Supplementary Information for
Learning to Feel Materials from Multisensory Tactile Data via Interpretable Models

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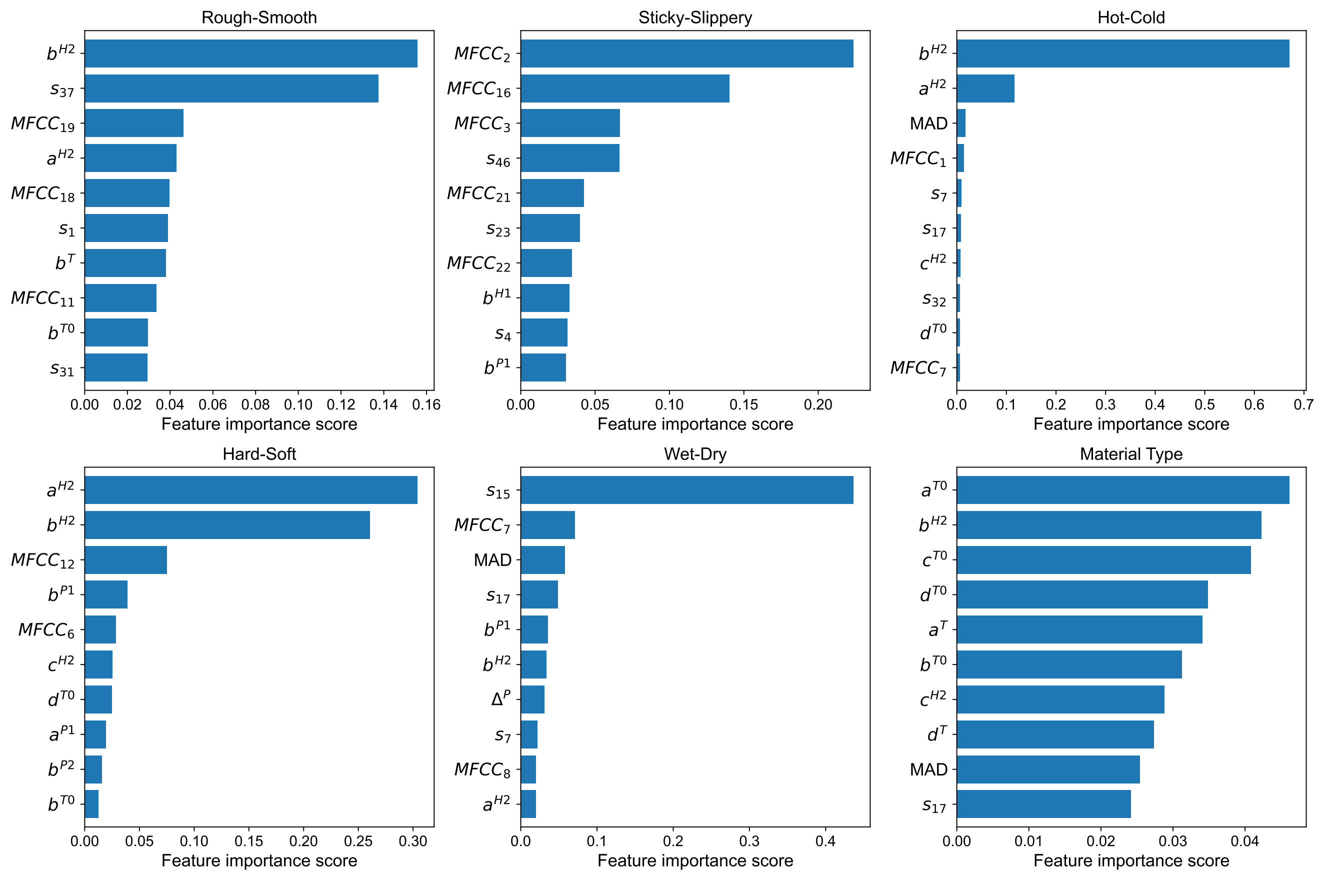

Fig. S1. The most important 10 features for predicting each sensory attribute (Model 1) and material type (Model 3) when all tactile features are used.

