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Temperature and emotion in English:
Corpus vs. Sentiment-AI analysis*

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Yoon, Suwon and James Yae. 2022. Temperature and emotion in English: Corpus vs. Sentiment-AI analysis. *Linguistic Research* 39(3): 603-629. The current study investigates emotional attitudes of temperature terms in English via *corpus* analysis and *sentiment AI* analysis. First, based on the collocation patterns that are extracted from corpora in English (*Corpus of Contemporary American English* and *iWEB*), we attempt to specify a potential emotive feature for each temperature term. Second, we compare the results of corpus-based analysis in English with what a *Sentiment Artificial Intelligence* (*Sentiment AI*) model predicts. These results reveal how the meaning of temperature terms can be multidimensional: (a) a literal or figurative meaning in the semantic descriptive dimension; and (b) a speaker's positive or negative emotional attitude in the evaluative dimension. Theoretical implications of the current study include the following: For one thing, we identify temperature terms as another clear case of *sentiment-encoded words* in English. Further, the current corpus analysis suggests adding to *sentiment dictionary* the newfound positive or negative connotational differences of temperature terms as a potential feature. Finally, our findings further support the notion of *multidimensionality* in meaning. **(University of Seoul · University of Houston)**

Keywords Sentiment AI, Temperature terms, Multidimensionality

1. Introduction

The description of temperature is universal phenomena, and languages exhibit diversity in the ways in which their experience of temperature is linguistically expressed (Sutrop 1998; Koptjevskaja-Tamm and Rakhilina 2006). Previous research on temperature

terms has focused on the question of how each temperature term can be defined in terms of morphological, syntactic, semantic features, or sociolinguistic factors.

Temperature may directly affect one of the five senses in human body. Hence, it is unsurprising that temperature terms tend to be reflective of one's feelings regarding a perceived temperature in the literal sense, or state of affairs in the figurative sense. In exploring their collocation patterns in a corpus, we examine the latent emotional attitude of each temperature adjective in English. The current study focuses on the emotional attitudes encoded in the basic temperature terms *warm/cool, hot/cold*, and *scalding/freezing* in English.

The current study starts from the assumption that the meaning of temperature terms can be analyzed in three dimensions: First, in the literal semantic dimension, the denotation of certain temperature is carried by the temperature adjective. Second, another possible semantic dimension is where the meaning of a given temperature term undergoes semantic extension, giving rise to a figurative meaning (e.g., the meaning of *warm* is extended to 'favorable state of affairs'). Finally, a speaker's emotional attitude may be reflected in the choice of a certain temperature term. Note that the speaker's emotional attitude may concern a literal temperature meaning or a figurative meaning on the state of affairs, but both literal and figurative meanings exist in the semantic at-issue dimension. The third emotional attitude, we argue, functions in the semantico-pragmatic, evaluative dimension (see Yoon 2015, 2018, 2021 for multidimensional meaning of other terms; cf. Zhong and Huang 2020).

The discussion proceeds as follows. In section 2, core meanings of basic temperature terms in English are discussed in three dimensions. Based on a corpus-based collocation analysis with *Corpus of Contemporary American English (COCA)* and *iWEB,* section 3 discusses how positive or negative sentiment in temperature terms, *warm/cool* vs. *hot/cold/scalding/freezing*, interrelates with other emotionally charged words within the sentence in English.[1] Given that the emotional attitude reflected in temperature terms exists in a separate evaluative dimension, we show how a corpus allows us to mine the large dataset for the collocation patterns of multiple emotive words. Therefore, we can observe how an emotive temperature term and its typical collocates enhance their common sentiment or interact to portray a more complex emotional state within the sentence. In section 4, we retest our main corpus data in English with a *Sentiment AI*

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[1]   For the discussion of recent trend of corpus analysis of linguistic data, see Davies and Kim (2019) and Park and Nam (2017).

model, *IBM Watson Tone Analyzer*, examining whether the current findings based on the corpus analysis can be also predicted by a machine, and discuss its limitations and potential solutions. Section 5 concludes the discussion.

2. The landscape of temperature terms in English

2.1 Sentiment of *warm* and *hot*

The meaning of the word *warm* can be at least three dimensional: (i) warm temperature (literal meaning); or (ii) warm favorable state of affairs (figurative meaning); and (iii) a potentially positive emotional attitude accompanying the warm temperature or situation (evaluative meaning).

First, in the literal dimension of meaning, *warm* conveys the basic sense of warm temperature as in *warm weather* or *warm day*. Second, after having undergone semantic extension, warm may convey a figurative meaning since the inherently positive meaning of warmth can be stretched to the non-temperature meaning (cf. Pasaribu 2019). In *warm welcome,* for instance, *warm* refers to the pleasant feeling of warmth that goes beyond the temperature. The dictionary definition of *warm* in Merriam-Webster Dictionary (1828) comprises the primary literal meaning 'having or giving out heat to a moderate or adequate degree,' as in (1a), and the secondary figurative meanings such as 'comfortably established,' as in (1b), or 'marked by or readily showing affection, gratitude, cordiality, or sympathy,' as in (1c).

(1)   a. Be sure to keep warm when you go outside.
       b. These boots will keep you warm and safe.
       c. We had a warm welcome home.

