



Puff Topography Among Non-smoking Electronic Cigarette Users During Three Hours of Ad Libitum Use



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Abstract

Significance: Electronic cigarettes (ECIGs) are not used over discrete time periods like combusted cigarettes, making puffing patterns more difficult to characterize. Despite developments in research to characterize ECIG puff topography, there is no consensus on the best definition of an ECIG use bout. This study sought to examine ECIG puffing patterns using previously defined criteria (St. Helen et al., 2016) among a sample of experienced users. **Methods:** Thirteen non-smoking ECIG users ($M_{age} = 20.0$, 54% female, 77% white) completed two within-subject, randomly ordered conditions that differed by ECIG use: *ad lib* use or abstinence. In the former condition, participants used their own ECIG for a 10-puff directed bout followed by 3 hours of puffing *ad lib*. Using video-based measurement, puff clusters were defined as the number of puffs with inter-puff intervals (IPI) < 60 sec: small (2-5 puffs), medium (6-10), large (11+). **Results:** Participant characteristics included: average ECIG use duration of 1.7 years ($SD = 0.8$); average Penn State ECIG Dependence Index score of 12.5 ($SD = 3.5$); 100% met DSM criteria for tobacco dependence; 77% preferred pod-style devices; and average lifetime number of cigarettes of 7.1 ($SD = 7.8$). Participants took an average of 43.6 puffs ($SD = 22.1$) with an average puff duration of 3.2 sec ($SD = 1.7$) and IPI of 292.3 sec ($SD = 157.3$). 45.7% of puffs were single puffs, 44.8% were in small clusters, 9.5% were in medium clusters, and 0% were in large clusters. There were 1.6 ($SD = 1.0$) puffs between clusters on average. Large individual variability was observed, with a range of 16-77 puffs, 1.1 to 7.7 sec durations, and 132.1 to 565.9 sec IPIs. **Conclusion:** Findings are similar to (42.9% small clusters) and different from (11.9% single puffs, 44.3% medium-large clusters) previous work with largely 2nd generation ECIG users. Cross-study differences may be due not only to the type of ECIG used, but also study design features (*ad lib* use period duration; pre-session abstinence requirement). Future work should continue to explore or adapt these definitions while considering individual differences to best categorize ECIG puffing patterns.

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Introduction

- Puff topography is a behavioral measure of ECIG consumption that may be predictive of nicotine and toxicant delivery.¹⁻²
- EIG topography varies as a function of user experience and device/liquid characteristics.³⁻⁵
- The characterization of broad ECIG puffing patterns is challenging.
- A single ECIG puffing bout has been defined previously by:
 - users' insertion/removal of ECIG from a computerized device.⁶⁻⁷
 - categorization of puff clusters (# of puffs separated by < 60 s IPI).⁸
- The purpose of this secondary analysis of data was to use this latter approach to characterize ECIG puff topography among non-smoking ECIG users during a 3-hour *ad libitum* bout.