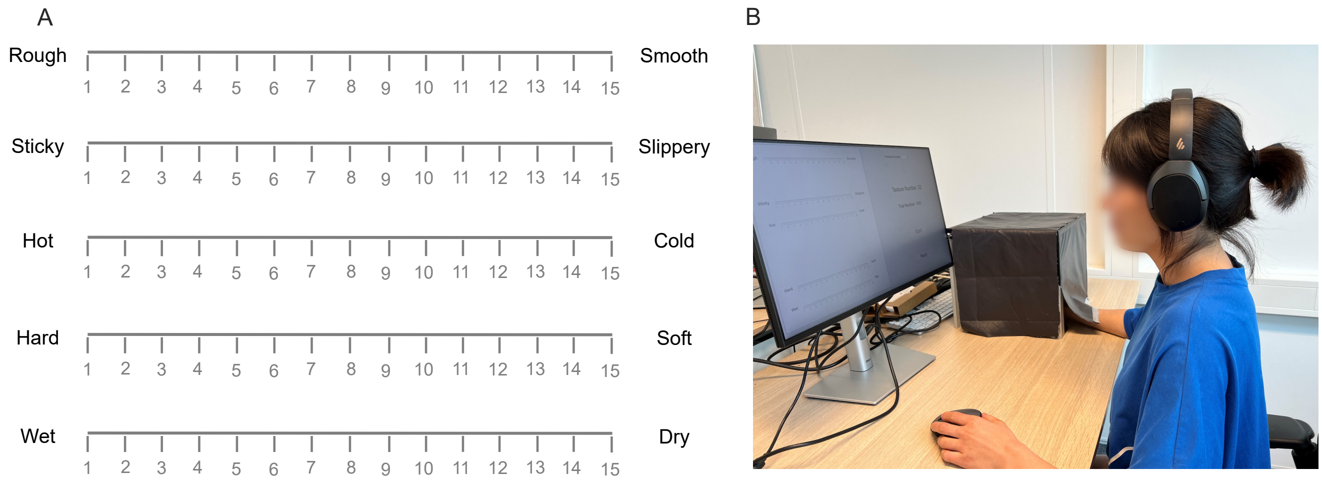

Fig. S2. Experiment illustration: (a) Five pairs of surface adjectives with a 15-point scale; (b) Psychophysical Sensation Experiment. Participants wearing headphones touch materials placed inside a black box, preventing visual and auditory cues. After each interaction, they provided sensation ratings, which were shown on a computer screen.

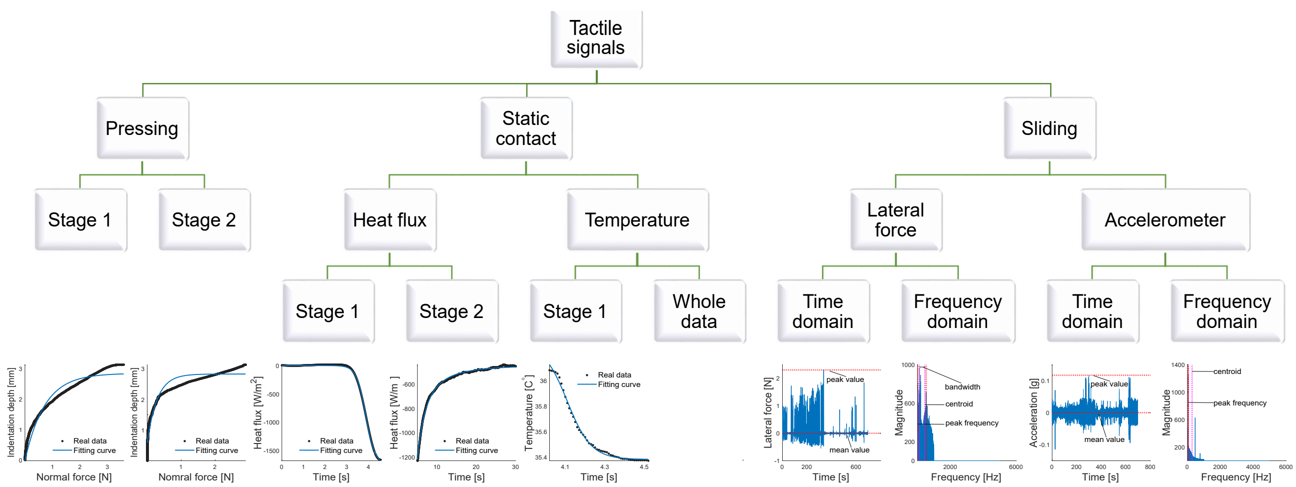

Fig. S3. A roadmap illustrating how features are extracted from pressing, static contact, and sliding data.

Table S1. All 98 features extracted from the three types of exploratory actions (EA), along with the contribution of each feature to predicting the sensory attributes—Rough–Smooth (RS), Sticky–Slippery (SS), Hot–Cold (HC), Hard–Soft (HS), Wet–Dry (WD)—and the material types (MT) when all tactile features are used.

