The pleasant heat?
Evidence for thermal-emotional implicit associations occurring with semantic and physical thermal stimulation

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Abstract

The association between thermal and emotional experiences in interpersonal relations is intuitively apparent and has been confirmed by previous studies. However, research has not yet elucidated whether such an association is grounded in mental processes occurring at an intrapersonal (internal) level. In two experiments we examined whether the thermal-emotional associations can be observed at an intrapersonal level. We looked at the speed and accuracy of stimuli categorization. Experiment 1 examined the implicit semantic association between temperature (warm versus cold) and emotional valence (positive versus negative). Experiment 2 examined the association between experience of physical temperature and emotional valence. In both experiments warm-positive/cold-negative associations were demonstrated. These results suggest a conceptual and perceptual mapping in the mental representation of emotion and temperature, which occurs at an intrapersonal level and which might serve as the ground to the interpersonal thermal-emotional interactions.

Keywords: thermal-emotional interactions, thermal perception, emotional responses, implicit associations, embodiment

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When describing a person's emotional qualities we often use temperature terms, one can be a warm person, offer a warm embrace, be a cold and unaffectionate person or give a cold response. Temperature and *interpersonal* behavior are thus linked together in daily language. It has been shown that subjective warmth is an important aspect in interpersonal relations and it is one of the main dimensions by which we judge others (Fiske, Cuddy, and Glick, 2007). The present study examined whether such thermal-emotional association also can be observed in *intrapersonal*, i.e. the internal mental processing at semantic and/or perceptual level.

Previous studies have shown that physical temperature in the environment affects our interpersonal behaviors. Physical warmth in an environment makes people judge others more favorably and act more generously (Williams & Bargh, 2008). Warm temperature in a room can induce greater social proximity between the people in the room (IJzerman & Semin, 2009). This relationship between temperature and interpersonal behaviors has proven to be effective also in the opposite direction. Individuals feeling higher social proximity tend to provide higher estimations of room temperature, while experiencing larger interpersonal distance results in lower estimation of the room temperature (IJzerman & Semin, 2010). Induced social exclusion can make one crave warm food, presumably because s/he feels colder (Zhong & Leonardelli, 2008). Social exclusion also makes one's physical skin temperature colder (IJzerman et al., 2012). These earlier studies have all revealed strong interactions between thermal sensation and interpersonal behaviors: warmth is associated with friendliness, generosity, social inclusion, while coldness is associated with loneliness, rejection, and social exclusion.

What are then the reasons for these associations? The occurrence of these interactions should theoretically rely on an internal association in our individual minds between temperature and emotion. Such association could derive from earlier experiences of physical temperature and emotional responses simultaneously (see embodied cognition theories, e.g., Lakoff and Johnson, 1999, Pecher and Zwaan, 2005), and frequent exposure to abstract semantic association between the two concepts (see e.g., Tillman, Datla, Hutchinson, and Louwerse, 2012; Louwerse, 2011). Nevertheless, somewhat surprisingly, no research has, to our knowledge, examined thermal-emotional associations in *intrapersonal* mental processes. The present study thus examined whether the existence of such an internal mapping occurs at an intrapersonal level by examining the existence of thermal-emotional associations for perceptual and semantic processing.