The current study, however, focuses on the fact that there is still another layer of meaning in temperature adjectives, revealing a speaker's emotional attitude, which is specified neither in a regular dictionary nor a sentiment dictionary (e.g. WordNet, SentiNet): Given the innate human affinity toward the warm moderate temperature, we can naturally expect its positive emotional attitude.[2] As illustrated in the following samples from various sources, including TV/movies subtitles, spoken, popular magazines,

newspapers, personal blogs, and academic journals, in Corpus of Contemporary American English (COCA), *warm* tends to convey a speaker's weak or strong positive attitude toward the object or state of affairs.[3]

(2) Samples of *warm,* extracted from various sources in COCA

    a. Even though it was a nice warm day in May, the water in the lake was still pretty cold⋯

    b. snow space, \<a\>*** classic short boots\</a\> will keep you warm and safe.

    c. It may give us a warm feeling to think that, in his or her own way⋯

    d. Get noticed and feel all warm and fuzzy at the same time. We call this a win-win.

    e. this reality is that I personally know many wonderful, warm, caring individuals whom are of the Islamic Faith.

    f. My living room is warm, cozy and filled with little Santas, butterflies, ribbons⋯

    g. quilt is on its way to keep its new owner warm and comfortable.

    h. Thank you so much for warm comments...

    i. Iowa Nice, 'just like everyone else, with warm hospitality, and I think it stuck.'

    j. A smile or warm greeting is sufficient to open another souls heart, and a handshake or hug⋯

    k. The dynamics between the cold and analytical man and the warm and emotional woman was also found in the popular literature of the day.

Observe that *warm* in English marks a positive feeling such as affection or pleasure that is in tune with its collocating words such as *nice, safe, fuzzy, wonderful, caring, cozy, comfortable, hospitality, greeting*, and with its typical clusters such as *warm feeling, warm comments, warm welcome.*

On the other hand, the meaning of *hot* with higher degree of temperature seems to be also three dimensional, yet with a more complex pattern: (i) hot temperature (literal meaning); or (ii) heated state of affairs (figurative meaning); and (iii) potentially negative

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2　See Lee (2016) for a discussion of stance marking in intensifiers in English.

3　See Kim and Moon (2014) for a corpus analysis of English SKT construction.

or positive emotional attitude accompanying the hot temperature or situation (evaluative meaning).

In the literal dimension of meaning, *hot* conveys the basic sense of high temperature, as in (3a). What is notable about *hot* is that its figurative meaning may be semantically extended in at least two opposite directions. In the definition of *hot* in Merriam-Webster Dictionary (1828), the primary literal meaning is 'having a relatively high temperature,' as in (3a). The secondary figurative meaning can be either a negative sense like 'marked by violence or fierceness,' as in (3b), or a rather positive one like 'sexually excited or receptive, or sexy,' as in (3c).

(3)   a. It is hot in the summer and cold in the winter.
      b. She has a hot temper.
      c. That guy she's dating is really hot.

Thus, we can expect that this bidirectionality of figurative meanings in *hot* leads to a bipolar nature in its third layer of meaning, as opposed to the uniformly positive (or neutral) meaning of *warm*. This means that a speaker may convey either a negative or positive emotional attitude depending on the context. Observe the following examples from various sources in COCA, in which *hot* is associated with either a positive or negative emotional attitude.

(4) Samples of *hot*, extracted from various sources in COCA
    a. Have you stood in those lines on a hot summer day in Southern
       California?
    b. given all the time they spend in "hot spots" they haven't found more than
       bupkus.
    c. Holy crimoly, mom, you look HOT in that!
    d. They're walking up to super hot fashionable women.
    e. Back in 2010-2011 this was quite the hot topic within our community.
    f. six of seven diamond drill holes at the newly discovered Hot Zone,
    g. I think Mom knew I was already a hot mental mess and tears wouldn't
       be helpful to my finishing.
    h. John got hot about the remark.
    i. I am forever grateful that I never had to participate in a hot battle.

We can see that *hot* may convey positive feelings such as being sexy or popular, as shown in its collocates like *fashionable, looking hot*, or its typical clusters such as *hot spots, hot topic, hot zone.* Notice that *hot* may also carry negative feelings, as in *hot mental mess* or *getting hot about the remark*, meaning 'angry.'

From the representative collocates, we can infer: (a) the polar axis of (positive or negative) emotion and (b) the intensity of emotional attitude encoded in these temperature terms. In exploring its behavior in corpus and sentiment AI, we will examine the semantic prosody of each temperature term in sections 3 and 4.

2.2 Sentiment of *cool* and *cold*

In Just like *warm,* another moderate temperature adjective *cool* in English also exhibits three dimensions of meaning in a positive sense: (i) cool temperature (literal meaning); or (ii) cool favorable state of affairs (figurative meaning); and (iii) potentially positive emotional attitude accompanying the cool temperature or situation (evaluative meaning). The fundamental connection between cool temperature and positive sense is also shown in its dictionary definition: The primary definition of *cool* concerns 'somewhat cold: not warm or hot' temperature, as in (5a); or it carries a positive figurative sense in its secondary dictionary meaning, 'able to think and act in a calm way: not affected by strong feelings,' as in (5b) (Merriam-Webster Dictionary 1828).

(5)   a. The weather is cool today.
       b. It is important to keep a cool head in a crisis.

This means that, as observed in *warm* or *hot* above, *cool* has undergone semantic extension towards the positive axis: Just like *warm,* general human preference to moderate temperature is extended to a positive feel about the state of affairs. Along with the crucial link between warmth and positivity that we observed above, this connection between coolness and positivity seems to hold across languages.[4] Its representative attitude, especially in its informal usage, seems to be a positive emotional attitude, as in *cool stuff* or *cool things* to convey 'very good, or hip things.' Similar tendency is

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4   Although there is a potentially negative sense of 'lacking ardor or friendliness' as in *a cool impersonal manner*, it must be mainly triggered by another overtly negative collocate like *impersonal.*

observed in the following examples in COCA.

(6) Samples of *cool,* extracted from various sources in COCA
  a. This is so cool. Computers are awesome.
  b. How cool would it be to play a console Zelda?
  c. The nuttiness is always nicely counterbalanced with a subdued yet cool, calm and collected determined demeanor on the part of Perry.
  d. Everyone wants the perfect flying experience: cool, fun, comfortable and most of all, VIP.
  e. Oh cool, well if you don't care why not restart?

