Emoto-Garm: A Study of Emotional Experience Manipulation via Wearable Garment

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ABSTRACT
This research is motivated by a recent study by Nummenmaa et al., which has produced self-reported body temperature maps of various emotions. This study is also inspired by another recent research by Yoshida et al. that investigated the possibility of evoking emotions by providing “pseudo-generated facial expressions”. There is a plethora of research in the field of affect and emotional study to support physiological changes evoke emotions, as well as studies that support effects of temperature in cognitive performance. However, the effects of a wearable garment capable of variable temperatures that can alter affective state has not been researched.

The main goal of this paper is to examine the possibility of evoking emotions in subjects by providing pseudo-bodily responses in the format of change in temperature. We also were interested in observing whether change in temperature can alter the cognitive performance in our subjects. The results from our study did not demonstrate a significant change in mean magnitude of self-reported change in affective-state, when exposed to covert change in body temperature. The results of our second study also did not demonstrate significant difference in the mean magnitude of change in cognitive performance when exposed to covert alteration of body suit temperature except for one particular case. In case of performing cognitive search task, when temperature of body suit was altered between Neutral and Hot, there was significant change in the performance of our subjects. The two other tasks involving typing and building playing-card pyramids, revealed insignificant results.

We discovered that increasing the resolution of the body suit we used to provide more accurate microclimate zones in order to more precisely matching the body-heat maps from Nummenmaa et al’s study, may have resulted in different findings. We also report that in eliciting self-reported affective state, using a larger step likert-scale (such as 7 or 11-steps) is likely to detect mean variance more accurately and result in different study outcomes.

Categories and Subject Descriptors
D.1.2 [Models and Principles]: User/Machine Systems – human factors

General Terms
Human factors, Design.

Keywords
Cognitive Performance, Microclimate suit, Wearable garment, Body Heat Map, Temperature Performance

1. BACKGROUND
Anger, happiness, sadness, love and pride – these and other emotions are often felt in the body and can affect our actions. It is known that emotions can play a role in decision-making, attention, competitiveness, learning and many others. All emotional states comprise of two components, physical sensation (heart rate, respiration, etc.) and conscious feelings (pride, anger, etc.). Within the body, hormones excreted by the endocrine system, cardiovascular system, autonomic nervous system and
the skeletal system work together to control emotional states. These systems synchronize together to identify stimuli, which then translated a stimulus into emotional significance, which are then used to coordinate the body’s affective state reflexes [1]. This coordination can be seen, for example, when an object frightens us [2]. We not only feel scared, but we also have an increased heart rate, dilated pupils and increase in adrenaline production.

Emotion is presumed to be a consequence of interpreting stimulation from our external environment and making internal bodily changes accordingly, like responding to a scary stimulus with an increased heartbeat. However, researchers do not fully understand how our brains appraise stimuli to illicit a response [3]. Furthermore, a well-cited study suggests bodily changes to an external environment like walking across a scary bridge evokes the same emotion as meeting an attractive woman, further alluding to the fact that our internal processing of emotions is still not fully understood [4].

1.1 Physiological Change Evokes Emotion

While research varies on how the environment affects our emotions based on bodily reactions, there is research to suggest that emotion actually results from the body’s physiological change, rather than the cause of the reaction [3]. The James-Lange theory confirms this by suggesting experiencing emotion occurs after the cortex is given a signal that there has been a physiological change [4]. In fact, the role of interpreting physiological senses is essential in cognitive science and affective computing, and its understanding has been used by many researchers to support their hypotheses [3]. In particular, Briese et al’s work supported the James-Lange theory by proving that there was a tight relationship between emotions and body temperatures [5]. Proving that the role of the temperature, and other physiological responses, should not be overlooked with emotional theories.

Notably, to this day it is still debated whether bodily changes associated with different emotions “are specific enough to serve as the basis for discrete emotional feelings, such as anger, fear or happiness” [6], [7]. The two-factor theory, by Schachter et al, suggests that a combination of bodily responses is required for several emotions; thus, discrete emotion cannot be determined by solely changes to bodily aspects [8]. The term “attribution of causality” is how the brain determines the type of emotion experienced, and its response is depended upon the recognition of senses like elevated temperature, increased heartbeat, etc.