In two experiments we examined the two possible intrapersonal associations between temperature and emotion. Experiment 1 examined whether the abstract semantic representations of warmth and coldness are associated with positive or negative emotional valence using the implicit association test (IAT; Greenwald, McGhee, and Schwartz, 1998). The IAT is widely used to measure strength of individuals' automatic associations between different concepts. IAT was primarily developed to measure attitudes in context of social psychology (e.g., Greenwald et al, 1998) but has also proven to be successful in other types of measures, e.g., crossmodal associations (e.g., Ho, Van Doorn, Kawabe, Watanabe, and Spence, 2014; Parise and Spence, 2012). The foundation of the IAT is that it is easier to map two concepts into the same response key when they are internally associated (congruent situations) than when they are internally unrelated (incongruent situations). For each trial it presents a single stimulus that thus reduces the risk of selective attention to one kind of stimulus (Spence, 2011). It should be noted that albeit the term *implicit* the test does not require the association to be implicit per se but rather that it does not require an introspective access (Nosek, Greenwald and Banaji, 2007). The participants in our experiment categorized thermal words (warm versus cold) and emotion words (positive versus negative) with two response keys. If the semantic associations between warmth and positive valence, and between coldness and negative valence were automatic and inevitable, we would expect slower and less accurate responses for the incongruent response key assignment of the temperature sensation and emotional valence (i.e., warm-negative and cold-positive combinations) than the congruent key assignment. Experiment 2 further examined whether there is a perceptual-based representation by looking at whether physical experience of temperature is associated with positive or negative emotional valence. We tested if categorization of emotion words based on their valence would be affected by mere presence of physical temperature at the response hand.

Experiment 1

Methods

The experiments reported here were conducted in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki, and the participants gave their informed consent to participate in the study prior to the start of the experiment. Twenty-four participants (*M*=28.2 years; *SD*=3.9; 12 females) took part. All were naïve as to the purpose of the experiment.

We followed the typical experimental procedure of the IAT (Greenwald, Nosek and Banaji, 2003). The participants performed an IAT task controlled by *Presentation* software (Neurobehavioral Systems, Inc.). Their task was to categorize either warmth (hot versus cold) of ten thermal words (warm, boil, heat, steam, burn, cool, ice, chill, frozen, and freeze; Nosek, 2005), or emotional valence (positive versus negative) of ten emotion words (joy, happy, pleasure, love, peace, agony, evil, horrible, hurt, and terrible) when presented on the center of the screen (Figure 1a). Each category was assigned to either the left or right key, and the assignments of the category to key were indicated at the left and right upper corner of the screen. The participants responded to the left (right) category by their left (right) hand. They were asked to respond as rapidly and accurately as possible. The IAT experiment consisted of seven blocks. The first two blocks were training for the speeded categorization of the thermal words and the emotion words respectively. In the third and fourth blocks, both the thermal and emotion words were mixed and presented in a random order, and the participants categorized the words according to the labels shown in the top left and right of the display. The fifth block was a training block and a repetition of the first block, but with the left-right position of the thermal categories switched. The sixth and seventh blocks again combined the two categories, but with the new thermal and emotion combination (opposite to that of the third and fourth blocks). In the third and sixth blocks the participants completed 20 trials (1 trial per word) and in the fourth and seventh blocks the participants completed 40 trials (2 trials per word). The results of the third, fourth, sixth, and seventh blocks were used in the analyses, as suggested by Greenwald et al. (2003). The positions of the categories (left or right) were counterbalanced across participants.

Please insert figure 1 here.

Results and discussion

Two participants whose erroneous rate exceeded 10% were excluded from the analyses. Reaction times (RTs) that fell three standard deviations above or below the individual means (3.6 % of the trials) were excluded from the analysis. The RTs for the correct responses and the number of errors were analyzed by a repeated measures analysis of variance (ANOVA) with congruency (congruent versus incongruent) and response modality (thermal versus emotion word) as within-participants factors. For significant results the effect size (Cohen's d; Cohen, 1977) was calculated.

As shown in Figure 1b, the responses in the IAT were much faster when the emotion and thermal words were categorized by the congruent key assignments (i.e., warm-positive and cold-negative) than when they were categorized by the incongruent key assignments (i.e., warm-negative and cold-positive), resulting in a significant main effect of congruency ($F(1,21)=55.55$, $p<.001$, $d=1.74$). The difference in mean RTs between the congruent and incongruent condition was 328 ms (724 ms versus 1052 ms). There was no significant difference between the RTs of thermal words and of emotion words ($F(1,21)=.42$, $p=.53$). The interaction between the two factors was also not significant ($F(1,21)=.51$, $p=.48$). The same analysis on the number of incorrect responses showed similar results of a significant main effect of congruency ($F(1,21)=8.78$, $p<.05$, $d=.81$) with neither a significant main effects of response modality nor their interaction.

