

# <sup>1</sup> lickcalc: Easy analysis of lick microstructure in experiments of rodent ingestive behaviour

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## Software

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## <sup>6</sup> Summary

<sup>7</sup> Lick microstructure is a term used in behavioural neuroscience to describe the information that  
<sup>8</sup> can be obtained from a detailed examination of rodent drinking behaviour. Rather than simply  
<sup>9</sup> recording total intake (volume consumed), lick microstructure examines how licks are grouped,  
<sup>10</sup> and the spacing of these groups of licks. This type of analysis can provide important insights  
<sup>11</sup> into why an animal is drinking, for example, whether it is influenced by taste or affected  
<sup>12</sup> by consequences of consumption (e.g., feeling “full”). The simplicity of using lickcalc,  
<sup>13</sup> a browser-based application with a simple interface, will make microstructural analysis accessible  
<sup>14</sup> to any researchers who wish to employ it while providing sophisticated analyses with high  
<sup>15</sup> scientific value.

## Statement of need

lickcalc is a software suite that performs microstructural lick analysis on timestamps of lick onsets and/or offsets. Microstructural analysis was first described in Davis & Smith (1992) and has since then been used to understand diverse phenomena. In-depth reviews on many of these, and microstructural parameters used to study them, are available (Johnson, 2018; Naneix et al., 2020; Smith, 2001). Briefly, although much of the foundational work on drinking microstructure was on licking for nutritive solutions (e.g., sucrose solutions), microstructural analysis can also be used to study intake of water (McKay & Daniels, 2013; Santollo et al., 2021), ethanol (Patwell et al., 2021), and other tastants such as non-caloric artificial sweeteners, sodium, and quinine (Lin et al., 2012; Spector & St. John, 1998; Verharen et al., 2019). Lick microstructure has been used to shed light on, for example, how licking is affected by neuropeptides (McKay & Daniels, 2013), enzymes in the mouth (Chometton et al., 2022), ovarian hormones (Santollo et al., 2021), nutrient restriction (Naneix et al., 2020), response to alcohol (Patwell et al., 2021), and diet (Johnson, 2012).

Lick microstructure can provide nuanced information about why an animal is drinking. Briefly, by considering the distribution on interlick intervals (ILIs), individual licks can be grouped into bursts (also sometimes referred to as clusters or bouts) based on a minimum ILI that separates each burst. The number of lick bursts during a session is thought to reflect post-ingestive feedback from the consumed fluid, whereas the average number of licks per burst is thought to reflect palatability of the solution. Often, changes in microstructure are accompanied by changes in total intake, but this is not always the case: sometimes, equal intake will be achieved by quite different licking patterns that indicate changes in orosensory and post-ingestive feedback (Johnson et al., 2010; Volcko et al., 2020). Analyzing lick microstructure is therefore highly valuable when trying to understand how a manipulation,  $X$ , affects appetite; if  $X$  causes an animal to feel more sated after drinking, that may lead to a different interpretation than if  $X$  were to reduce the palatability of the solution. Because of the value of microstructural data, many labs habitually record and analyze it. There are many others, however, that have

43 not yet begun collecting and/or analysing these data. Investing in lickometers can be costly,  
44 but there are an increasing number of cost-effective alternatives to commercial products. As  
45 such, several open-source lickometer designs are now available (e.g. Frie & Khokhar (2024);  
46 Monfared et al. (2024); Petersen et al. (2024); Silva et al. (2024); Raymond et al. (2018)).

47 Recording individual licks with high temporal resolution is necessary for microstructural analysis  
48 of drinking behavior, but another barrier to reporting microstructure is its analysis. This  
49 problem is now easily solved by lickcalc. lickcalc does not require any special software  
50 or coding knowledge: all the user has to do is load a file with timestamps of lick onsets  
51 (and, ideally, offsets) into the application and lickcalc will generate detailed microstructural  
52 analysis, with a high degree of user control over key parameters. Resulting data provide values  
53 for number of licks, number of bursts, and burst size (among others) – the values that are  
54 often reported and used to draw inferences about postigestive and orosensory feedback of  
55 the solution. But importantly, several plots are also displayed that show information that  
56 helps with quality control of the data and challenges the user to think critically about which  
57 parameters they have chosen. In short, lickcalc makes microstructural analysis accessible  
58 to any with appropriate data, while providing detailed information needed for appropriate  
59 parameter selection and quality control.