Conversely, researchers have taken James-Lange and Schacter’s theories further to find another requirement needed to elicit emotion. A study by Valins et al confirmed that emotion evocation doesn’t necessarily depend on your body actually changing to a stimulus i.e. increasing skin temperature. Instead, the body only needs to recognize the state (like warm skin temperature), and not the process, allowing the brain to be ‘tricked’ [9]. A false heart-rate study, by Valin et al, demonstrated that when the user is subjected to false change in heartbeat, they reported noticing an emotional shift. Furthermore, Nishimura et al built a tactile device that attached to the users side to better display the pseudo-heartbeat phenomena, which successfully evoked feelings of love [10]. This advocates that a specific emotion might be elicited by a physical sensation and a bodily responses unconsciously affect a person’s corresponding emotion, and b) recognizing a pseudo-bodily response can elicit emotions.

1.2 Effects of Temperature on Cognitive Performance

Performing tasks when exposed to varying temperatures has been proven to influence performance, however it is highly dependent upon the duration, temperature change and the cognitive load of the task [11]. Some studies have indicated that a small increase in core body temperature, as little as 2 degrees Celsius can improve reasoning [12], while other authors have reported that incremental heat exposure impairs performance in complex tasks between 31-35 degrees Celsius [13]. Furthermore, a study performed in 2002, by Pilcher et al, determined that exposure to heat during tasks, including motor-skills and reasoning, resulted in an ‘inverted U-shape function’ where <32.22°C or >10°C gave the worst performance [14]. Lastly, current literature contradicts Ramsey et al and hints that overall cognitive performance decrements can be attributed to elevated core temperature [15] and cooling may have no impact on sequential game performance [16]. From contradiction in the literature, it’s implied that the effect of temperature versus cognitive performance is still not fully understood.

1.3 Contributions

The purpose of this study is to investigate how changing a subject’s body temperature using a pseudo-bodily response using a temperature variable garment is a) capable of manipulating a subject’s affective state and b) performance during basic activities. We propose that somatosensory feedback can trigger conscious emotional experiences, and that by consistently manipulating body temperature we can control short-term mood and performance.

The principal element of this study, which assumes that bodily responses to a stimulus can evoke emotions, have been widely supported by other researchers in the past [17]. However, we attempt to invert the results specifically reported in Nummenmaa et al’s research. Similar studies have shown that providing a positive feedback loop to reinforce an affective state can also alter the subject’s decision making [18]. The emotional influence can occur both consciously and sub-consciously and it translates into external reflexes including motor responses; some that are not even conscious [19]. Our aim is to establish a set of activities to observe whether the covert reinforcement of Nummenmaa et al’s emotion heat-maps can be observed in performance changes in the subject, while executing simple and routine tasks.

2. RELATED WORK

Researchers have proven that temperatures of different parts of the body can be associated with emotions [20], [21], [22] and some have hypothesized that a reversed ‘causal effect’ [23] where skin temperature can change a subjects affect may be possible. However, most research studying the relation between temperature and affect, has mostly been concerned with hot temperatures versus aggression [24], especially in video games [25], [26]. Conversely, there has been research done to suggest general negative affect may occur at hot temperatures as well as cold temperatures [27]. Nevertheless, to the best of our knowledge, our work is novel because the only research concentrating on the emotion induction through temperature, via personal device, is described in [28] and [29]. The study performed by Kok et al’s researched how our bodily state is a response to our emotional state. Specifically, how a psychological response can evoke pleasure and arousal through an interactive chair. Their interactive chair was able to change many of the body’s senses, including temperature via a ventilation system that
4. EXPERIMENT DESIGN