Just like the negative flavor of *hot*, *cold* generally reveals a negative sense: (i) having or being a temperature that is uncomfortably low for humans (literal meaning), as in (7a); or (ii) marked by a lack of the warmth of a normal human emotion, friendliness, or compassion (figurative meaning), as in (7b) (Merriam-Webster Dictionary 1828). Further, it may also convey a negative emotional attitude accompanying the cold temperature or situation (evaluative meaning).

(7)   a. It is cold outside today.
      b. a cold stare

This means that, as observed in sample sentences of *hot* above, *cold* has undergone semantic extension towards the negative axis: We can see that typical human aversion to *hot* or *cold* temperature is extended to a negative emotion toward the state of affairs. Again, we see the pattern of the crucial link between coolness and positivity, and between coldness and negativity, which seems to be universal. In the following samples in COCA, the negative emotional attitude of *cold* is revealed in its typical clusters like *a cold stare*, or collocates such as *hungry, darkness, tired, painful,* and *dead.*

(8) Samples of *cold*, extracted from various sources in COCA
  a. wild wolves DO attract humans when they are cold and hungry!!!
  b. as though PlayStation 3 owners are being left in the cold, I ⋯
  c. who hunger and are not fed, those who are cold and are not clothed
  d. And then out into the darkness and cold.

  e. I get hungry, I get cold, I get tired, …
  f. His career is pretty cold right now and it might be a little painful to watch
  Kim can have my gun when you pry it from my cold dead hands!

  The negative emotive stance may concern either a literal cold temperature or a figurative coldness toward the state of affairs, as shown in these examples. Note that the extended meaning 'marked by a lack of the warmth of normal human emotion, friendliness, or compassion' still exists in the semantic descriptive dimension. We argue, however, that the third layer of meaning, an overall negative emotive stance, is located in the evaluative dimension and activated in utterances with a similar type of negative collocate.

2.3 Sentiment of extreme temperature terms: *freezing* and *scalding*

  In The dictionary definition of *freezing* only concerns the basic low temperature meaning of 'very cold,' as in (9a), or 'being at or below the temperature at which water freezes,' as in (9b) (Merriam-Webster Dictionary 1828).

(9) a. Put on your jacket. It's freezing outside!
   b. a forecast for freezing temperatures overnight

  The problem of the dictionary definition is that it overlooks the other important role of *freezing*, i.e., semantic extension toward a negative axis, to a greater extent than *cold*.
  Given this strong negative connotation in a freezing temperature in English, frequent association of strong negative sentience is anticipated in actual uses. As shown in the following samples of *freezing* obtained from diverse text types in COCA, the basic meaning of 'very cold' typically extends to undesired outcomes.

(10) Samples of *freezing*, extracted from various sources in COCA
  a. from the troposphere is sucked downward, instantly freezing to death all
   who arecaught in the eye.
  b. they then get worse again and are in danger of freezing or starving.
  c. #fuel lines on the descent engine are at risk of freezing. If they do, the

craft   will   crash.

d. #you   have   selected   for   your   perennials.   Can   it   survive   freezing
temperatures,   or   will   it   crack   or   break?

e. #lots of human beings, thousands of them, from freezing and starving to
death.

f. #alive. ALEX No I'm not... NICK (freezing her with a stare) We're not
getting   very   far   into   the   levels···

g. #by companies with links or sympathies to the opposition, freezing bank
accounts,   seizing   assets,   poring   over   the   tax   returns   of   lesser   donors.

h. are doing the regime change through political, military and freezing of
financial   assets   of   the   regime,   while   at   the   same   time   applying   military.

For one thing, the strong negative emotion may arise from the literal temperature
meaning since an exceedingly low temperature of freezing may be fatal, as shown in its
typical collocates like *death, starving, danger, risk,* and *survive.* Further, at the
metaphorically extended meaning of *freezing her with a stare* or *a freezing stare* implies
a strong negative emotional attitude of the speaker. Another metaphorical extension, due
to the immobility sense of *freezing* as verb, is found in the financial contexts of *freezing
bank accounts,* and *freezing of financial assets,* which typically involve a strong negative
sentiment due to its life-threatening nature in English.

Note that an extreme temperature in the opposite direction, as in *scalding* in English,
also conveys a strong negative emotional attitude. Unlike *freezing*, the dictionary
definition of *scalding* has the basic high temperature meaning of 'hot enough to scald,'
as in (11a), or the negative semantic extension of 'having or producing the feeling of
being burned' or 'scathing' as in (11b-c) (*Merriam-Webster Dictionary* 1828).

(11) a. scalding water
    b. scalding sun
    c. scalding criticism

The association of negative emotional attitude is further shown in the samples of
scalding   found   in   COCA,   with   negative   clusters   such   as   s*calding
tweets/critique/rebuke/attack,* or *scalding feeling/mad/noise/tears/wave of embarrassment.*
Its strong negativity is also shown in its use as an emphatic negative epithet, *the scalding*

rag in (12j) in English.

(12) Samples of *scalding*, extracted from various sources in COCA
a. #voting to gut the Congressional Ethics office followed by a scalding tweet from Donald Trump and spanking by the pundits on the right as well.
b. #fairway, then threw his club down and directed a scalding critique at the heavens. " I'd have to get a full report...
c. #"Armstrong wrote " East Jesus Nowhere, "a scalding rebuke of fundamentalist religion, after attending a church service where a friend's...
d. #acid-tongued conservative Democrat, who had become known for his scalding attacks on liberal elites.
e. #class was already over! Couldn't happen! A scalding feeling at the base of her skull...
f. #work here, son! "# I felt a scalding mad rising in me, rising like the summer heat I watch coming off ⋯
g. #, 8; 00 A.M. "# Serge made the scalding noise of steam, but Amar, his groin flushed with blood, did⋯
h. #telling her to put on eyeshadow brought at last the scalding tears she had forced back for Laurie's sake.
i. #and he was sure he looked like one. A scalding wave of embarrassment drenched him in waves of sweat as debilitating as a hot⋯
j. #but in the streets of the slums. "The scalding rag stopped its advance across Casimir's back.