## 60 Key features

61 lickcalc has several features that make it exceptionally user-friendly while providing sophisticated  
62 and detailed microstructural analysis. Some of these features include:

- 63   ■ **Ease of use:** Files of various formats can simply be dragged into the lickcalc software  
64   to trigger analyses. Parameters can be set manually using sliders, and results exported  
65   to Excel with the push of a button.
- 66   ■ **Flexibility:** The user sets key parameters appropriate for their experimental setup and  
67   data. Data can be analysed across the whole-session, within different epochs, or based  
68   on a trial structure.
- 69   ■ **Customization:** By using the configuration file, users can change default settings to  
70   match their preferences and avoid manually changing settings for each file loaded.
- 71   ■ **Results compilation:** Data from multiple sessions and/or individuals can be exported into  
72   a single Excel file, which streamlines analysis. A batch mode is also included allowing  
73   multiple files to be analysed simultaneously.
- 74   ■ **Detail of analysis:** One of the benefits of using lickcalc is the level of detail it provides.  
75   In addition to the properties often reported (e.g., burst number, burst size), lickcalc  
76   computes and displays attributes of the data that are important in establishing the quality  
77   of the data and determining appropriate parameters for its microstructural analysis. Four  
78   charts are:
  - 79     1) *intraburst lick frequency*, or how often certain interlick intervals within a burst of  
80       licking occur. While a rodent is licking, its tongue makes rhythmic protrusions that  
81       are under the control of a central pattern generator (Travers et al., 1997). Rats  
82       typically lick 6–7 times per second (Davis & Smith, 1992), while mice lick at a  
83       slightly higher rate (Johnson et al., 2010). In addition to these species differences,  
84       there are also strain differences (Johnson et al., 2010; St. John et al., 2017).  
85       Because intraburst lick rate is under the control of the central pattern generator, it  
86       should remain relatively stable across mice and conditions (unless a manipulation  
87       is expected to cause changes in the central pattern generator). A typical chart  
88       for a mouse might show a sharp peak around an intraburst ILI of ~129 ms, which  
89       corresponds to a lick rate of 7.75 Hz. Much smaller peaks are often present at the  
90       harmonics of the intraburst ILI (e.g., a primary peak at 129 ms will have smaller  
91       peaks at 258 ms, 387 ms, and so on), often because of “missed licks” in which the

- 92 mouse attempts to lick but its tongue misses the spout. A large number of these,  
 93 or other differences from the expected pattern of results, may indicate problems  
 94 with the experimental setup (e.g., if the animal fails to reach the spout frequently,  
 95 then perhaps the spout is too far away).
- 96 2) *lick length* is only available when lick offsets are included in the data file. As with  
 97 intraburst lick frequency, lick length should show little variability and the graph  
 98 will have a sharp peak. Occasionally a lickometer will register longer licks than  
 99 normal. A common cause of this is formation of a fluid bridge between the tongue  
 100 and the spout during periods of high frequency licking. This can be prevented by  
 101 moving the bottle further from the animal. In addition, other causes are if a rodent  
 102 grabs the spout with its paws, or if a fluid droplet hangs between the spout and  
 103 the cage and thus completes the electrical circuit. Concerns about data quality may  
 104 be warranted with increasing number and duration of long licks. `lickcalc` displays  
 105 both the number and maximum duration of licks above the threshold that the user  
 106 has set. There is also an option to remove these problematic licks from the dataset.
- 107 3) *burst frequency*, or how often certain burst sizes occurred. This is informative  
 108 because burst size, by virtue of being a mean (mean licks per burst), does not  
 109 take into account potentially relevant information about the distribution of licks in  
 110 each burst. For example, a burst size of 80 could result from bursts all containing  
 111 between 70 and 90 licks, or from many single licks and one or two bursts with a lot  
 112 of licks. The latter case might raise some questions about how reliable the burst  
 113 size value is. Although single licks occur, they can also be caused by non-tongue  
 114 contact with the lickometer. Changing the minimum licks/burst parameter can  
 115 filter out some of these suspect “licks.”
- 116 4) *Weibull probability*. The Weibull analysis, as described in Davis (1996), uses a  
 117 mathematical equation to fit data to a survival function. Although used by some  
 118 (Aja et al., 2001; Moran et al., 1998; Spector & St. John, 1998), it is still relatively  
 119 rare to find Weibull probabilities in microstructural analyses. The Weibull function  
 120 can be used on several aspects of data, such as lick rate across a session, but in  
 121 the `lickcalc` program the Weibull probability is calculated for burst size. It plots  
 122 the probability that, given  $n$  licks, the mouse will continue to lick. This makes it  
 123 sensitive to the licks per burst parameter that is set by the user. The Weibull  $\alpha$   
 124 and  $\beta$  values reflect the slope and shape parameters, respectively. Slope ( $\alpha$ ) has  
 125 been shown to vary with palatability.

