Journal of Experimental Social Psychology 48 (2012) 579–582

Contents lists available at SciVerse ScienceDirect

Journal of Experimental Social Psychology

journal homepage: www.elsevier.com/locate/jesp

FlashReport

Bitter struggle for survival: Evolved bitterness embodiment of survival motivation

Bin-Bin Chen, Lei Chang *

The Chinese University of Hong Kong, Hong Kong, China

ARTICLE INFO

Article history:
Received 2 September 2011
Revised 3 November 2011
Available online 12 November 2011

Keywords:
Evolution
Embodiment
Bitterness
Survival motivation

ABSTRACT

In four experiments, we tested the hypothesis that survival motivation is grounded in the physical experience of bitter taste. Chinese (Experiment 1) and non-Chinese participants (Experiment 2) who tasted a bitter drink were quicker than the control participants who drank plain water in responding to survival-related words in a lexical decision task. Chinese participants who chewed bitter lotus root were more likely to discount the future than those who chewed sour lemon (Experiment 3). Finally, surprise retention tests revealed that experiencing a bitter rather than sweet taste led to higher retention of words processed for survival rather than mating scenarios (Experiment 4). These findings support our prediction that the taste of bitterness embodies survival motivation because both are adaptations to harsh environment.

The current theory and research on embodiment have revealed the connection on many levels between bodily-based physical experience and the corresponding psychological meaning (Barsalou, 1999, 2008; Niedenthal, 2007; Schubert & Semin, 2009; Semin & Smith, 2008; Wilson, 2002). From an evolutionary perspective, embodiment as a mental phenomenon may have been shaped by way of co-evolution of the body and the mind in adapting to a similar environment (Glenberg, 2010). Phylogenetically, some of the sensory-motor systems that enable lower organisms to interact with the environment are incorporated or embodied by the more complex, higher-order mental systems among higher animals to encode meanings from motor-perceptual interactions with the environment (Barsalou, 1999; Kaschak & Maner, 2009). Ontogenetically, human infants first learn about the world through motor-perceptual experiences which serve to embody or scaffold the subsequent development of the high-order mental systems in solving recurrent challenges of the environment (Williams, Huang, & Bargh, 2009). Thus, physical and psychological experiences become correlated when they both adapt to the same or similar evolutionary challenges. For example, physical distance or closeness may embody emotional attachment because physical distances and embodied emotional distances both carry the same adaptive significance in conveying safety and proximity (Williams & Bargh, 2008). Forward and backward body positions or movement and their embodied approach and avoidance cognition (Centerbar & Clore, 2006) are both precursors to adaptive actions in response to potential fitness-enhancing *vs* fitness-endangering environment.

Another example is bitter taste and survival motivation which may be co-evolved adaptations to a harsh environment. Immediate survival challenges demand enhanced motivation to attend the present and discount the future and this survival motivation is coupled with energy reallocation from reserves otherwise stored for development and reproduction (Hill & Kaplan, 1999). Ample evidence supports the heightened motivation in the face of survival challenges (e.g., Fernandez et al., 2006; Promislow & Harvey, 1990; Quinlan, 2007; Wardle & Steptoe, 2003). For example, a recent experiment shows that survival-threatening cues made individuals and especially those who grew up relatively poor to discount the future by taking immediate rather than delayed rewards (Griskevicius, Tybur, Delton, & Robertson, 2011). In contrast, self-protective motives made individuals become loss-aversive (Li, Kenrick, Griskevicius, & Neuberg, in press). One of the most frequent and recurrent survival challenges in human history has been food shortages resulting from severe weather and other natural disasters. Most crops and plants taste bitterer when grown in an extremely abiotically stressed environment brought about by drought or floods (Barceloux, 2009; Johns, 1990; Keutgen & Pawelzik, 2007; Waller & Nowacki, 1978). For example, a high level of glycoalkaloid content resulting in bitterness is found in potatoes grown in extremely frigid and arid conditions (Johns, 1990). The effect of drought stress on seed bitterness was also found (Christiansen, Jornsgard, Buskov, & Olsen, 1997). Therefore, tolerating bitter taste is adaptive to a harsh environment that reduces sweet-tasting and increases bitter-tasting vegetation. Archeological records indicate that bitter food is eaten only by the very poor, or in times of famine (Zohary & Hopf, 2000). Moskowitz, Kumaraiah, Sharma, Jacobs, and Sharma (1975) found that Indian laborers who subsisted on a sparse daily diet showed high preferences for bitterness.

