- We developed three working prototypes of smart rings embedded with multiple (4, 6, and 8) thermoelectric coolers (TECs), of various sizes, which can be used with the in-ring spatial thermal patterns described in the paper.

- Our pilot study investigated how well users could localized the in-ring thermal feedback with three different settings. Results showed that users could reliably recognize 4 points with cold stimulation (97.2% accuracy), while the other two settings with 6 and 8 TECs couldn't result in an average accuracy above 80%.

- In the two main experiments, we investigated the use of 4 in-ring TECs to achieve two combinations of spatial thermal patterns (i.e. simultaneously trigger two neighboring or opposite elements). The results revealed three neighboring patterns and five opposite patterns that were reliably recognized by the participants with the accuracy above 80%.

- The follow-up studies showed that it could be confusing for users by combining four single-spot cold stimulations, three neighboring patterns, and five opposite patterns in the same group (average accuracy: 50.2%). However, the follow-up results also showed that the participants could identify the thermal patterns in the combined group of the single-spot cold stimulations and the neighboring patterns (average accuracy: 85.3%), and the combined group of the single-spot cold stimulations and the opposite patterns (average accuracy: 89.3%). This suggested it could feasible to use these combined group of thermal patterns as thermal icons for information representation.

- We further conducted three design workshops, involving six product/interface designers, to investigate the potential of using these thermal patterns for different applications. The designers suggested different mappings between the given thermal patterns and the information, including direction cueing through single-spot and neighboring patterns, artifact comparison through opposite patterns, notifying incoming calls/messages from different persons with different locations and temperatures of the TECs, etc.