As hypothesized, our results demonstrate that congruent thermal-emotional combinations give rise to shorter latencies than the incongruent combinations. The effect was consistent across response modality (thermal and emotional words), indicating that the associations between thermal and emotional semantic information works in both directions, that is, temperature is associated with emotional valence and, similarly, emotional valence is associated with temperature.

The association between thermal sensation and emotion observed in the IAT experiment may be anchored in our bodily experiences, as theories on embodied cognition suggest that abstract concepts (e.g. friendliness or love) are grounded in the perceptual contents of concrete experiences, such as bodily sensations (e.g. feelings of physical warmth; Lakoff & Johnson, 1999). The associations between temperature sensation and emotion could have been established through co-experience of thermal warmth and positive emotions in childhood such as caring and nursing, and co-experience of thermal cold and negative emotions such as abandonment and insecurity. Thus we hypothesize that the physical experiences of temperature are associated with positive or negative emotional valence at an intrapersonal level.

Experiment 2 studied whether the mere presence of physical temperature can affect intrapersonal emotional processing. We tested the association between perceptual thermal experience and emotional valence. The experiment employed a speeded valence categorization of the emotion words, while one of the two response buttons was physically warm and the other was physically cold. If the thermal-emotional association were based on the co-experience of thermal sensation and emotional valence, we would expect faster responses when the thermal stimulation is congruent to the emotional valence of the presented words (i.e., positive words with warm temperature and negative words with cold temperature) than when thermal stimulation and emotional valence are incongruent.

Experiment 2

Methods

The same twenty-four participants from Experiment 1 subsequently took part in Experiment 2. Each of the two response buttons was connected to a warmed (39 degrees Celsius) or a cooled (25 degrees Celsius) Peltier element (PELT 30, Misumi Inc, Japan). The temperatures were chosen for its similarity in terms of subjective thermal intensity (see Greenspan, Roy, Caldwell, & Farooq, 2003). The participants placed their palms on each Peltier element and their index fingers on the response buttons placed in front of the elements (Figure 2a). The participants performed a speeded categorization of emotional valence of ten emotion words; these were the same as those used in Experiment 1. They were presented 3 times (a total of 30 trials) for each congruent (i.e., warm-positive and cold-negative) and incongruent (i.e., warm-negative and cold-positive) key assignment. The participants responded by their left and right hands based on the category labels presented on the upper corners of the screen.

Please insert figure 2 here.

Results and discussion

All participants were included in the analyses as no participant exceeded 10% error rate. RTs that fell three standard deviations above or below the individual means (2.1% of the trials) were excluded from the analysis. RTs for the correct responses were analyzed. As hypothesized, physical temperature modulates the time needed to classify emotion words (Figure 2b). Faster responses were observed when physical thermal stimulation was congruent to the valence of the emotion words (i.e., warm-positive and cold-negative) compared to when it was incongruent (M=637 ms versus 706 ms) regardless of the valence of the emotion words. A paired t-test confirmed that they differed significantly ($t(23)=4.1$, $p<.001$, $d=0.60$). Although the number of errors was numerically larger for the incongruent combination than for the congruent combination, the difference was not significant ($t(23)=.72$, $p=.48$, $d=.24$). The results showing that the mere presence of the task-irrelevant physical temperature modulated the speed of the responses suggest that the thermal sensation is associated with emotion at perceptual level, and that the association is based on the co-experience of thermal sensation and emotional valence.

General discussion

The results of Experiment 1 demonstrate a semantic association between temperature and emotion supporting our hypothesis. The congruent thermal-emotional combinations (i.e., warm-positive and cold-negative), give rise to faster responses as compared to the incongruent combinations. The differences in response time between the congruent and incongruent conditions were large (about 300 ms), indicating that the association between thermal and emotional experience is robust. The results of Experiment 1 show that this association is bidirectional as it affects both the processing of temperature as well as the processing of emotional valence. These results demonstrate the existence of thermal-emotional association at an abstract semantic level, which modulates the efficiency of human information processing. The results of Experiment 2 further demonstrate that experiencing physical temperature can modulate the speed of response to emotion words. Faster responses were observed when the physical thermal stimulation was congruent to the valence of the emotion words.