Responding to the same harsh environment, the physiological adaptation resulting in a taste for bitterness and the psychological adaptation of a heightened survival motivation could have co-evolved to result in the embodiment of bitterness for survival motivation. Because of this evolutionarily selected co-adaptation, a gustatory

* Corresponding author at: Department of Educational Psychology, The Chinese University of Hong Kong, New Territories, Hong Kong, China. Fax: +852 2603 6392.
E-mail address: leichang@cuhk.edu.hk (L. Chang).

0022-1031/$ – see front matter
doi:10.1016/j.jesp.2011.11.005

experience of bitterness should influence, in an unintentional manner, the processing of higher-level mental activities associated with survival including attending to the present and discounting the future. In four experiments, we demonstrate that the physical experience of bitter taste is associated with enhanced motivation for survival.

Experiment 1

We used a lexical decision task to measure survival motivation among two groups of participants who drank either bitter or plain water. If bitter gustatory stimuli enhanced survival motivation, then lexical concepts related to survival should become cognitively more accessible, resulting in a faster response time when experiencing bitter compared to plain taste. Bitter drink was produced by mixing 400 ml water with 10 g lotus seeds, which, used in Chinese cuisine, are bitter but contain no caffeine.

Method

Thirty-seven undergraduate students (average age = 24.08, SD = 4.17, 16 female) of a university in China participated in the experiment for moderate payment. Upon arrival at the laboratory, the participants were told that they were about to participate in two unrelated tasks. One was to test-drink a new beverage, and, for the control condition, a new bottled water. The other was to take a cognitive test for a different researcher unrelated to the taste test. Participants were then given either a cup of bitter beverage or a cup of plain water, and were then asked to rate the test drink and mood states (e.g., pleasant, nervous; $\alpha = 0.65$). Immediately afterwards, they were given the lexical decision task, where the participants were asked to indicate as quickly and accurately as possible whether or not each presented letter string constituted a Chinese word. More detailed method sections are provided in the supplementary data.

Results and discussion

Response latencies that exceeded 1500 ms (0.5% of the responses) and incorrect responses (2.2% of the responses) were excluded from the analyses. Only the response time of the 16 real words was used. The response time was log-transformed, but, for the sake of clarity, we presented non-transformed means. A 2 (gender) × 2 (bitter *vs* plain water, between participants) × 2 (survival *vs* control words, within participants) mixed ANOVA revealed a significant main effect for word type ($F_{1,33} = 4.80$, $p = 0.04$, $\eta^2 = 0.13$). Participants were faster in responding to survival ($M = 501$, SD = 59.46) than control words ($M = 521$, SD = 72.55; $t_{36} = -2.34$, $p = 0.025$). As expected, the interaction between taste and word type was significant ($F_{1,33} = 4.09$, $p = 0.05$, $\eta^2 = 0.11$). Participants were faster with the survival words after tasting bitter ($M = 477$, SD = 54.09) rather than plain water ($M = 529$, SD = 53.95; $t_{35} = 2.89$, $p = 0.007$), whereas the control words showed no difference between bitter ($M = 510$, SD = 65.58) and plain drink ($M = 534$, SD = 80.03; $t_{35} = 0.93$, $p = 0.36$). ANCOVA with mood states as the covariate yielded the same interaction effect ($F_{1,32} = 7.40$, $p = 0.01$, $\eta^2 = 0.19$). These findings demonstrate that drinking bitter as opposed to plain water rendered survival-relevant words faster and more readily accessible, supporting the association between bitter taste and survival motivation.

Experiment 2

To rule out potential cultural effect (e.g., traditionally prepared Chinese medicine tastes bitter), we replicated Experiment 1, using the same lexical test in English rather than Chinese, on a sample of 47 exchange students studying in Hong Kong (average age = 22.96, SD = 3.93; 25 males; 37 from America, Australia, Europe and 9, Asia, 1, Africa). Their average stay in China including Hong Kong was less than 3 months. Consistent with Experiment 1, ANOVA yielded a significant interaction between taste and word type ($F_{1,43} = 4.86$, $p = 0.03$, $\eta^2 = 0.10$). Participants were faster with survival words after tasting bitter ($M = 582$, SD = 64.76) rather than plain water ($M = 647$, SD = 85.77; $t_{45} = -2.91$, $p = 0.006$), whereas the control words showed no difference between bitter ($M = 641$, SD = 103.77) and plain drink ($M = 660$, SD = 102.72; $t_{45} = -0.65$, $p = 0.52$). ANCOVA with mood states as the covariate showed the same significant interaction effect ($F_{1,42} = 4.97$, $p = 0.03$, $\eta^2 = 0.11$). See supplementary data for details.