## 126 Design and usage

127 `lickcalc` is hosted by UiT The Arctic University of Norway and can be accessed at [lickcalc.uit.no](https://lickcalc.uit.no).  
 128 Alternatively, it can be installed locally following instructions in the repository. To use `lickcalc`,  
 129 the user drags a file into the application, changes file format if necessary, and indicates which  
 130 column contains the lick onsets (and, if applicable, the lick offsets). A plot is automatically  
 131 generated that displays a histogram of licks across the session. Session length defaults to the  
 132 time of the last lick but can be manually changed, or set in the optional config file. Session  
 133 length can be set in seconds, minutes, or hours. The bin size (licks per unit of time) can be  
 134 changed manually or in the config file. The user can toggle between the default histogram and  
 135 a plot showing cumulative licks.

136 A microstructural analysis is, in essence, a division of individual licks into groups of licks. To  
 137 perform this grouping, the user must set several parameters. One of these is the ILI threshold,  
 138 which is the minimum amount of time licks must be separated by in order to be considered  
 139 separate bursts. Early studies identified ILIs of 251–500 ms as separating “bursts” of licking,  
 140 and pauses of >500 ms as separating “clusters” of licking (i.e., a cluster of licks is made up  
 141 of several bursts of licking). Others have argued that an ILI threshold of 1 s provides better

separation of lick bursts ([Spector & St. John, 1998](#)). In `lickcalc`, the user can set the ILI to any value (values between 250 ms and 3 s provided by default but can be adjusted using the config file). Another parameter that needs to be decided prior to the lick analysis is the minimum number of licks per burst. `lickcalc` allows between 1 and 5 licks by default. The appropriate number of minimum licks per burst may vary depending on experimental set up, and the likelihood that a single lick represents a lick rather than, for example, a paw touching the spout. Finally, in `lickcalc`, the user must set a “long-lick threshold” between 0.1 and 1 s. This parameter is only available when lick offset is included. Licks that are longer than the set threshold are counted as “long” and may indicate a problem (e.g., fluid bridges or a mouse holding the spout with its paws) rather than a true lick. The user can decide whether to remove “long licks” or not. All of these parameters can be set manually or through the config file. Four plots are generated (see *Key Features* section above), and tables are displayed showing values of several properties: total licks, intraburst frequency, number of long licks, maximum duration of long licks, number of bursts, mean licks per burst, Weibull  $\alpha$ , Weibull  $\beta$ , and Weibull  $r^2$ .

To save these data, the user has two options. The first is to export a single Excel file in which the user sets the animal ID and chooses which data to export. These data allow the user to recreate the plots displayed in `lickcalc` or perform further analyses. The second option for saving the data is to add the loaded data to the *Results Summary* table. The results in this table remain even as new data files are loaded, so the data from many sessions (and/or individual animals) can be exported into a single Excel file. In addition to the data from the whole session, the user can choose to divide the session into epochs, or to examine only the first  $n$  bursts, or perform a trial-based analysis (e.g., for Davis rig experiments). Each of these analysis epochs can be added to the table. The table contains the data and the analysis parameters (e.g., minimum burst size) used to generate them. Finally, a batch process feature is available allowing multiple files to be analysed using the same parameters.