3. Corpus analysis of sentiment in temperature terms

In this section, we discuss the collocation trend of each temperature term that is obtained from the COCA corpus of English. We show a clear pattern that moderate temperature terms such as *cool* or *warm* tend to have a positive favorable emotional attitude, while terms of higher or lower than ideal temperature like *cold* or *hot* tend to have negative unfavorable semantic prosody (Sinclair 1987, 1991). Further, variants of extremely high or low temperature terms like *freezing* or *scalding* carry an even stronger

negative semantic attitude.

3.1 Collocation trend for temperature terms in English

First, we examine the real uses of *cool, warm, cold, hot, freezing,* and *scalding* in corpus data to understand how these temperature terms interact with other emotionally charged elements. For this purpose, we extract their collocation patterns in *Corpus of Contemporary American English* (COCA). In COCA website, it is defined as the "largest freely-available corpus of English, and the only large and balanced corpus of American English." Through the COCA search, we can observe semantic prosody of each temperature term at a glance, by observing the major trend of positive emotive stance of *cool,* for example.

We report the results of the following two analyses. In section 3.1, we conducted a collocation search for basic temperature terms in English, *cool, warm, cold, hot,* and some non-basic ones like *freezing* or *scalding*. We show how the typical collocation pattern reveals an inherently positive or negative emotive stance of a particular temperature term.

First, let us observe the collocation trend of *cool/cold, warm/hot* and *scalding/freezing* from their frequently collocating surrounding words within a ten-word window forward and backward. Table 1 below summarizes the results of sentiment words from top collocation search for *cool* and the results for *cold*.

Table 1. Sentiment words among top collocates of *cool* and *cold* in English

Collocates types	Collocates of *cool*	Frequency	Collocates of *cold*	Frequency
ADV	*pretty*	3207	*bitterly*	241
	way	198	*brutally*	44
	kinda	185	*unreasonably*	42
	pleasantly	39	*dangerously*	32
	effortlessly	18	*shockingly*	22
	deliciously	11	*miserably*	17
	refreshingly	11	*uncomfortably*	17
	blessedly	11	*numbingly*	12
	awesomely	10	*unbearably*	10
NOUN	*breeze*	690	*war*	12945
	II (legit	382	*end*	1819

	laughing)			
ADJ/	*super*	369	*dark*	575
VERB	*calm*	226	*shiver*	249

Among the most frequent collocates for these two temperature terms, an opposing pattern of their representative semantic prosody is clearly shown in adverbs. Top collocates for *cold* tend to be strongly negative ones such as *bitterly, brutally, unreasonably, dangerously, shockingly, miserably, uncomfortably, numbingly,* and *unbearably,* while top collocates for *cool* are shown to be strongly positive ones like *pleasantly, effortlessly, deliciously, refreshingly, blessedly, awesomely, pretty (cool), kinda (cool), way (cool)* in the adverb group. In the noun group also, *cold* co-occurs with negative words like *war, end, blood, wind,* while *cool* co-occurs with a positive counterpart like *breeze, LL (legit laughing),* or *(cool) shade.* In the adjective group, words like *calm* and *super* exhibit a positive flavor of *cool* in the sense of a relaxed attitude, while *dark* reveals a negative aspect of *cold.* In the verb group, the positive attitude in *prevail* for *cool* contrasts with the negative attitude in *shiver* for *cold.* In sum, we can see that a sharp contrast between *cool* and *cold* concerns positive favorable and negative unfavorable attitudes, respectively.

Second, the following table shows sentiment words among top collocates for another pair of temperature terms, *warm* and *hot,* in COCA.

Table 2. Sentiment words among top collocates of *warm* and *hot* in English

Colloca tes types	Collocates of *warm*	Frequency	Collocates of *hot*	Frequency
ADV	*cuddly*	63	*unbearably*	57
	pleasantly	45	*brutally*	46
	uncomfortably	36	*uncomfortably*	41
NOUN	*l l (l e g i t laughing)*	382	*spot*	3034
	feeling	686	*topic*	1800
	welcome	657		
ADJ/	*fuzzy*	741	*burn*	679
VERB	*soft*	565		

At first glance, the pair of *warm* and *hot* seems to exhibit an opposing pattern of positive and negative emotional attitudes across categories, just like the pair of *cool* and

cold. In the adverb group, top collocates for *hot* include several negative ones such as *unbearably, brutally, uncomfortably* (cf. *ridiculously, oppressively, blisteringly, insanely, unnaturally, ferociously*), whereas *warm* tends to accompany positive ones like *cuddly, pleasantly, comfortably.*[5] Recall, however, that *hot* can be positive in *deliciously hot* in the sense of 'spicy' or in *hot topic* in the sense of 'popular' or 'sexy.' Emotional attitudes are less obvious in other categories; *warm* cooccurs with positive words like w*elcome, fuzzy, soft,* while the only potentially emotive collocate for *hot* is *burn*. As such, we observe the contrast between a positive favorable attitude of *warm* and a bipolar attitude of *hot* that depends on the context.

Finally, let us see how the top collocates for extreme temperature terms for either direction, *freezing* and *scalding*, reveal their emotional attitudes in COCA.

Table 3. Sentiment words among top collocates of *freezing* and *scalding* in English

Collocates types	Collocates of *freezing*	Frequency	Collocates of *scalding*	Frequency
ADV	*fucking*	27	*painfully*	1
	bloody	6	*hideously*	1
	violently	2		
NOUN	*death*	236		
ADJ / VERB	*starving*	41	*burn*	5
	survive	37	*spill*	4

Regarding *freezing*, we can see that it often occurs with vulgar terms like *fucking* and *bloody*, expressing an extremely negative emotive stance, or with other negative words, describing severe living conditions, such as *violently, death, starving,* or *survive*. Likewise, *scalding* typically collocates with negative words such as *painfully, hideously, burn,* or *spill*.