Experiment 3

Experiments 1 and 2 used plain taste as the control condition. In Experiment 3, we used sour taste as the control condition to rule out the potential confounding that any unpleasant taste but not just bitter taste may induce survival motivation. We used the same design and procedures used in Experiment 1 but a future discounting task as the dependent variable.

Method

Participants who were 38 Chinese undergraduate students (average age = 23.84, SD = 3.71; 19 females) were asked to chew either lotus seeds or lemon for 5 minutes while answering the future discounting questions. Adopted from Wang and Dvorak (2010), the 7 questions were monetary decisions on binary choices between accepting a smaller reward (HK$120 to HK$570) on the following day and a larger reward (HK$330 to HK$780) after a specified delay (4 to 939 days). To encourage genuine response, participants were told they would roll dice at the end of the experiment for the opportunity of receiving the rewards they had selected. Participants finally rated emotional states ($\alpha = 0.51$) as in Experiment 1.

Results and discussion

The future-discounting rate was calculated based on Kirby and Maraković (1996).

A 2 (gender) × 2 (bitter *vs* sour) ANOVA on time-discounting scores showed a significant effect for taste ($F_{1,34} = 4.31$, $p = 0.045$, $\eta^2 = 0.11$). The future-discounting rate was higher under bitter ($M = 0.099$, SD = 0.18) than sour taste condition ($M = 0.009$, SD = 0.012). ANCOVA with mood states as the covariate yielded the same effect for taste ($F_{1,33} = 5.10$, $p = 0.03$, $\eta^2 = 0.13$). These results provide support for the association between survival motivation and bitter but not any unpleasant taste.

Experiment 4

The three experiments compared a survival context against adaptation-irrelevant contexts (e.g., non-survival words). In Experiment 4, we investigated the survival embodiment against an adaptation-relevant context. We gave participants an unexpected memory test for words they had rated for relevance to survival as compared to mating. Because of the survival embodiment, a bitter taste should enhance the retrieval of words encoded for survival but not for mating.

Method

Fifty-seven female undergraduate students (average age = 21.75, SD = 1.34) of a university in China participated in the experiment for small payment. Participants were randomly assigned to one of two rating scenarios. One was related to a survival situation that was adopted from Nairne, Pandeirada, and Thompson (2008). The other was related to a long-term mating situation adopted from Griskevicius, Cialdini, and Kenrick (2006). Under each rating condition, 30 words were presented on a computer screen for 5 seconds each. The participants were asked to rate the words for relevancy to survival or mating by clicking the mouse on the chosen option.

After rating the words, the participants worked on a recall task of digit strings for 2 minutes. Afterwards, they were given lotus seeds or sweetened berries, with half of the two groups of raters (survival and mating) randomly assigned to the two taste conditions. They were asked to chew the food for 5 minutes, during which they were instructed to write down the words they had rated earlier, in any order. They finally filled out mood state questions measured by PANAS ($\alpha = 0.78$ for positive and 0.89 for negative emotion).

Results and discussion

A 2 (bitter *vs* sweet, between participants) × 2 (survival *vs* mating, between participants) ANOVA on proportion of correct recall yielded a significant main effect concerning the rating scenario ($F_{1,53} = 15.48$, $p < 0.001$, $\eta^2 = 0.23$). Participants showed higher retention rates when words were rated for survival ($M = 0.50$, $SD = 0.10$) rather than mating ($M = 0.41$, $SD = 0.10$; $t(55) = 3.35$, $p = 0.001$). The hypothesized two-way interaction between taste and rating scenario was significant ($F_{1,53} = 12.13$, $p = 0.001$, $\eta^2 = 0.19$). In the survival scenario, the proportion of correct recall under the bitterness condition ($M = 0.54$, $SD = 0.08$) was significantly higher than that under the sweetness condition ($M = 0.46$, $SD = 0.10$; $t(27) = 2.27$, $p = 0.03$), whereas in the mating scenario, the proportion of correct recall under the sweetness condition ($M = 0.45$, $SD = 0.08$) was significantly higher than that under the bitterness condition ($M = 0.36$, $SD = 0.11$; $t(26) = 2.66$, $p = 0.01$) (Fig. 1). We also conducted ANCOVA by controlling mood states, the word relevance rating, and the response time as covariates. There were the main effects due to rating scenario ($F_{1,49} = 7.74$, $p = 0.008$, $\eta^2 = 0.14$) and the taste by rating interaction ($F_{1,49} = 10.11$, $p = 0.003$, $\eta^2 = 0.18$). These results support our embodiment prediction that bitter taste is associated with survival motivation, leading to enhanced retrieval of words encoded in a survival rather than mating context.