The experiment was based on a 3x3 within-subjects design. Each participant was asked to wear the custom designed variable temperature garment for the upper body shown in Figure 1 and 2. The suit was intended to emulate a microclimate with controlled temperature. Circulating water through the garment’s tubing stitched on the inside controlled the temperature. Each participant was asked to perform, in random and after a learning period, 3 blocks of tasks with each block consisting of all of the following tasks in no particular order:

- **Search Activity**: A participant was given one of 3 ‘eye-spy’ boards such as the one shown in Figure 3 with many objects on it. The participant was also given a deck of cards each containing 8 objects. One and only one of the objects on each card were on the board. The order of cards given to each user to play was preserved.
- **Build Activity**: The user was given a deck of standard game cards and asked to build a variation of pyramids such as the one shown in Figure 3.
- **Typing Activity**: Each subject was given one of three passages from “The Tragedy of Julius Caesar” by William Shakespeare such as the one shown in Figure 3. The subject was asked to refrain from pressing the “delete” or “backspace” buttons. The subject was informed that punctuation is not required however, capitalization and correct spelling was required.

![Figure 3: Materials used in this experiment. This image includes one search board, search cards, a typing passage and one variation of the building task.](image)

Figure 3: Materials used in this experiment. This image includes one search board, search cards, a typing passage and one variation of the building task.

Each subject was given 3 minutes for each task, and at the end of the task, based on the measurement markers, their performance was evaluated. The user was asked if they were comfortable to carry on with the study or if they had any questions regarding the next task at the end of each activity. To remove any effects of implementation order on the temperature change, the change order was randomly assigned and counterbalanced across participants. Also in order to eliminate the effects of subject’s affect towards the order of performed tasks in all three blocks, the order of tasks were randomly assigned and counter balanced across all blocks for each participant.

Subjects were all given full training instructions on each task and its varieties and were given time to practice on a standard training set that was similar but separate from the examination sets. Participants were asked to refrain from asking questions.
regarding the theory, logic or purpose of the study during the study but were allowed to ask questions regarding the tasks they were asked to perform. This was intended to eliminate the possible effects of self-assessed bias of the subject towards the results of the study, from presenting itself in the questionnaires or the performance results for the tasks.

For each block the body suit of the subject was altered to one of “Hot”, “Cold” or Neutral” temperatures throughout the execution of all three tasks for that block. During each task, the participant was observed for performance markers, which were recorded for further analysis of change in performance. At the end of each block, the user was asked to fill out an emotional awareness questionnaire that elicited the self-reported affective state of the subject.

4.1 Participants
The study for both suggested hypotheses (H1 and H2) was conducted with the same group of participants. The study had 12 subjects (7 males and 5 females with mean age of 27 falling in the range of 24:31). The participants were not fully aware of the purpose of the study in order to reduce for any perception bias. Subjects were fully informed of the study’s purpose at the end.

5. EVALUATION OF THE EFFECTS OF VARIANCE OF TEMPERATURE ON AFFECTIVE STATE

5.1 Hypothesis
We hypothesized that the participant’s affective state would be influenced by change in temperature in creating a pseudo-bodily response. More specifically, the authors investigated if changing the temperature of the body from Neutral to Cold or from Neutral to Hot, would cause a shift in the magnitude of the means of any one of the following 7 emotions: Happiness, Shame, Pride, Love, Anger, Depression, or Anxiety. For instance, if the user felt happy when performing a simple everyday task, we propose that by altering the temperature of the suit from Neutral to Cold or Hot, it may increase or decrease the strength level for that specific self-reported emotion.

5.2 Evaluation Indicators
We used a standard affect elicitation likert-scale questionnaire with statements used in prior research to elicit affective state. [33], [34], [35], [36]. For each emotion we used statements such as below and asked the user to rate them (Strongly Disagree, Disagree, Neutral, Agree, or Strongly Agree):

- Anxiety: “I feel at ease” [33]
- Anger: “I feel irritated, I feel like yelling at somebody”[34]
- Shame: “I feel self-conscious and embarrassed” [35]
- Happiness: “I have a good amount of enthusiasm” [36]

We assigned a negative to positive range to the 5 step likert-scale used (-2, -1, 0, 1, 2) for evaluation.