Methods

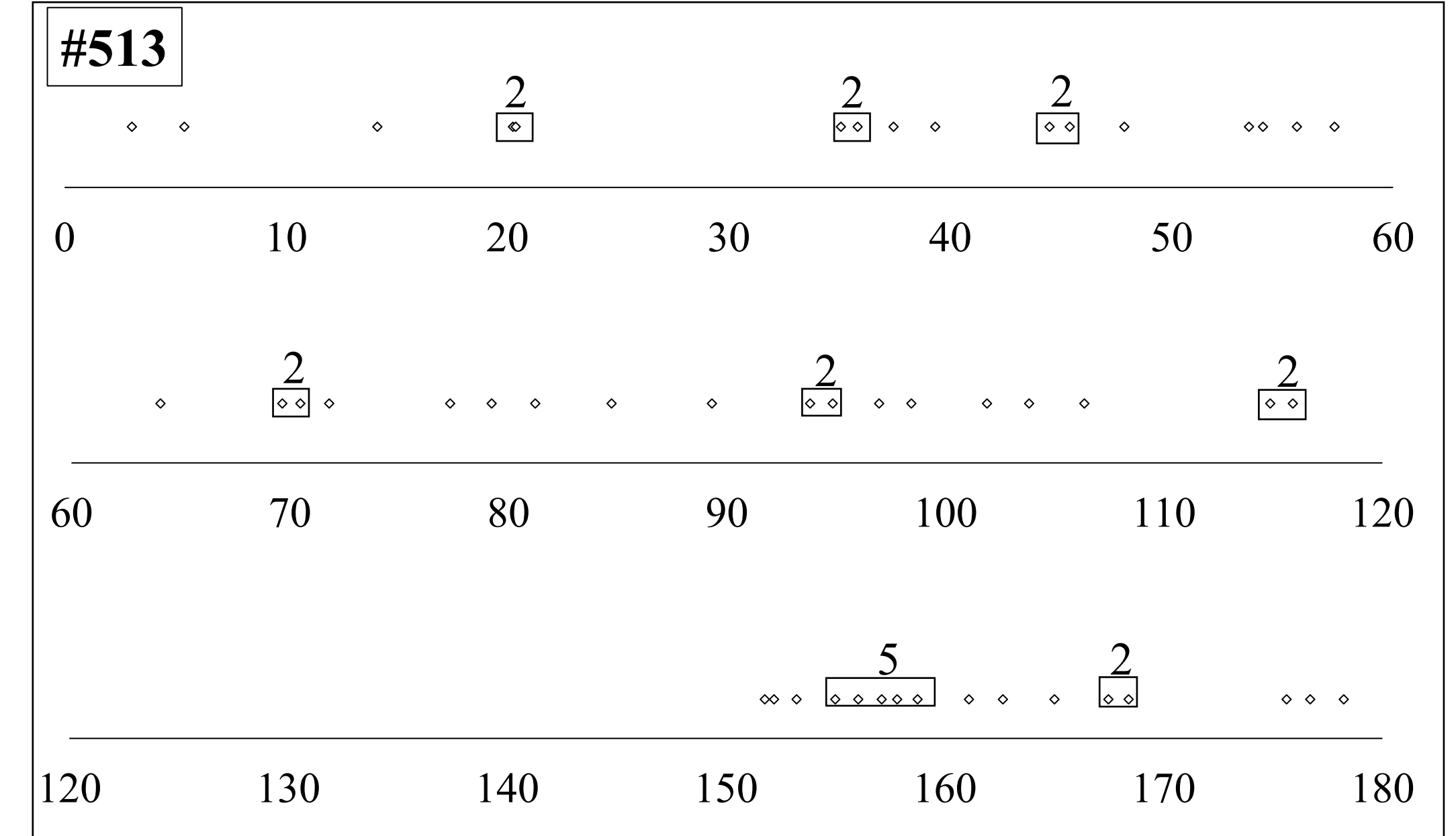
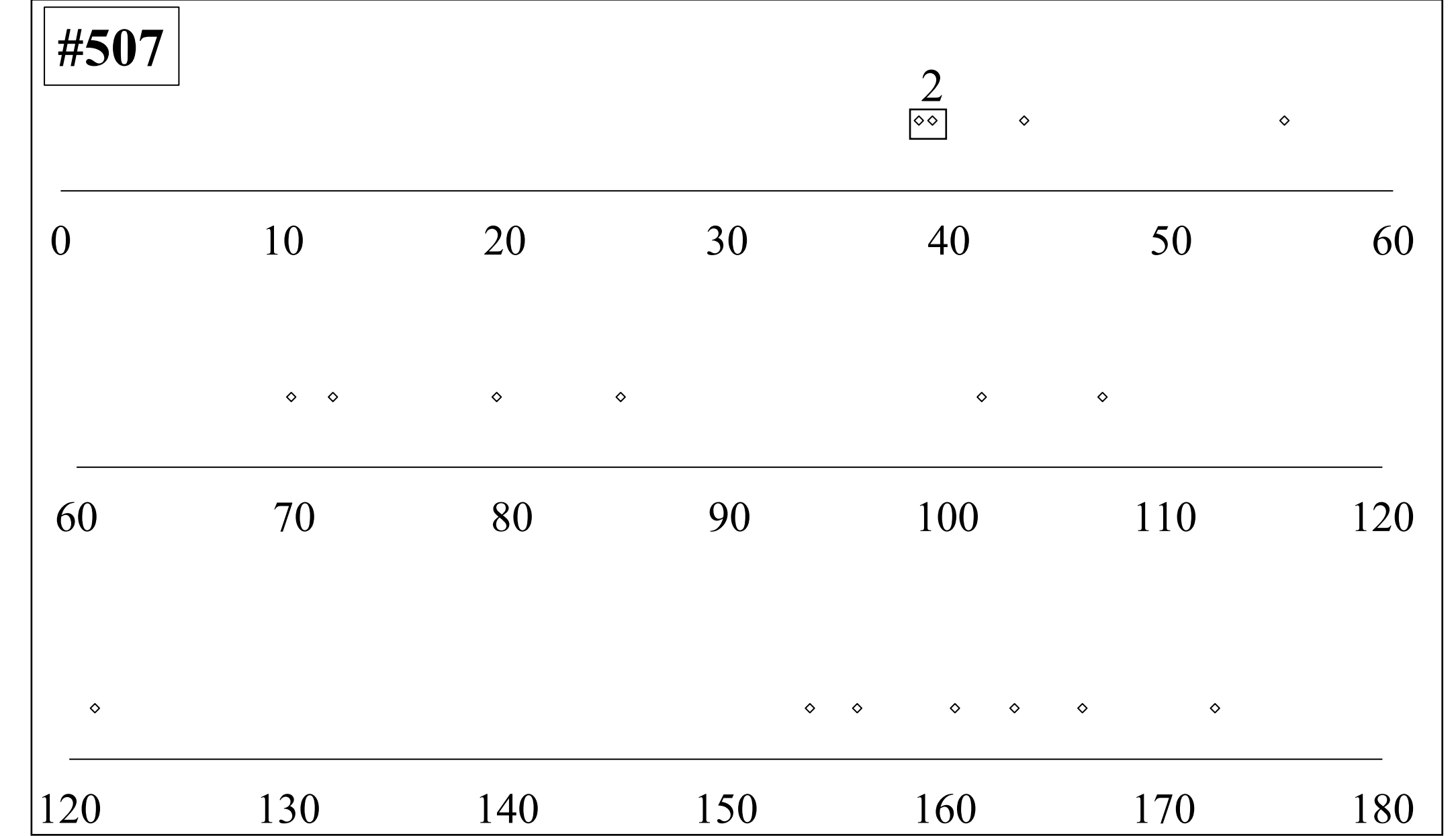
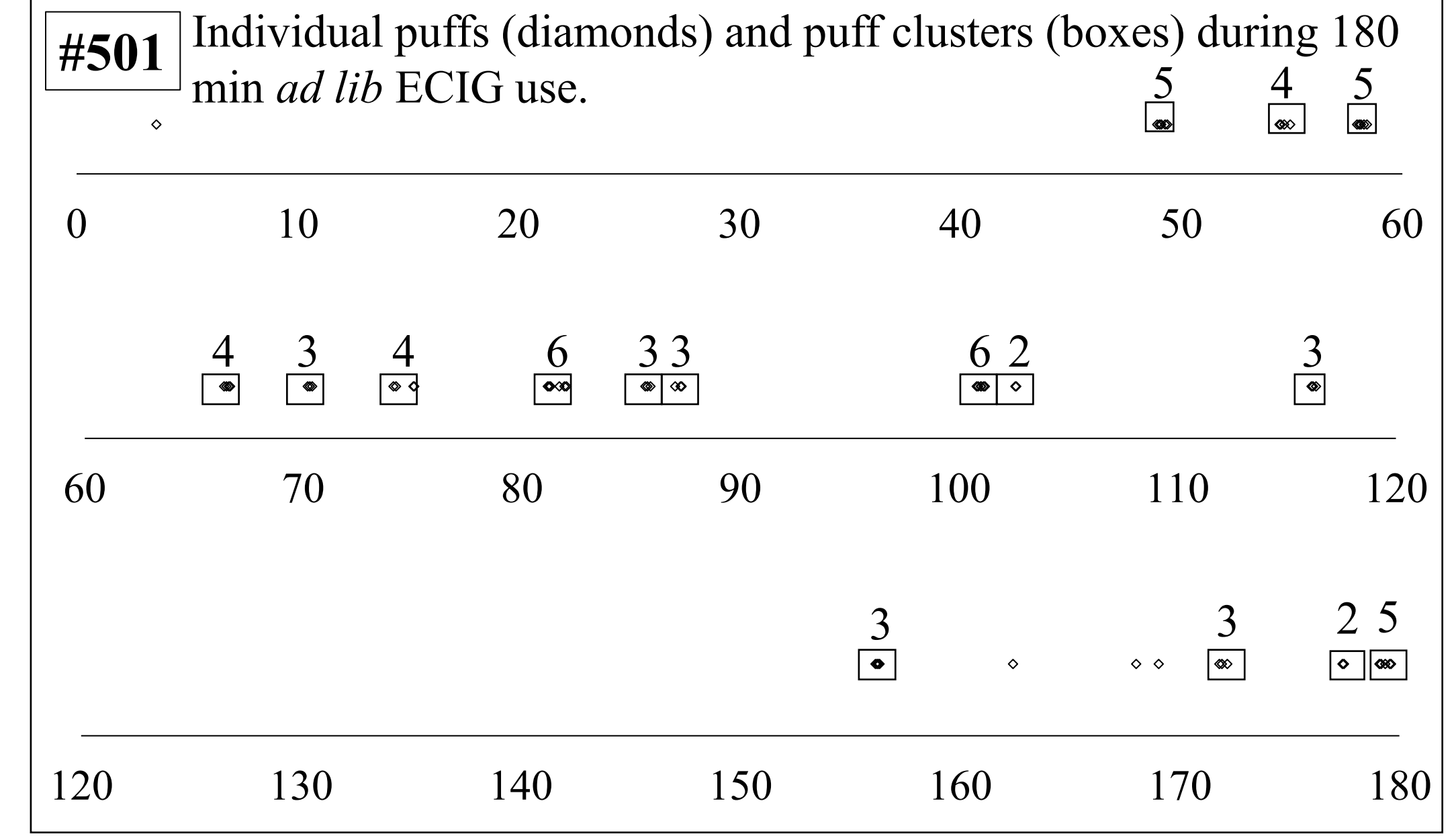
- Inclusion criteria:** use nicotine-containing ECIG ≥ 6 months; use ≤ 10 cigarettes past year and ≤ 2 cigarettes past month; Penn State Electronic Cigarette Dependence Index (PSECDI) ≥ 7 ; age 18-40
- Exclusion criteria:** uncontrolled medical or psychiatric conditions; medication use; past month use of marijuana ≥ 10 days, alcohol ≥ 25 days, or other illicit substances
- Within-subjects design** with two randomly-ordered conditions that differed by length of nicotine abstinence: 0 min (*ad lib* use of own ECIG) or 180 min (ECIG abstinence)
- Ad lib** ECIG use videotaped for measurement of puff number, duration, and inter-puff-interval (IPI)
 - high inter-rater reliability for video scores (ICCs = 0.98 – 1.0, $ps < .001$)
- Modeling** St. Helen and colleagues,⁸ puff clusters were defined as the number of puffs with IPIs <60 sec and then categorized as:
 - single puffs
 - small clusters (2-5 puffs)
 - medium cluster (6-10 puffs)
 - large cluster (>10 puffs)