By comparing our results from Experiments 1 and 2, the effect of the congruency (i.e., the difference in RT and effect size between the congruent and incongruent conditions) was much smaller in Experiment 2 (M=69 ms, d=.60) than in Experiment 1 (M=328 ms, d=1.74). More specifically, the incongruent combination prolonged the response time for about 300ms in Experiment 1, but only 70 ms in Experiment 2. This suggests that the experience-based perceptual association in Experiment 2 is weaker than the interference effect given by the semantic association in Experiment 1. An alternative explanation to the weaker effect in Experiment 2 is the possibility that the physical temperature was processed by semantic representation. The perceptual experiences of the warmed and cooled Peltier elements would then be "translated" to a semantic representation such as "warm" or "cold". The effect of Experiment 2 would then be a result of the association between the semantic representation and valence. Thus, as an "indirect" thermal input, the incongruent thermal experience could only have a weaker interference effect.

The existence of an experience-based association between temperature and emotions are however supported by research on the insular cortex. It has been suggested that the insular cortex is the neural substrate for thermal-emotion associations. In particular, the insula has been shown to be the primary cortex for thermal sensation (Craig, Chen, Bandy & Reiman, 2000) and to be engaged in experiences of different emotions such as sadness, happiness, anger and fear (Damasio et al., 2000; Phan, Wager, Taylor, & Liberzon, 2004; Reiman et al., 1997). The insula is also known to activate when looking at pictures of romantic partners or when judging whether a face is trustworthy or not (Insel & Young, 2001). This could suggest that neural processes at the insula are responsible for the observed thermal-emotion association. However, further research using neuropsychological methods is needed to clarify this. Furthermore, a conceptual and perceptual mapping between emotions and temperature is consistent with the somatic marker hypothesis, as suggested by Damasio and colleagues (2000). The somatic marker hypothesis suggests that conceptual mappings are stored and replayed subconsciously, thus when thermal and emotional valence are congruent, the mapping could serve as shorthand for incorporating remembered associations into the process of decision-making. As a result, the required processing time (RT in Experiment 2) is reduced, which facilitates the efficiency of human information processing. In contrast, incongruent mappings interfere with the information processing and prolong the required processing time.

The use of the IAT provides an objective performance measure of a semantic thermal-emotional association that is automatic and inevitable. While the metaphors in language between temperature and emotions are mainly related to *interpersonal* levels (e.g. a warm embrace, a cold response), our results suggest that the thermal-emotional association is grounded in *intrapersonal* semantic processing. The overall results of our experiments implicate that the thermal-emotion association is robust, with a large RT difference between congruent and incongruent conditions. Previous studies indicate that this association is presumably formed both at a neurological level in the insular cortex as well as at a behavioral level by a co-experienced positive warmth as well as negative cold. This leads to the main implication that the connection between emotions and temperature is not restricted to the interpersonal or metaphorical level, but has bearing on general intrapersonal positive and negative emotions.

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Figure captions.

Figure 1. a) Schematic illustration of the experimental setup. The upper panel shows a hypothesized congruent combination and the lower panel shows a hypothesized incongruent combination of the two concepts: emotion and temperature. b) The mean RTs when participants categorized thermal and emotion words. Congruent response-key assignments are shown in white; incongruent assignments are shown in grey. Error bars indicate the standard errors of the means. The mean error rate for each response modality is indicated above each bar.

Figure 2. a) The response-key assignments with physical thermal stimulation. The warm button was on the left side in half of the trials, and on the right side in the other half of the trials. b) Mean RTs when participants categorized emotion words. The congruent response-key assignments are shown in white; incongruent assignments are shown in grey. Error bars indicate the standard errors of the means. The mean error rate for each assignment is indicated above each bar.

** indicates $p<.001$