Supplementary Figure 1

Examples of learning curves and lick timing from individual mice during thermal detection task.

**a**, Examples of individual learning curves from 3 mice, bold cyan line showing the correct hit rate, light cyan the false licks. Mice were trained one session / day. **b**, Peri-stimulus time histograms (PSTHs) of licking during stimulus presentation from day 5 from the corresponding mice in **a**. Thermal stimulus onset is at time = 0s and lasted for 3 s. Top PSTHs shows the successful hits, bottom PSTHs in light cyan show the false licks.
Supplementary Figure 2

A cold responsive L2/3 excitatory cortical pyramidial neuron in mouse forepaw S1.

a, Anatomical reconstruction of a cortical pyramidial neuron in mouse forepaw somatosensory cortex. b, Single trial examples of the response of the same cell to cold stimulation of the paw under isoflurane anesthesia with averaged membrane potential response underneath and PSTH on bottom to 40 presentations of a cooling stimulus. Horizontal marks on V_m represent –60 mV for single trials and –74 mV for the averaged response.
Supplementary Figure 3

Mouse forepaw does not move during cooling thermal stimulation under isoflurane anesthesia.

**a, b, c,** Three example, averaged Layer 2/3 cortical whole-cell recordings (black traces) from different mice during cold-thermal (32-22°C) stimulation of the forepaw (blue trace). The distance of paw movement (orange) was monitored with a movement sensor arm resting on top of the forepaw digits while the force was kept constant (green). The movement sensor was sensitive enough to record a slow (about 3 s duration) movement of the peltier element during cooling that moved the paw by about 1 μm. This slight movement did not cause responses in cortex as (i) cortical control recordings showed no response, data not shown; (ii) the same stimulator was used for single nerve afferent fibers recordings and did not evoked tactile responses in low threshold mechanoreceptors; (iii) the cold response starts before movement onset in the middle cell, see vertical red dashed line in (b). Horizontal marks next to V_m represent, (a) −56 mV, (b) −64 mV, (c) −64 mV.
Supplementary Figure 4

Layer 2/3 cortical neurons in \textit{Trpm8}\textsuperscript{−/−} mice respond to tactile stimulation of the forepaw.

\textbf{a, b, c}, Three example cells from different mice showing significant averaged subthreshold responses (magenta) to 100 Hz vibrotactile stimulation (orange) of the forepaw digits.
Supplementary Figure 5

Trpm8<sup>−/−</sup> mice are able to learn an acoustic detection task.

a, cartoon schematic of head-restrained mouse undergoing acoustic training with water rewards. b, 2 Trpm8<sup>−/−</sup> mice were trained to lick in response to brief (5 ms) acoustic stimulus presentation at randomized times directly after cooling detection training. These Trpm8<sup>−/−</sup> mice were not able to learn to report mild cooling, they learned to lick after the acoustic stimulus already in the first trial. On the forth session, the mean hit rate was 86.1 ± 3.0% (mean in purple) compared to false licks 8.5 ± 3.5% (mean in black). Error bars show s.e.m.
Supplementary Figure 6

Primary sensory afferent recordings from \textit{Trpm8}^{-/} and \textit{Trpm8}^{+/} mice during a 10 °C cooling stimulus

\textit{a}, Example recordings from cutaneous C-fibers in WT (blue) and \textit{Trpm8}^{+/} (magenta) mice during cold stimulation matching the stimulus used during behavioral training (32-22°C). Inset shows colored spikes that were selected for analysis, and in grey the discarded spikes. 

\textit{b}, Temperature threshold for the first spike in all fibers responding to cold. In good agreement with the dataset in Figure 6, very few cold responsive A-\(\beta\) or A-\(\delta\) fibers were identified with the 10°C cooling stimulus. In comparison, a large number of C-MHC (C-MechanoHeatCold) and C-MC (C-MechanoCold) fibers with low response threshold were identified. The C-fiber population showed a large reduction in \textit{Trpm8}^{+/} mice. Grey dot shows a unimodal, cold specific C-fiber with similar threshold to other cold sensitive C-fibers. Horizontal bars represent mean with s.e.m..
Supplementary Figure 7

Population analysis of all fibers recorded in entire dataset from \textit{Trpm8\textsuperscript{-/-}} and \textit{Trpm8\textsuperscript{+/+}} mice

\textbf{a}, From the entire surveyed population, 15.6\% (24/154 single units) responded to cooling in \textit{Trpm8\textsuperscript{+/+}} mice but only 5.7\% (11/193 single units) in the \textit{Trpm8\textsuperscript{-/-}} mice (Chi-squared test $P = 0.0024$). There was no change in the proportion of heating sensitive afferents in the \textit{Trpm8\textsuperscript{+/+}} mouse. 

\textbf{b}, From the four subtypes of C recorded (C-M, C-Mechano; C-MH, C-MechanoHeat; C-MC, C-MechanoCold, C-MHC, C-MechanoHeatCold), there was a significant reduction in the numbers of recorded C-MC (Chi-squared test $P = 0.0025$) and no C-MHCs were identified, but there was no change in the numbers of in C-M and C-MH in the \textit{Trpm8\textsuperscript{-/-}} mouse. 

\textbf{c}, We recorded 5 major types of A fiber (A-\textbeta; A-\delta; A-\textbeta\textgamma; A-\delta\textgamma; A-\delta\textgamma\textdelta) none of which showed significant changes in numbers in the \textit{Trpm8\textsuperscript{-/-}} mouse.