5.3 Results
We used repeated-measure ANOVA for this analysis using significance level of p<0.05. We analyzed the survey results for all seven elicited emotions across all three conditions (Cold, Neutral, Hot) and found that the effect of temperature change on the change in mean magnitude of every single one of the 7 elicited emotions to be not significant:

<table>
<thead>
<tr>
<th>Emotion</th>
<th>F</th>
<th>Fcritical</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anger</td>
<td>0.86</td>
<td>3.28</td>
<td>0.43</td>
</tr>
<tr>
<td>Anxiety</td>
<td>0.12</td>
<td>3.28</td>
<td>0.88</td>
</tr>
<tr>
<td>Shame</td>
<td>0.12</td>
<td>3.28</td>
<td>0.88</td>
</tr>
<tr>
<td>Depression</td>
<td>0.05</td>
<td>3.28</td>
<td>0.95</td>
</tr>
<tr>
<td>Happiness</td>
<td>0.29</td>
<td>3.28</td>
<td>0.75</td>
</tr>
<tr>
<td>Love</td>
<td>0.03</td>
<td>3.28</td>
<td>0.97</td>
</tr>
<tr>
<td>Pride</td>
<td>0.02</td>
<td>3.28</td>
<td>0.98</td>
</tr>
</tbody>
</table>

Table 1: Comparison of Fcritical for 12 subjects with p<0.05 and the measured F from repeated-measure ANOVA on questionnaire results

Additionally we investigated the effect of change of temperature between Cold and Neutral as well as Neutral and Hot in isolation, using repeated-measure ANOVA, and found that they were also not significant. Furthermore, when we studied the frequency of change in the magnitude of self-reported affective-state resulting from change in temperature, we found out that:

- When temperature was changed between Neutral and Cold 69% reported some change in affective state and 31% reported no change.
- When temperature was changed between Neutral and Hot 63% reported some change in affective state and 37% reported no change.

5.4 Discussion
In post-experiment discussion, all users reported that they were aware of changes in temperature in the body suit, including some that anticipated temperature changes after the first block of tasks. This may indicate that we were not successful in covertly simulating the body heat maps. As seen in Figure 4, the changes in temperature did result in a change in self-reported affective-state, however, based on our ANOVA analysis of the reported data, there were no significant mean differences to reject the null hypothesis. Given the frequency of change in self-reported affective state is considerable, we argue that the resolution of the likert-scale we used was too small. If a 7-step or an 11-step scale was used to elicit affective-state change instead, we may have recorded the changes with greater sensitivity. We also believe that the resolution of the body suit that we utilized for the study was not high enough. We suggest based on our findings and the

![Diagram depicting the distribution of frequency of subjects that reported some change in affective-state after being exposed to change in temperature inside the body suit](image-url)
discussions with test subjects, that by creating a more high resolution suit which can simulate the body maps from Nummenmaa et al more precisely, the results may have been different; and more precise. These improvements may have resulted in more significant mean change and therefore our ANOVA tests may have produced more significant results.

### 6. EVALUATION OF THE EFFECTS OF VARIANCE OF TEMPERATURE ON COGNITIVE PERFORMANCE

#### 6.1 Hypothesis
We hypothesized that the participant’s cognitive performance would be influenced by change in temperature in creating a pseudo-bodily response. More specifically, we thought that by changing the temperature of the body suit from Neutral to Cold or from Neutral to Hot, it would cause a change in the performance indicated by specific markers for one of three category of tasks: Building Activity, Searching Activity, or Typing Activity. For example, we thought that by altering the temperature of the body suit from Neutral to Cold, the number of spelling mistakes the subject would make in the typing activity, would increase or decrease.