Participant Demographics (N=13)

	Mean (SD) or %
Age (years)	20.00 (2.12)
% Non-Hispanic	76.90%
% Female	53.80%
Education (years)	13.38 (1.26)
Lifetime Cigarettes	7.08 (7.79)
Carbon Monoxide (ppm)	2.31 (1.25)
MINI Tobacco Use Disorder	
Severe	61.50%
Moderate	23.10%
Mild	15.40%
Penn State ECIG Dep Index	12.54 (3.48)
ECIG Device Type	
Pods (4th gen)	76.90%
Mods (3rd gen)	23.10%
Nicotine Concentration (mg/ml)	46.85 (20.32)
Liquid Use / Day (ml)	1.61 (2.70)
Duration Use (years)	1.66 (0.81)
Flavor	
Mint	46.20%
Fruit	46.20%
Mixed	7.70%
% Vegetable Glycerin	62.27 (5.18)
Wattage	21.27 (24.56)

Results

Participant	Frequency of puff clusters				Average number of puffs per cluster			Percent of total puffs in session (%)			
	1 puff	2-5 puffs	6-10 puffs	>10 puffs	2-5 puffs	6-10 puffs	>10 puffs	1 puff	2-5 puffs	6-10 puffs	>10 puffs
501	4	13	2	0	3.77	6.00	n/a	6.15	75.38	18.46	0.00
502	24	21	0	0	2.43	n/a	n/a	32.00	68.00	0.00	0.00
504	19	16	0	0	2.44	n/a	n/a	32.76	67.24	0.00	0.00
505	7	13	3	0	3.62	7.67	n/a	9.09	61.04	29.87	0.00
507	17	1	0	0	2.00	n/a	n/a	88.24	11.76	0.00	0.00
510	22	5	0	0	2.60	n/a	n/a	62.86	37.14	0.00	0.00
513	28	9	0	0	2.44	n/a	n/a	56.00	44.00	0.00	0.00
514	27	12	0	0	2.67	n/a	n/a	45.76	54.24	0.00	0.00
515	15	3	1	0	2.33	6.00	n/a	53.57	25.00	21.43	0.00
517	5	2	1	0	2.50	6.00	n/a	31.25	31.25	37.50	0.00
518	14	9	1	0	2.56	7.00	n/a	31.82	52.27	15.91	0.00
519	12	6	0	0	2.50	n/a	n/a	44.44	55.56	0.00	0.00
520	16	0	0	0	n/a	n/a	n/a	100.00	0.00	0.00	0.00
Mean	16.15	8.46	0.62	0.00	2.65	6.53	n/a	45.69	44.84	9.47	0.00
SD	7.86	6.36	0.96	0.00	0.51	0.77	n/a	27.21	22.79	13.49	0.00
Minimum	4	0	0	0	2.00	6.00	n/a	6.15	0.00	0.00	0.00
Maximum	28	21	3	0	3.77	7.67	n/a	100.00	75.38	37.50	0.00



	Mean (SD)	Median	Range
Puffs per session	43.6 (22.12)	44	16 - 77
Duration (sec)	3.16 (1.73)	2.87	1.08 - 7.72
IPI (sec)	292.26 (157.30)	209.87	132.06 - 565.85
Single puffs between clusters	1.58 (1.02)	1.3	0.2 - 3.2
IPI between clusters	345.99 (125.85)	329.89	185.61 - 583.61
IPI between single puffs	483.36 (307.24)	424.77	189.88 - 1315.11

Discussion

- Pattern observed here vs. by St. Helen and colleagues:⁸
 - 44.8% vs 42.9% small clusters
 - 45.7% vs 11.9% single puffs
 - 9.5% vs 27.8% medium clusters
 - 0% vs 16.5% large clusters
 - 51.4 puffs vs 64 puffs
- Relative St. Helen,⁸ the current study included a longer period of *ad lib* use (180 vs 90 min), no pre-session abstinence (vs 4 hours), and users of 4th generation (vs 2nd generation) ECIGs with higher concentrations of nicotine (42.3 vs 8.4 mg/ml).
- ECIG puffing bouts defined by computerized device reveal an average of 10-12 puffs/bout with 21.7 sec IPIs.⁶⁻⁷
- Future Directions:
 - characterize topography by device type and in natural settings
 - consider alternate definitions of clustering

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