General discussion

We found that survival motivation is grounded in the physical experience of a bitter taste. Bitter taste produced future discounting (Experiment 3) and fast access to (Experiment 1 and 2) and enhanced retention of survival words (Experiment 4). These findings support the evolutionary explanation of embodiment of bitterness as an adaptation to harsh environment that co-selects tolerance of or preference for bitter taste and elevated motivation for immediate survival.

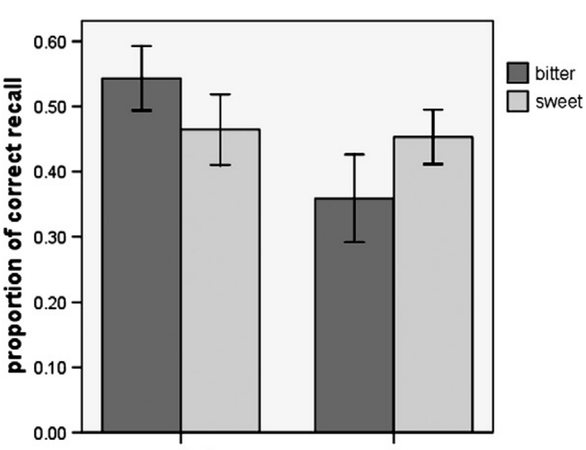

Fig. 1. Average proportion correct recall by condition for Experiment 3 (error bars indicate standard error).

Severe weather and the subsequent food shortages represent one of the recurrent challenges to animal survival. Bad weather causes reduction in vegetation which results in food shortages across the food chain. Abiotic stress due to severe weather such as drought and flood increases bitter-tasting compounds causing crops and plantations taste bitter (Keutgen & Pawelzik, 2007; Waller & Nowacki, 1978). To survive the harsh environment, humans and other animals must eat the bitter tasting plants which would otherwise be avoided in good times. Among human beings at least, there is an evolved tolerance of and preference for bitter taste associated with plants but not meat products. For example, gall bladder also tastes bitter but, even though many human groups eat animal intestines, few eat gall bladder or gall-tinted meat. Tea and coffee, on the other hand, become most commonly consumed beverages across cultures. Some of the other bitter tasting vegetations that different human groups eat as food rather than spice or medicine include bitter melon, bamboo shoot, dandelion green, eggplant, endive, pear fruit, papaya leaf, radish, and rapini. This human taste for plant-derived bitterness may have been adaptive particularly for a depleting and impoverished environment. Such a challenging environment also selects elevated motivation for immediate survival rather than mating or development. This motivation exerts attention and effort onto the present rather than the future. There is likely co-evolution of a human taste for bitterness and a motivation and mental preparedness to survive hard times. Human beings drink coffee or tea especially when they are tired. The caffeine effect may have been an accidental byproduct of the bitter taste which draws human beings especially when their tired body signals hard times; many human beings drink de-caffeinated coffee or tea certainly for the bitter taste. Thus, a survival cognition embodied in bitter taste may be shaped by the co-evolution of palatable acceptance of bitter-tasting plants and the mental preparedness for difficult times.

Appendix A. Supplementary data

Supplementary data to this article can be found online at doi:10.1016/j.jesp.2011.11.005.

References

Barceloux, D. G. (2009). Potatoes, tomatoes, and solanine toxicity (*Solanum tuberosum* L., *Solanum lycopersicum* L.). *Disease-a-month: DM*, *55*, 391–402.

Barsalou, L. W. (1999). Perceptual symbol systems. *Behavioral and Brain Sciences*, *22*, 577–660.

Barsalou, L. W. (2008). Grounded cognition. *Annual Review of Psychology*, *59*, 617–645.

Centerbar, D. B., & Clore, G. L. (2006). Do approach–avoidance actions create attitudes? *Psychological Science*, *17*, 22–29.

Christiansen, J. L., Jornsgard, B., Buskov, S., & Olsen, C. E. (1997). Effect of drought stress on content and composition of seed alkaloids in narrow-leafed lupin, *Lupinus angustifolius* L. *European Journal of Agronomy*, *7*, 307–314.