3.2 Analysis: Correlation between temperature and human emotion

Thus far, we have observed the corpus results on the potential emotive stance that is encoded in each temperature term. To systematically analyze the correlation between temperature and human emotion, let us compare our corpus results of linguistic data with the results of human experiment data and see what we can learn from considering the

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5   Potential exceptions here include the negative attitude in *uncomfortably warm.*

correlation from both perspectives.

For one thing, according to a recent experiment conducted by Escobar et al. (2021, Fig. 2), the overall association of temperature and human emotion can be represented as follows. The numbers in the heatmap indicates the average ratings of the temperature-emotion associations with all the data from their experiment, in which less saturated red or orange in the circled region shows stronger associations.
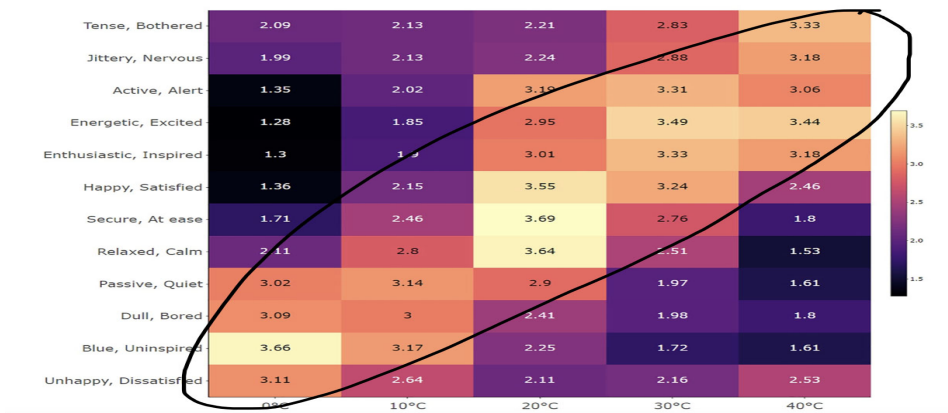

Figure 1. The average ratings of temperature-emotion associations (Escobar et al. 2021, Fig. 2)

For ease of comparison with Escobar et al.'s above findings, we reorganize our corpus search results of each temperature term and their representative emotive collocates. In the following Fig. 2 Emotive level of temperature terms and their emotive collocates (current proposal 1), we can clearly see the parallel between their experimental results (distribution pattern of less saturated red or orange colors with high association scores in Fig. 1) and our corpus results (distribution pattern of frequent collocates in Fig. 2): in both figures we can clearly see the concentration on the general upward diagonal line that reveals the correlation of each temperature and human emotion.

Emotive level	Emotive collocates that are most frequent in COCA					
Super strong					*blisteringly:*	*painfully: 1,*

negative (tense, bothered)					*23, insanely: 21*	*hideously: 1*
Strong negative (jittery, nervous)				*uncomfortably: 36*	*uncomfortably:41,ridiculously:37, oppressively:33,ferociously:8,unnaturally:10,burn:679*	*burn: 5, spill: 4*
Weak positive (active, alert)				*ll(legit laughing): 382*	*(hot) spot: 3034,(hot) topic: 1800*	
Strong positive (energetic, excited)				*cuddly: 63, pleasantly: 45,(warm) feeling: 686, welcome: 657,fuzzy: 741,soft:565*		
Super strong positive (enthusiastic, Inspired)			*blessedly: 11,awesomely:10,super:369*			
Strong positive (happy, satisfied)			*pleasantly: 39,deliciously:11,refreshingly:11, ll(legit laughing)*			
Positive (secure, at ease)			*pretty (cool):3207 way (cool): 198.kinda (cool):185, breeze:690*			
Weak positive			*calm:226*			

	freezing	cold	cool	warm	hot	scalding
(relaxed, calm)						
Neutral(passive, quiet)						
Weak negative (dull, bored)		*end: 1819, dark: 575, shiver: 249*				
Strong negative (blue, uninspired)		*bitterly:241, brutally:44, dangerousl: 32,shockingl y:22,miserab ly:17,uncomf ortably: 17,numbingl y:12,unbear ably:10, war:12945*				
Super strong negative (unhappy, dissatisfied)	*fucking:27, bloody: 6, violently: 2, death: 236, starving:41, Survive:37*					
	freezing	*cold*	*cool*	*warm*	*hot*	*scalding*

Figure 2. Emotive level of temperature terms and their emotive collocates (current proposal 1)

Based on the collocation patterns in COCA that we have observed so far, we reorganize our corpus data again and propose the following simplified representation for the correlation between temperature and human emotional attitude: First, terms of pleasant moderate temperature (e.g., *warm, cool*) tend to carry neutral-to-positive emotional attitudes; second, terms of higher or lower than an optimal level (e.g., *hot, cold*) convey neutral-to-negative emotional attitudes, (although *hot* can be also perceived good in the sense of 'popular, sexy' or 'spicy'); finally, terms of exceedingly high or low temperature (e.g., *scalding, freezing*) express strongly negative emotional attitudes, as schematized in the following Fig.3.
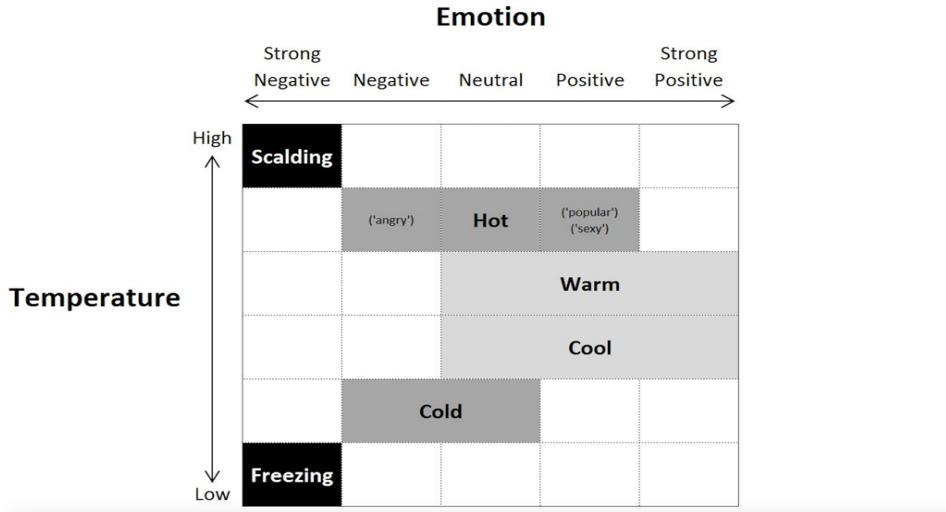
Figure 3. Potential correlation between temperature and human emotional attitude (current proposal 2)

