M. (2026). Palatability changes during attenuation of flavor neophobia assessed with licking microstructure and taste reactivity. Appetite, 216, 108305. https://doi.org/10.1016/j.appet.2025.108305

Mukherjee, N., Wachutka, J., & Katz, D. (2017). *Python meets systems neuroscience: affordable, scalable and open-source electrophysiology in awake, behaving rodents*.

Mukherjee, N., Wachutka, J., & Katz, D. B. (2019). Impact of precisely-timed inhibition of gustatory cortex on taste behavior depends on single-trial ensemble dynamics. *eLife, 8*. doi:10.7554/eLife.45968

Posadas-Andrews, A., & Roper, T. J. (1983). Social transmission of food-preferences in adult rats. *Animal behaviour, 31*(1), 265-271. doi:10.1016/S0003-3472(83)80196-1

Robinson, E., & Higgs, S. (2012). Liking food less: the impact of social influence on food liking evaluations in female students. PloS one, 7(11), e48858.

Sadacca, B. F., Mukherjee, N., Vladusich, T., Li, J. X., Katz, D. B., & Miller, P. (2016). The Behavioral Relevance of Cortical Neural Ensemble Responses Emerges Suddenly. *J Neurosci, 36*(3), 655-669. doi:10.1523/JNEUROSCI.2265-15.2016

Story, M., Neumark-Sztainer, D., & French, S. (2002). Individual and environmental influences on adolescent eating behaviors. Journal of the American Dietetic association, 102(3), S40-S51.

Strickland, J. A., Austen, J. M., & Sanderson, D. J. (2018). A biphasic reduction in a measure of palatability following sucrose consumption in mice. *Physiology & Behavior, 184*, 129-134. doi:10.1016/j.physbeh.2017.11.019