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## References

- Aja, S., Schwartz, G. J., Kuhar, M. J., & Moran, T. H. (2001). Intracerebroventricular CART peptide reduces rat ingestive behavior and alters licking microstructure. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, 280(6), R1613–R1619. <https://doi.org/10.1152/ajpregu.2001.280.6.R1613>
- Chometton, S., Jung, A.-H., Mai, L., Dal Bon, T., Ramirez, A. O., Pittman, D. W., & Schier, L. A. (2022). A glucokinase-linked sensor in the taste system contributes to glucose appetite. *Molecular Metabolism*, 64, 101554. <https://doi.org/10.1016/j.molmet.2022.101554>
- Davis, J. D. (1996). Deterministic and probabilistic control of the behavior of rats ingesting liquid diets. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, 270(4), R793–R800. <https://doi.org/10.1152/ajpregu.1996.270.4.R793>
- Davis, J. D., & Smith, G. P. (1992). Analysis of the microstructure of the rhythmic tongue movements of rats ingesting maltose and sucrose solutions. *Behavioral Neuroscience*, 106(1), 217–228. <https://doi.org/10.1037/0735-7044.106.1.217>

- 189 Frie, J. A., & Khokhar, J. Y. (2024). FARESHARE: An open-source apparatus for assessing  
190 drinking microstructure in socially housed rats. *NPP—Digital Psychiatry and Neuroscience*,  
191 2(1), 1. <https://doi.org/10.1038/s44277-024-00002-z>
- 192 Johnson, A. W. (2012). Dietary manipulations influence sucrose acceptance in diet induced  
193 obese mice. *Appetite*, 58(1), 215–221. <https://doi.org/10.1016/j.appet.2011.09.015>
- 194 Johnson, A. W. (2018). Characterizing ingestive behavior through licking microstructure:  
195 Underlying neurobiology and its use in the study of obesity in animal models. *International  
196 Journal of Developmental Neuroscience: The Official Journal of the International Society for  
197 Developmental Neuroscience*, 64, 38–47. <https://doi.org/10.1016/j.ijdevneu.2017.06.012>
- 198 Johnson, A. W., Sherwood, A., Smith, D. R., Wosiski-Kuhn, M., Gallagher, M., & Holland, P.  
199 C. (2010). An analysis of licking microstructure in three strains of mice. *Appetite*, 54(2),  
200 320–330. <https://doi.org/10.1016/j.appet.2009.12.007>
- 201 Lin, J.-Y., Amodeo, L. R., Arthurs, J., & Reilly, S. (2012). Taste neophobia and palatability:  
202 The pleasure of drinking. *Physiology & Behavior*, 106(4), 515–519. <https://doi.org/10.1016/j.physbeh.2012.03.029>
- 204 McKay, N. J., & Daniels, D. (2013). Glucagon-like peptide-1 receptor agonist administration  
205 suppresses both water and saline intake in rats. *Journal of Neuroendocrinology*, 25(10),  
206 929–938. <https://doi.org/10.1111/jne.12086>
- 207 Monfared, M., Mascret, Q., Marroquin-Rivera, A., Blanc-Árabe, L., Lebouleux, Q., Lévesque,  
208 J., Gosselin, B., & Labonté, B. (2024). High-throughput low-cost digital lickometer system  
209 for the assessment of licking behaviours in mice. *Journal of Neuroscience Methods*, 410,  
210 110221. <https://doi.org/10.1016/j.jneumeth.2024.110221>
- 211 Moran, T. H., Katz, L. F., Plata-Salaman, C. R., & Schwartz, G. J. (1998). Disordered  
212 food intake and obesity in rats lacking cholecystokinin A receptors. *American Journal  
213 of Physiology-Regulatory, Integrative and Comparative Physiology*, 274(3), R618–R625.  
214 <https://doi.org/10.1152/ajpregu.1998.274.3.R618>
- 215 Naneix, F., Peters, K. Z., & McCutcheon, J. E. (2020). Investigating the Effect of Physiological  
216 Need States on Palatability and Motivation Using Microstructural Analysis of Licking.  
217 *Neuroscience*, 447, 155–166. <https://doi.org/10.1016/j.neuroscience.2019.10.036>
- 218 Patwell, R., Yang, H., Pandey, S. C., & Glover, E. J. (2021). An operant ethanol self-  
219 administration paradigm that discriminates between appetitive and consummatory behaviors  
220 reveals distinct behavioral phenotypes in commonly used rat strains. *Neuropharmacology*,  
221 201, 108836. <https://doi.org/10.1016/j.neuropharm.2021.108836>
- 222 Petersen, N., Adank, D. N., Quan, Y., Edwards, C. M., Hallal, S. D., Taylor, A., Winder, D. G.,  
223 & Doyle, M. A. (2024). A Novel Mouse Home Cage Lickometer System Reveals Sex- and  
224 Housing-Based Influences on Alcohol Drinking. *eNeuro*, 11(10), ENEURO.0234–24.2024.  
225 <https://doi.org/10.1523/ENEURO.0234-24.2024>
- 226 Raymond, M. A., Mast, T. G., & Breza, J. M. (2018). An open-source lickometer and  
227 microstructure analysis program. *HardwareX*, 4, e00035. <https://doi.org/10.1016/j.ohx.2018.e00035>
- 229 Santollo, J., Edwards, A. A., Howell, J. A., & Myers, K. E. (2021). Bidirectional effects  
230 of estradiol on the control of water intake in female rats. *Hormones and Behavior*, 133,  
231 104996. <https://doi.org/10.1016/j.yhbeh.2021.104996>
- 232 Silva, A., Carriço, P., Fernandes, A. B., Saraiva, T., Oliveira-Maia, A. J., & Da  
233 Silva, J. A. (2024). High-Precision Optical Fiber-Based Lickometer. *Eneuro*, 11(7),  
234 ENEURO.0189–24.2024. <https://doi.org/10.1523/ENEURO.0189-24.2024>
- 235 Smith, G. P. (2001). John Davis and the meanings of licking. *Appetite*, 36(1), 84–92.  
236 <https://doi.org/10.1006/appet.2000.0371>