4. Sentiment AI analysis of temperature terms

In section 4, we retest the corpus sample sentences with a sentiment AI analysis, and discuss whether the current AI model can predict what we have observed from the corpus analysis in English.

4.1 What is Sentiment AI?

As defined in the IBM Watson webpage, sentiment analysis refers to "a subset of natural language processing (NLP) capabilities that provides high level filters for users when exploring and evaluating data." Sentiment analysis has become popular for business purposes since it provides instant feedback on general customer experiences. Sentiment analysis is the most frequently used NLP features that can be used together with other NLP features like text classification or keyword detection.

In section 4, we compare the above results of corpus analysis with Sentiment AI analysis of temperature terms, using the *IBM Watson Tone Analyzer* (WTA), the basic mechanism of which is depicted below:[6]
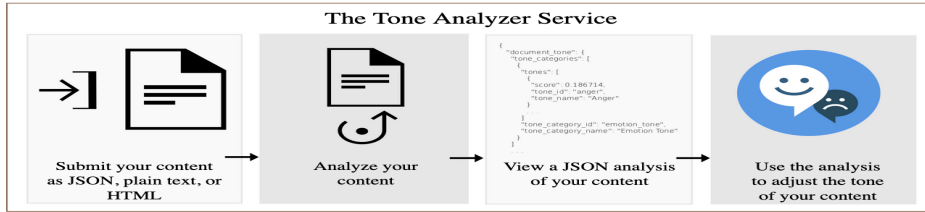
Figure 4. Watson Tone Analyzer workflow

Based on a linguistic analysis, WTA is designed to extract emotions from a given text, speech, or document, and reports detected sentiment such as joy, fear, sadness, anger, analytical, confident, or tentative. WTA is equipped with a higher-level classifier for further classifying the spectrum of emotions into positive, neutral, or negative.

4.2 Sentiment AI analysis of temperature terms

Given this background, let us examine how WTA detects sentiment in our main data of temperature terms in English.

First, let us examine two positive terms *warm* and *cool* for conveying a pleasant temperature. As shown in Fig. 5, the document-level analysis of the above sample sentences of *warm* that are extracted from COCA, exhibits the general tone of 'joy' in WTA. (N.B. We disregard other detected sentiments such as 'analytical' or 'tentative,' that are irrelevant to the current purposes.)
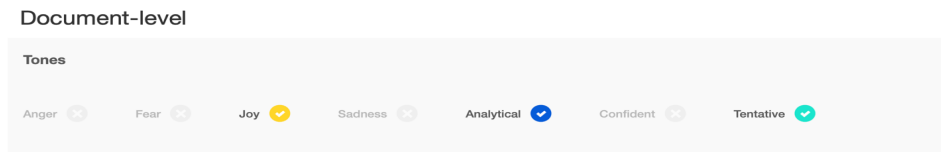
Figure 5. Document-level analysis of sample sentences of *warm* in WTA

In WTA, 'joy' is defined as "joy or happiness has shades of enjoyment, satisfaction and pleasure. There is a sense of well-being, inner peace, love, safety, and contentment."

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6   This figure is taken from the IBM Watson Tone Analyzer website in the following URL:
    https://www.ibm.com/cloud/watson-tone-analyzer?p1=Search&p4=43700051010330300&p5=e&gclid=EAIaI
    QobChMI44qY2ZOE8wIV7mpvBB0BJQvjEAAYASAAEgJQpPD_BwE&gclsrc=aw.ds

From this overall picture, we can see that this *Sentiment AI* analysis of the entire document containing *warm* corresponds to the result from COCA as well as a native speaker's intuition. WTA, however, also offers a more detailed sentiment analysis for each example, as shown in Fig. 6. Sentence-level analysis of sample sentences of *warm.*
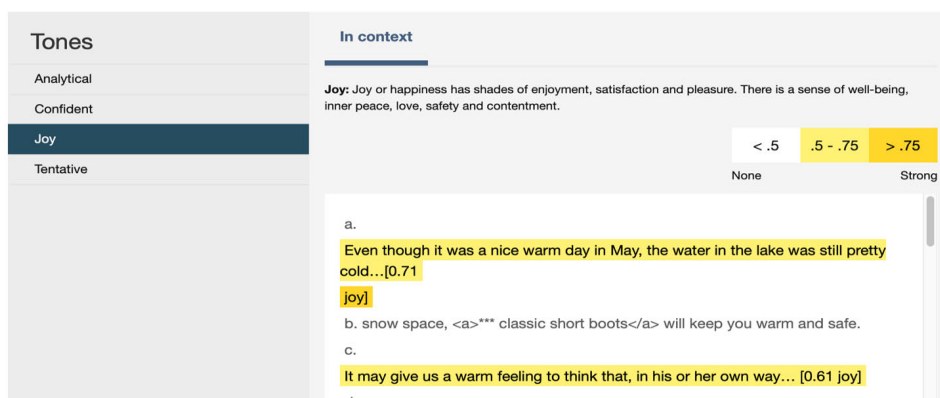

Figure 6. Sentence-level analysis of sample sentences of *warm* in WTA

The sentence-level analysis of WTA is designed to measure the score of detected sentiment and to identify stronger tones in context. The highlighted sentences in Fig. 6 report the likelihood of relevant tone; for instance, the likelihood of conveying 'joy' in the above sentence in (a) is high (> .71).