ID	EA	Description	Symbol	RS	SS	HC	HS	WD	MT
1	Pressing	Pressing stage	a^{P1}	0.003	0.008	0.001	0.019	0.007	0.021
2	Pressing	Pressing stage	b^{P1}	0.027	0.030	0.007	0.039	0.036	0.009
3	Pressing	Lifting stage	a^{P2}	0.001	0.001	0.001	0.005	0.008	0.017
4	Pressing	Lifting stage	b^{P2}	0.003	0.008	0.001	0.016	0.001	0.007
5	Pressing	Lifting stage	c^{P2}	0.004	0.001	0.002	0.003	0.006	0.003
6	Pressing	Difference	Δ^P	0.013	0.001	0.005	0.006	0.031	0.013
7	Thermal	Heatflux	a^{H1}	0.001	0.002	0.001	0.003	0.001	0.024
8	Thermal	Heatflux	b^{H1}	0.001	0.033	0.001	0.000	0.003	0.004
9	Thermal	Heatflux	c^{H1}	0.018	0.000	0.001	0.002	0.003	0.006
10	Thermal	Heatflux	a^{H2}	0.043	0.005	0.116	0.304	0.020	0.019
11	Thermal	Heatflux	b^{H2}	0.156	0.002	0.671	0.261	0.034	0.042
12	Thermal	Heatflux	c^{H2}	0.002	0.001	0.008	0.025	0.004	0.029
13	Thermal	Temperature	a^T	0.013	0.003	0.002	0.009	0.003	0.034
14	Thermal	Temperature	b^T	0.038	0.001	0.006	0.003	0.010	0.007
15	Thermal	Temperature	c^T	0.006	0.002	0.002	0.006	0.000	0.011
16	Thermal	Temperature	d^T	0.005	0.000	0.005	0.008	0.001	0.027
17	Thermal	Temperature	a^{T0}	0.003	0.000	0.002	0.003	0.003	0.046
18	Thermal	Temperature	b^{T0}	0.029	0.014	0.003	0.013	0.000	0.031
19	Thermal	Temperature	c^{T0}	0.000	0.005	0.005	0.009	0.003	0.041
20	Thermal	Temperature	d^{T0}	0.000	0.003	0.007	0.025	0.002	0.035
21	Thermal	Temperature	MAD	0.001	0.004	0.017	0.004	0.058	0.025
22	Sliding	Lateral, time domain, mean	s_1	0.039	0.009	0.005	0.006	0.004	0.014
23	Sliding	Lat., time domain, std	s_2	0.000	0.003	0.001	0.001	0.001	0.003
24	Sliding	Lat., time domain, rms	s_3	0.000	0.005	0.001	0.000	0.000	0.007
25	Sliding	Lat., time domain, max	s_4	0.000	0.031	0.001	0.000	0.001	0.003
26	Sliding	Lat., time domain, skewness	s_5	0.000	0.026	0.001	0.001	0.002	0.010
27	Sliding	Lat., time domain, kurtosis	s_6	0.027	0.002	0.002	0.003	0.004	0.005
28	Sliding	Lat., time domain, shape factor	s_7	0.009	0.000	0.009	0.003	0.022	0.006
29	Sliding	Lat., time domain, impulse factor	s_8	0.001	0.000	0.002	0.000	0.002	0.006
30	Sliding	Lat., time domain, crest factor	s_9	0.000	0.001	0.000	0.001	0.005	0.008
31	Sliding	Lat., time domain, clearance factor	s_{10}	0.002	0.002	0.003	0.001	0.001	0.005
32	Sliding	Lat., time domain, total harmonic distortion	s_{11}	0.000	0.000	0.002	0.001	0.005	0.002
33	Sliding	Lat., time domain, sinad	s_{12}	0.012	0.002	0.000	0.001	0.003	0.002
34	Sliding	Lat., time domain, friction coefficient	s_{13}	0.000	0.001	0.006	0.008	0.002	0.020
35	Sliding	Lat., time domain, average power	s_{14}	0.001	0.001	0.001	0.000	0.000	0.003
36	Sliding	Lat., fre. domain, centroid	s_{15}	0.011	0.007	0.001	0.008	0.437	0.008
37	Sliding	Lat., fre. domain, spread	s_{16}	0.007	0.003	0.000	0.001	0.000	0.002
38	Sliding	Lat., fre. domain, rolloff freq	s_{17}	0.028	0.019	0.009	0.005	0.049	0.024
39	Sliding	Lat., fre. domain, flatness	s_{18}	0.001	0.003	0.000	0.002	0.000	0.001
40	Sliding	Lat., fre. domain, bandwidth	s_{19}	0.002	0.002	0.000	0.000	0.005	0.011
41	Sliding	Lat., fre. domain, peak frequency	s_{20}	0.000	0.002	0.001	0.001	0.001	0.002
42	Sliding	Lat., fre. domain, energy band 1	s_{21}	0.000	0.000	0.001	0.001	0.001	0.008
43	Sliding	Lat., fre. domain, energy band 2	s_{22}	0.001	0.006	0.001	0.000	0.001	0.008
44	Sliding	Lat., fre. domain, energy band 3	s_{23}	0.000	0.040	0.001	0.001	0.001	0.012
45	Sliding	Lat., fre.domain, energy band 4	s_{24}	0.000	0.004	0.001	0.000	0.019	0.002
46	Sliding	Lat., fre. domain, energy band 5	s_{25}	0.001	0.001	0.001	0.002	0.001	0.003
47	Sliding	Acceleration, time domain, mean	s_{26}	0.002	0.002	0.003	0.001	0.002	0.002
48	Sliding	Acc., time domain, std	s_{27}	0.004	0.000	0.001	0.000	0.003	0.004
49	Sliding	Acc., time domain, rms	s_{28}	0.000	0.000	0.001	0.002	0.001	0.005