- 237 Spector, A. C., & St. John, S. J. (1998). Role of taste in the microstructure of quinine  
238 ingestion by rats. *American Journal of Physiology-Regulatory, Integrative and Comparative*  
239 *Physiology*, 274(6), R1687–R1703. <https://doi.org/10.1152/ajpregu.1998.274.6.R1687>
- 240 St. John, S. J., Lu, L., Williams, R. W., Saputra, J., & Boughter, J. D. (2017). Genetic control  
241 of oromotor phenotypes: A survey of licking and ingestive behaviors in highly diverse strains  
242 of mice. *Physiology & Behavior*, 177, 34–43. <https://doi.org/10.1016/j.physbeh.2017.04.007>
- 244 Travers, J. B., Dinardo, L. A., & Karimnamazi, H. (1997). Motor and Premotor Mechanisms  
245 of Licking. *Neuroscience & Biobehavioral Reviews*, 21(5), 631–647. [https://doi.org/10.1016/S0149-7634\(96\)00045-0](https://doi.org/10.1016/S0149-7634(96)00045-0)
- 247 Verharen, J. P. H., Roelofs, T. J. M., Menting-Henry, S., Luijendijk, M. C. M., Vanderschuren,  
248 L. J. M. J., & Adan, R. A. H. (2019). Limbic control over the homeostatic need for sodium.  
249 *Scientific Reports*, 9(1), 1050. <https://doi.org/10.1038/s41598-018-37405-w>
- 250 Volcko, K. L., Brakey, D. J., Przybysz, J. T., & Daniels, D. (2020). Exclusively drinking  
251 sucrose or saline early in life alters adult drinking behavior by laboratory rats. *Appetite*,  
252 149, 104616. <https://doi.org/10.1016/j.appet.2020.104616>