At the sentence-level analysis, however, we can see that not all sentences containing *warm* fall into the category of 'joy.' In below examples, repeated from section 2, the result of WTA now specifies: (i) a detected sentiment and (ii) to what extent the sentence may express the relevant emotion with a precise score. The first sentence in (13a), for instance, is analyzed to be highly likely to convey 'joy' (71%). Most other sample sentences also contain 'joy' in the results, except for (13b, k).

(13) Samples of *warm,* extracted from various sources in COCA
    a. Even though it was a nice warm day in May, the water in the lake was still pretty cold⋯   [WTA analysis: 0.71 joy]
    b. snow space, \<a\>*** classic short boots\</a\> will keep you warm and safe.
                                            [no tone]
    c. It may give us a warm feeling to think that, in his or her own way⋯

[0.61 joy]

    d. Get noticed and feel all warm and fuzzy at the same time. We call this a win-win.   [0.75 (strong) joy]

    e. this reality is that I personally know many wonderful, warm, caring individuals whom are of the Islamic Faith.   [0.87 (strong) joy]

    f. My living room is warm, cozy and filled with little Santas, butterflies, ribbon s⋯   [0.58 joy]

    g. quilt is on its way to keep its new owner warm and comfortable.

[0.69 joy]

    h. Thank you so much for warm comments...   [0.85 (strong) joy]

    i. Iowa Nice,' just like everyone else, with warm hospitality, and I think it stuck.'   [0.65 joy]

    j. A smile or warm greeting is sufficient to open another souls heart, and a handshake or hug⋯   [0.91 (strong) joy]

    k. The dynamics between the cold and analytical man and the warm and emotional woman was also found in the popular literature of the day.

[no tone]

In a similar vein, WTA's prediction for the following sample sentences of *cool,* extracted from COCA, is also analyzed to be 'joy.'

(14) Samples of *cool,* extracted from various sources in COCA
    a. This is so cool. [no tone] Computers are awesome.   [0.90 (strong) joy]
    b. How cool would it be to play a console Zelda?   [0.72 joy]
    c. The nuttiness is always nicely counterbalanced with a subdued yet cool, calm and collected determined demeanor on the part of Perry.

[0.78 (strong) joy]

    d. Everyone wants the perfect flying experience: cool, fun, comfortable and most of all, VIP.   [0.90 (strong) joy]
    e. Oh cool, well if you don't care why not restart?   [0.78 (strong) joy]

Second, let us move on to the pair of *hot* and *cold.*

(15) Samples of *hot*, extracted from various sources in COCA

a. Have you stood in those lines on a hot summer day in Southern
California?   [no tone]

b. given all the time they spend in "hot spots" they haven't found more than
bupkus.   [no tone]

c. Holy crimoly, mom, you look HOT in that!   [0.66 joy]

d. They're walking up to super hot fashionable women.   [0.51 joy]

e. Back in 2010-2011 this was quite the hot topic within our community.
[0.62 joy]

f. six of seven diamond drill holes at the newly discovered Hot Zone...
[no tone]

g. I think Mom knew I was already a hot mental mess and tears wouldn't
be helpful to my finishing.   [no tone]

h. John got hot about the remark.   [no tone]

i. I am forever grateful that I never had to participate in a hot battle.
[0.78 (strong) joy]

Recall that, due to polysemy, *hot* may associate with either a positive or a negative feeling. However, WTA analysis of sentences containing *hot* only captures the positive feelings like 'joy,' but misses with negative feelings like 'anger,' as in *hot mental mess* in (15g), or *getting hot about the remark* in (15h).

In the samples of *cold,* WTA also overlooks the general negative feelings that we predicted from their collocation patterns in COCA, except for a couple of examples in (16e, g).

(16) Samples of *cold,* extracted from various sources in COCA
a. wild wolves DO attract humans when they are cold and hungry!!!
[no tone]

b. as though PlayStation 3 owners are being left in the cold, I ⋯
[no tone]

c. who hunger and are not fed, those who are cold and are not clothed
[no tone]

d. And then out into the darkness and cold.   [no tone]

e. I get hungry, I get cold, I get tired, ⋯   [0.54 sadness]

f. His career is pretty cold right now and it might be a little painful to watch

Kim.   [no tone]

   g. can have my gun when you pry it from my cold dead hands!

                                                          [0.54 fear]

In the WTA system, 'sadness' detected in (16e) is defined as "indicates a feeling of loss and disadvantage. When a person can be observed to be quiet, less energetic and withdrawn, it may be inferred that sadness exists."; 'fear' in (16g) is defined as "a response to impending danger. It is a survival mechanism that is a reaction to some negative stimulus. It may be a mild caution or an extreme phobia." WTA's prediction, however, diverges from COCA or human intuition in other examples (16a-d, f), which are classified into the category of 'no tone' (or irrelevant sentiments such as 'analytical' or 'tentative' which are excluded here).

Finally, let us observe how WTA analyzes extreme temperature terms, *scalding* and *freezing*, the sentiment of which is expected to be strongly negative, according to the collocation patterns in COCA. In WTA analysis of sample sentences of *scalding* below, however, we can see only three instances of negative feeling 'anger,' as in (17b,h,k). (Note that another negative feeling 'sadness' in (17e) is the result of the preceding sentence without *scalding*.)