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Table S1 – continued from previous page

ID	EA	Description	Symbol	RS	SS	HC	HS	WD	MT
50	Sliding	Acc., time domain, max	s_{29}	0.010	0.000	0.000	0.001	0.000	0.004
51	Sliding	Acc., time domain, skewness	s_{30}	0.022	0.000	0.001	0.001	0.006	0.004
52	Sliding	Acc., time domain, kurtosis	s_{31}	0.029	0.001	0.004	0.003	0.000	0.007
53	Sliding	Acc., time domain, shape factor	s_{32}	0.010	0.001	0.007	0.001	0.006	0.006
54	Sliding	Acc., time domain, impulse factor	s_{33}	0.001	0.001	0.000	0.004	0.002	0.007
55	Sliding	Acc., time domain, crest factor	s_{34}	0.001	0.000	0.000	0.001	0.001	0.007
56	Sliding	Acc., time domain, clearance factor	s_{35}	0.002	0.000	0.001	0.002	0.000	0.007
57	Sliding	Acc., time domain, total-harmonic-distortion	s_{36}	0.009	0.000	0.001	0.002	0.014	0.006
58	Sliding	Acc., time domain, sinad	s_{37}	0.138	0.012	0.000	0.001	0.001	0.004
59	Sliding	Acc., time domain, average power	s_{38}	0.002	0.001	0.000	0.000	0.001	0.003
60	Sliding	Acc., frequency domain, centroid	s_{39}	0.001	0.000	0.000	0.001	0.001	0.006
61	Sliding	Acc., frequency domain, spread	s_{40}	0.011	0.002	0.001	0.002	0.007	0.007
62	Sliding	Acc., frequency domain, rolloff freq	s_{41}	0.001	0.000	0.001	0.002	0.000	0.003
63	Sliding	Acc., frequency domain, flatness	s_{42}	0.004	0.000	0.000	0.000	0.000	0.005
64	Sliding	Acc., frequency domain, bandwidth	s_{43}	0.005	0.000	0.002	0.001	0.001	0.004
65	Sliding	Acc., frequency domain, peak frequency	s_{44}	0.001	0.000	0.000	0.001	0.002	0.003
66	Sliding	Acc., frequency domain, energy band 1	s_{45}	0.008	0.000	0.000	0.001	0.001	0.004
67	Sliding	Acc., frequency domain, energy band 2	s_{46}	0.002	0.066	0.000	0.000	0.004	0.005
68	Sliding	Acc., frequency domain, energy band 3	s_{47}	0.000	0.000	0.001	0.000	0.001	0.006
69	Sliding	Acc., frequency domain, energy band 4	s_{48}	0.002	0.000	0.003	0.001	0.001	0.003
70	Sliding	Acc., frequency domain, energy band 5	s_{49}	0.000	0.006	0.001	0.000	0.001	0.003
71	Sliding	Lateral force, MFCC	$MFCC_1$	0.007	0.013	0.014	0.008	0.008	0.016
72	Sliding	Lateral force, MFCC	$MFCC_2$	0.002	0.224	0.001	0.003	0.000	0.012
73	Sliding	Lateral force, MFCC	$MFCC_3$	0.003	0.067	0.001	0.001	0.000	0.008
74	Sliding	Lateral force, MFCC	$MFCC_4$	0.003	0.008	0.003	0.001	0.000	0.019
75	Sliding	Lateral force, MFCC	$MFCC_5$	0.012	0.009	0.001	0.000	0.002	0.007
76	Sliding	Lateral force, MFCC	$MFCC_6$	0.004	0.005	0.004	0.029	0.003	0.015
77	Sliding	Lateral force, MFCC	$MFCC_7$	0.029	0.006	0.007	0.008	0.071	0.016
78	Sliding	Lateral force, MFCC	$MFCC_8$	0.018	0.001	0.001	0.001	0.020	0.019
79	Sliding	Lateral force, MFCC	$MFCC_9$	0.005	0.002	0.001	0.006	0.001	0.008
80	Sliding	Lateral force, MFCC	$MFCC_{10}$	0.000	0.000	0.001	0.002	0.004	0.005
81	Sliding	Lateral force, MFCC	$MFCC_{11}$	0.034	0.004	0.001	0.001	0.017	0.013
82	Sliding	Lateral force, MFCC	$MFCC_{12}$	0.001	0.004	0.001	0.075	0.001	0.009
83	Sliding	Lateral force, MFCC	$MFCC_{13}$	0.000	0.001	0.001	0.000	0.000	0.008
84	Sliding	Lateral force, MFCC	$MFCC_{14}$	0.003	0.002	0.002	0.001	0.000	0.012
85	Sliding	Acceleration, MFCC	$MFCC_{15}$	0.000	0.000	0.006	0.002	0.001	0.003
86	Sliding	Acceleration, MFCC	$MFCC_{16}$	0.002	0.140	0.000	0.000	0.000	0.007
87	Sliding	Acceleration, MFCC	$MFCC_{17}$	0.005	0.004	0.000	0.001	0.001	0.005
88	Sliding	Acceleration, MFCC	$MFCC_{18}$	0.040	0.001	0.001	0.001	0.001	0.003
89	Sliding	Acceleration, MFCC	$MFCC_{19}$	0.046	0.001	0.003	0.000	0.001	0.006
90	Sliding	Acceleration, MFCC	$MFCC_{20}$	0.001	0.004	0.002	0.003	0.003	0.009
91	Sliding	Acceleration, MFCC	$MFCC_{21}$	0.000	0.042	0.002	0.001	0.004	0.009
92	Sliding	Acceleration, MFCC	$MFCC_{22}$	0.000	0.035	0.001	0.004	0.001	0.004
93	Sliding	Acceleration, MFCC	$MFCC_{23}$	0.000	0.005	0.000	0.001	0.002	0.007
94	Sliding	Acceleration, MFCC	$MFCC_{24}$	0.002	0.008	0.001	0.000	0.000	0.006
95	Sliding	Acceleration, MFCC	$MFCC_{25}$	0.001	0.000	0.001	0.004	0.000	0.004
96	Sliding	Acceleration, MFCC	$MFCC_{26}$	0.000	0.025	0.001	0.001	0.003	0.005
97	Sliding	Acceleration, MFCC	$MFCC_{27}$	0.003	0.000	0.000	0.001	0.001	0.017
98	Sliding	Acceleration, MFCC	$MFCC_{28}$	0.003	0.002	0.001	0.003	0.001	0.003