Fernandez, E., Schiaffino, A., Borrell, C., Benach, J., Ariza, C., Ramon, J. M., et al. (2006). Social class, education, and smoking cessation: Long-term follow-up of patients treated at a smoking cessation unit. *Nicotine & Tobacco Research*, *8*, 29–36.

Glenberg, A. M. (2010). Embodiment as a unifying perspective for psychology. *Wiley Interdisciplinary Reviews: Cognitive Science*, *1*, 586–596.

Griskevicius, V., Cialdini, R. B., & Kenrick, D. T. (2006). Peacocks, Picasso, and parental investment: The effects of romantic motives on creativity. *Journal of Personality and Social Psychology*, *91*, 63–76.

Griskevicius, V., Tybur, J. M., Delton, A. W., & Robertson, T. E. (2011). The influence of mortality and socioeconomic status on risk and delayed rewards: A life history theory approach. *Journal of Personality and Social Psychology*, *100*, 1015–1026.

Hill, K., & Kaplan, H. (1999). Life history traits in humans: Theory and empirical studies. *Annual Review of Anthropology*, *28*, 397–430.

Johns, T. (1990). *With bitter herbs they shall eat it: Chemical ecology and the origins of human diet and medicine.* Tucson: University of Arizona Press.

Kaschak, M. P., & Maner, J. K. (2009). Embodiment, evolution, and social cognition: An integrative framework. *European Journal of Social Psychology*, *39*, 1236–1244.

Keutgen, A., & Pawelzik, E. (2007). Modifications of taste-relevant compounds in strawberry fruit under NaCl salinity. *Food Chemistry*, *105*, 1487–1494.

Kirby, K. N., & Maraković, N. N. (1996). Delay-discounting probabilistic rewards: Rates decrease as amounts increase. *Psychonomic Bulletin & Review*, *3*, 100–104.

Li, Y. J., Kenrick, D. T., Griskevicius, V., & Neuberg, S. L. (in press). Economic decision biases in evolutionary perspective: How mating and self-protection motives alter loss aversions. *Journal of Personality and Social Psychology*.

Moskowitz, H. W., Kumaraiah, V., Sharma, K. N., Jacobs, H. L., & Sharma, S. D. (1975). Cross-cultural differences in simple taste preferences. *Science*, *190*, 1217–1218.

Nairne, J. S., Pandeirada, J. N. S., & Thompson, S. R. (2008). Adaptive memory: The comparative value of survival processing. *Psychological Science*, *19*, 176–180.

Niedenthal, P. M. (2007). Embodying emotion. *Science*, *316*, 1002–1005.

Promislow, D. E. L., & Harvey, P. H. (1990). Living fast and dying young: A comparative analysis of life history variation among mammals. *Journal of Zoology*, *220*, 417–437.

Quinlan, R. J. (2007). Human parental effort and environmental risk. *Proceedings of the Royal Society B: Biological Sciences*, *274*, 121–125.

Schubert, T. W., & Semin, G. R. (2009). Embodiment as a unifying perspective for psychology. *European Journal of Social Psychology*, *39*, 1135–1141.

Semin, G. R., & Smith, E. R. (2008). *Embodied grounding: Social, cognitive, affective, and neuroscientific approaches.* New York: Cambridge University Press.

Waller, G. R., & Nowacki, E. K. (1978). *Alkaloid biology and metabolism in plants.* New York: Plenum.

Wang, X. T., & Dvorak, R. D. (2010). Sweet future: Fluctuating blood glucose levels affect future discounting. *Psychological Science*, *21*, 183–188.

Wardle, J., & Steptoe, A. (2003). Socioeconomic differences in attitudes and beliefs about healthy lifestyles. *Journal of Epidemiology and Community Health*, *57*, 440–443.

Williams, L. E., & Bargh, J. A. (2008). Keeping one's distance: The influence of spatial distance cues on affect and evaluation. *Psychological Science*, *19*, 302–308.

Williams, L. E., Huang, J. Y., & Bargh, J. A. (2009). The scaffolded mind: Higher mental processes are grounded in early experience of the physical world. *European Journal of Social Psychology*, *39*, 1257–1267.

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin & Review*, *9*, 625–636.

Zohary, D., & Hopf, M. (2000). *Domestication of plants in the Old World: The origin and spread of cultivated plants in West Asia, Europe, and the Nile Valley* (2nd ed.). Oxford: Oxford University Press.