#### 6.2 Evaluation Indicator
For each of the three types of tasks, we used the following markers and metrics to measure each subject’s performance:

- **Search Activity**: Number of cards where the user was successful in finding the object in the given card. Change in performance was measured in change in number of successfully searched cards.
- **Building Activity**: Number of pyramids left standing at the end of the given time. Change in performance was measured in change of number of standing pyramids.
- **Typing Activity**: Number of spelling errors in addition to number of times backspace was pressed. Punctuation errors were ignored, capitalization errors were counted as spelling error and backspace was counted only once if pressed several times in erasing the same word. Performance was measured in ratio of errors to total number of words per passage typed. Change in performance was measured in change of this ratio.

#### 6.3 Results
We used a repeated-measure ANOVA for this analysis using significance level of $p<0.05$. We analyzed the performance markers of all three activities across all three conditions (Cold, Neutral, or Hot). We found that the effect of change in temperature on change of mean magnitude in performance for the Build and Type activities to be not significant. However, we observed that the effect of change in temperature on the change in mean magnitude of performance for the Search task was significant.

Additionally we investigated the effect of change of temperature between Cold and Neutral as well as Neutral and Hot in isolation, and found that they were also not significant in all scenarios except for one. The only scenario where the effect was significant was in the case of the Search activity when temperature changed between Hot and Neutral.

<table>
<thead>
<tr>
<th>Activity</th>
<th>$F$</th>
<th>$F_{critical}$</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Search Activity</td>
<td>4.71</td>
<td>3.28</td>
<td>0.02</td>
</tr>
<tr>
<td>Build Activity</td>
<td>0.15</td>
<td>3.28</td>
<td>0.86</td>
</tr>
<tr>
<td>Type Activity</td>
<td>0.03</td>
<td>3.28</td>
<td>0.97</td>
</tr>
</tbody>
</table>

Table 2: Comparison of $F_{critical}$ for 12 subjects with $p<0.05$ and the measured $F$ from repeated-measure ANOVA on task performance results

### 6.4 Discussion
In post-experiment discussion, users reported that they were aware of change in temperature in the body suit. Subjects also reported that they felt the build task, where they made pyramids from playing cards, was not homogenous in difficulty compared to the searching task. Subjects also reported elements such as: having longer nails, size of the font of the passage given, or prior exposure to Shakespeare, may have affected their performance in the typing task. This indicates that the typing task was also not as homogenous amongst subjects compared to the search task. Going forward we recommend choosing tasks that are more similar to the searching activity in terms of learning curve, homogeneity and difficulty level to draw better change in levels resulted from change in temperature. In particular, searches in visual acuity are recommended as we successfully found significant performance improvement in ‘eye-spy’ when the subject was heated. This improvement supports Brisswalter et al.’s research [12].

### 7. CONCLUSION AND FUTURE WORK
To conclude, our experiment only showed significance difference in mean variance for one particular task between Neutral and Hot. We found that subjects completing the searching task when heated performed differently than when exposed to neutral temperature. All other tasks provided no correlation of performance with respect to changes in temperature. Furthermore, we were not able to produce evidence that our inverse study of heat body maps provided by Nummenmaa et al, was able to reliably evoke a specified emotion. As mentioned, this could be caused by the low resolution of our suit as well as the likert-scale size of the questionnaires. To increase the resolution of the suit we intend to use more tubes, and spread them farther across the upper body as well as possibly the lower extremities. By increasing the resolution of the suit, and achieving a wider range of temperatures, which may be able to ratify our hypotheses. We also believe that increasing the steps of our likert-scale questionnaires increases the sensitivity level in detecting changes in mean magnitude of self-reported affective-states. Nevertheless, we believe our hypotheses were reasonable as past research and theories suggest that manipulating affect via temperature is an exploitable psychological phenomenon.

Finally, current research that compares task performance, especially cognitive performance, suggests that the searching task should have performed more poorly under heat. However, we argue that there is no standard for task performance with a variable temperature garment, only variable temperature environments. Further work in this study includes creating a higher resolution suit, more specific and a wider range of temperature microenvironments, tasks that focus more upon cognitive load instead of motor ability and a more sensitive emotional awareness study.
8. REFERENCES


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