Thermal interfaces: reduction in discriminative accuracy despite enhanced subjective confidence after topical application of menthol.

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***Abstract*— Thermosensation represents a relatively unexplored modality for information transmission in communication interfaces. To explore the upper limits of discriminative ability, we asked if performance at warm temperatures (35-37C) could be enhanced by topical application of the cold-sensitizing compound menthol, to bring cold sensing channels within the range of warm channels. We found that although menthol enhanced subject's confidence in their ability to finely discriminate phasic cooling-from-baseline pulses, actual performance was clearly impaired. This indicates that the brain cannot easily integrate cold and warm thermal afferent channels to improve discrimination, and that metacognitive and actual performance is dissociable.**

I. Introduction

Humans have a fine-grained ability to discriminate temperature, making it a possible channel for information delivery in communications devices (e.g. in haptic displays) [1]. However, capacity is limited by the maximum discriminative ability within ambient, non-noxious temperature ranges, raising the question as to whether this can be enhanced by biological manipulations. Temperature is sensed by cold and warm thermosensitive afferent neurons, with relatively non-overlapping response profiles [2]. In principle, therefore, thermosensation might be enhanced by elevating the temperature-response function of cold fibers towards warmer temperatures - which is possible by topical application of menthol (which sensitizes TRPM8 chemosensitive cold afferents). Accordingly, both neuron types might then be able to simultaneously contribute to temperature coding within warm ranges, and subsequently integrate their information to improve thermal discrimination.

II. Methods

We applied a contact peltier thermode (Medoc PATHWAY ATS 30mm x 30mm) to the face of young adult healthy subjects (n=16), who were required to judge the cooler of two sequential pulses (i.e. a two-interval detection task) from three different baseline temperatures (cold 21C, intermediate 30C and warm 39C). The pairs of pulses were between 2C and 4C below each baseline, 2 secs apart, and differed by 0.1, 0.3, 0.5 or 0.7C yielding 4 difficulty levels. We compared cold detection thresholds, discriminative accuracy, subjective cold ratings and performance confidence immediately after 5mins application of 2% menthol cream to the maxillary area of the face on one side, versus control (the other side of the face), in multiple sessions over two days.

III. Results

Menthol raised cold detection thresholds from 34.7C to 36.1C, and subjective cold ratings increased across all baseline temperatures (0-10 coolness rating 6.8 (menthol) vs 6.0 (control) at cold; 6.3 vs 5.4 at intermediate; 3.3 to 4.3 for warm baseline). Warm temperatures were judged easier to discriminate with menthol (0-10 confidence rating 5.4 (menthol) vs 4.3 (control), $p<0.01$), with no difference at intermediate (5.0 vs 5.0) and harder at cold temperatures (2.8 vs 4.1, $p<0.01$). However, discriminative performance was reduced at warm (across all difficulties $p<0.001$) and cold ($P<0.001$) but not intermediate temperatures (Fig 1).

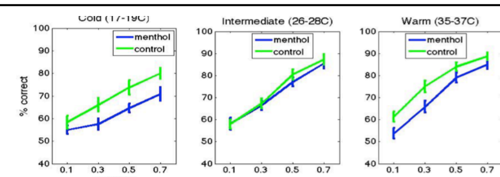

Fig 1. Performance (% correct) in the 3 temperature ranges (cold, intermediate and warm) across difficulty levels (defined by difference in the two pulse temperatures) in menthol-treated and control skin.

IV. Conclusions

The cold detection thresholds suggest that at warm temperatures (35-37C), menthol brings cold afferent pathways within range. Consequently, this 'richer' thermal input leads to a greater confidence in discriminative ability, but a surprising reduction in actual discriminative performance. This indicates firstly that unlike visuo-haptic information [3], humans are not immediately capable of integrating different thermal channels to optimize discrimination, suggesting functional dissociation of warmth and cold at the level of cerebral cortex (in theory, this might be reversed with extended perceptual learning). Second, it dissociates metacognitive function from basic perceptual ability in thermosensation, indicating that subjective report may not always be a reliable indicator of performance.

References

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