(17) Samples of *scalding*, extracted from various sources in COCA
   a. #voting to gut the Congressional Ethics office followed by a scalding tweet from Donald Trump and spanking by the pundits on the right as well.   [no tone]
   b. #fairway, then threw his club down and directed a scalding critique at the heavens. "I'd have to get a full report.   [0.55 anger]
   c. #"Armstrong wrote "East Jesus Nowhere, "a scalding rebuke of fundamentalist religion, after attending a church service where a friend's···
                                                          [no tone]
   d. #acid-tongued conservative Democrat, who had become known for his scalding attacks on liberal elites.   [no tone]
   e. #class was already over! [.53 sadness] Couldn't happen! A scalding feeling at the base of her skull...   [no tone]
   g. #work here, son! "# I felt a scalding mad rising in me, rising like the summer heat I watch coming off ···   [no tone]

h. #, 8; 00 A.M. "# Serge made the scalding noise of steam, but Amar, his groin flushed with blood, did⋯   [0.54 anger]

i. #telling her to put on eyeshadow brought at last the scalding tears she had forced back for Laurie's sake.   [no tone]

j. #and he was sure he looked like one. A scalding wave of embarrassment drenched him in waves of sweat as debilitating as a hot⋯   [no tone]

k. #but in the streets of the slums. "The scalding rag stopped its advance across Casimir's back."   [0.53 anger]

Another extreme temperature term *freezing*, on the other hand, is shown to convey negative feelings such as 'sadness' or 'fear' in most examples, except for (18f) and (18g).

(18) Samples of *freezing*, extracted from various sources in COCA

a. from the troposphere is sucked downward, instantly freezing to death all who are caught in the eye.   [0.62 sadness]

b. they then get worse again and are in danger of freezing or starving.
                                        [0.54 fear]

c. #fuel lines on the descent engine are at risk of freezing. If they do, the craft will crash.   [0.60 fear][0.63 sadness]

d. #you have selected for your perennials. Can it survive freezing temperatures, or will it crack or break?   [0.51 sadness]

e. #lots of human beings, thousands of them, from freezing and starving to death.   [0.72 sadness]

f. #alive. ALEX No I'm not... NICK (freezing her with a stare) We're not getting very far into the levels⋯   [no tone]

g. #by companies with links or sympathies to the opposition, freezing bank accounts, seizing assets, poring over the tax returns of lesser donors.
                                        [no tone]

h. are doing the regime change through political, military and freezing of financial assets of the regime, while at the same time applying military.
                                        [0.51 sadness]

4.3 Remaining challenges in Sentiment AI

Although a *Sentiment AI* model like WTA can be extremely useful in extracting key insights or determining key business decisions based on a big data-based trend analysis, there still are limitations. IBM WTA website mentions potential errors by including biased examples such as "My boss is older than me," labeled as negative, and "My boss is younger than me," labeled as neutral, which reveals an inherent *bias against age* in the original data. Other challenges have to do with the *lack of context knowledge.* A typical example of polysemy is the sentiment of the word *return*: *return* in an investment context indicates a positive sentiment while *return* in a retail business context involves a negative sentiment. Another problematic case is multi-polarity, which refers to the case with mixed feelings in a restaurant or product review, for example. Such confusing overall sentiment of the text is tricky to be handled by AI and possibly even by humans. Further, *sarcasm, irony, hyperbole,* and *humor* require deep understanding of *pragmatic and world knowledge.*

These issues pose serious challenges to Sentiment AI analysis and NLP-based AI in general. There are algorithmic approaches to tackling some of the challenges. For example, the sentiment analysis of *return* importantly tells us that the simple classification of the relevant contexts as business is insufficient, and a more customized context classification is necessary to improve the performance of Sentiment AI.

The current study, however, identifies another problematic case for Sentiment AI analysis, i.e. the incorrect predictions of sentiment, as shown in temperature terms in section 4.2. To tackle this issue, we suggest that information in the emotional dimension for temperature terms needs to be encoded in a *sentiment dictionary* (cf. Gatti et al. 2016), perhaps in the form of *uninterpretable feature* that can be only activated by other words with interpretable feature of identical or similar sentiment, which further strengthens the overall sentiment of that feature. Such information can be included in the process of model training, or directly in the sentiment dictionary, along with part-of-speech tagging across languages.

5. Conclusion

In exploring the spectrum of sentiments conveyed by basic temperature terms in

English, we show how the meanings of temperature terms systematically convey a speaker's positive or negative emotional attitude. This kind of subtle sentiments are normally undefined in a regular dictionary, and even a *sentiment dictionary* tends to miss such nuanced flavors that is only *optionally triggered.*

Through a comparative study of Corpus analysis and Sentiment AI analysis, the current study has established that the lexical entry must be enriched with the potentially positive or negative connotational differences amongst basic temperature terms. This further suggests that the meaning of temperature terms can be understood as at least three dimensional: First, the indication of temperature exists in the literal semantic dimension; second, the basic temperature meaning is stretched to the semantically extended meaning regarding the state of affairs in the figurative dimension; and, finally, the speaker's emotive stance is located in the semantico-pragmatic evaluative attitudinal dimension.

In section 2, we discuss how the figurative extension of basic temperature terms, *warm/cool, hot/cold,* and *scalding/freezing* in English conveys a speaker's negative or positive emotive stance. Section 3 shows how positive vs. negative temperature terms, i.e. *warm/cool* vs. *hot/cold/scalding/freezing* interact with various other emotive items in their vicinity. In section 4, we examine whether such a nuanced sentiment in each temperature term can be predicted by the *Sentiment AI* model, WTA, and discuss its challenges and potential solutions.

In so doing, the current study aims to contribute to a better understanding of the nature of subtle emotional attitude encoded in certain lexical items, and to show how such sentiment of individual item achieves attitudinal harmony with accompanying elements. In exploring the emotional attitude of temperature terms, the current findings shed light on the mechanism of intercommunication system amongst various sentiment-encoding items and the notion of multidimensional meaning (Potts 2005). The empirical findings in English are thus instructive in that they unveil systematic distribution patterns of various emotive elements in big data. It is important to note, however, that there still remain numerous issues (e.g., polysemous meanings with opposing attitudes, as in negative *hot*, meaning 'angry,' and positive *hot*, meaning 'popular' or 'sexy') that require further investigation, and the current study only took a small step toward that direction.

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