Table S2. The tuned hyperparameters for each algorithm.

Machine learning model	Hyperparameters name	Hyperparameters values
RandomForestRegressor	n_neighbors	range (20, 500, 20)
KNN	n_neighbors	range (2, 20, 1)
BaggingClassifier	n_estimators	range (20, 500, 20)
	max_features	[1, 2, 3, 4, 5, 6, 7, 8, 9, 10]
LogisticRegression	solver	[newton-cg, lbfgs, liblinear, newton-cholesky, sag, saga]
	penalty	[l1, l2, elasticnet, None]
	C	[100, 10, 1.0, 0.1, 0.01, 0.001, 0.0001, 0.00001]
MLPClassifier	hidden_layer_sizes	[(100, 100, 100)]
	activation	[tanh, relu]
	solver	[sgd, adam]
	alpha	[0.0001, 0.001, 0.01, 0.1]
	learning_rate	[constant, adaptive]
BernoulliNB	alpha	np.logspace(0, -10, num = 100)
GaussianNB	var_smoothing	np.logspace(0, -10, num = 100)
NearestCentroid	shrink_threshold	[None, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0]
	metric	[euclidean, manhattan]
RandomForestClassifier	n_estimators	range (20, 500, 20)
SVC	C	[0.00001, 0.0001, 0.001, 0.01, 0.1, 1, 10, 100, 1000]
	gamma	[100, 10, 1, 0.1, 0.01, 0.001, 0.0001, 0.00001]
	kernel	[linear, poly, rbf, sigmoid]
GradientBoosting	n_estimators	range (100, 1000, 100)
	learning_rate	[0.001, 0.01, 0.1]