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ARTICLE
Recognition Without Words: Using Taste to Explore Survival Processing

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Many educational demonstrations of memory and recall employ word lists and number strings; items that lend themselves to semantic organization and "chunking." By applying taste recall to the adaptive memory paradigm, which evaluates memory from a survival-based evolutionary perspective, we have developed a simple, inexpensive exercise that defies mnemonic strategies. Most adaptive memory studies have evaluated recall of words encountered while imagining survival and non-survival scenarios. Here, we've left the lexical domain and hypothesized that taste memory, as measured by recognition, would be best when acquisition occurs under imagined threat of personal harm, namely poisoning. We tested participants individually while they evaluated eight teas in one of three conditions: in one, they evaluated the toxicity of the tea (survival condition), in a second, they considered the marketability of the tea and, in the third, they evaluated the bitterness of the tea. After a filler task, a surprise recognition task required the participants to taste and identify the eight original teas from a group of 16 that included eight novel teas. The survival condition led to better recognition than the bitterness condition but, surprisingly, it did not yield better recognition than the marketing condition. A second experiment employed a streamlined design more appropriate for classroom settings and failed to support the hypothesis that planning enhanced recognition in survival scenarios. This simple technique has, at least, revealed a robust levels-of-processing effect for taste recognition and invites students to consider the adaptive advantages of all forms of memory.

Key words: taste; memory; recall; adaptive memory; levels-of-processing; survival processing; classroom demonstration

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Memory and recall are common topics in general psychology courses as well as others that explore perception, learning, and cognition. Cited work and suggested demonstrations, however, often revolve around a few familiar paradigms like recalling word lists and number strings, recognizing faces, and reporting past events. A current and popular cognitive psychology textbook cites 781 references and while at least 300 of these sources describe memory research, none of the studies addresses taste memory (Goldstein, 2015). This is not surprising, considering the importance of remembering sights and sounds and the ease with which visual and auditory recall experiments can be designed, but students should be aware of the multimodal nature of memory and educators should explore ways to demonstrate recall across the senses. This report describes a novel method that applies taste memory to an established experimental framework.

Specific forms of human memory may have evolved to serve specific survival-based functions and one experimental paradigm attempts to take adaptive mechanisms into account (Nairne et al., 2007). These "adaptive memory" studies have shown a mnemonic advantage for survival processing that is superior to some well-established encoding conditions including mental imagery, self-reference, relational processing, and intentional learning (Nairne and Pandeirada, 2008; 2010; Nairne et al., 2008). Nairne et al. (2007), asked participants to imagine that they had been stranded on an unfamiliar grassland. They then viewed a list of words and provided a score for each one to indicate its importance for surviving in such an environment. Control conditions included one in which participants were asked to score the words while imagining a move to a new home in a foreign country, and another in which participants were simply asked to rate the pleasantness of each word. A surprise free-recall task given at the conclusion of the experiment showed superior word recall for the adaptive memory condition compared to the other two. Other investigators have replicated these findings both within- and between-subjects and with alternate scenarios meant to control for schematic processing (Kang et al., 2008; Weinstein et al., 2008). Some see these results as evidence that selective pressures have shaped memory and that the effects of this shaping are manifest in superior recall for items easily associated with survival (Nairne et al., 2009).

Several researchers have challenged or refined the survival processing explanation, igniting a rich debate (Butler et al., 2009; Otgaar and Smeets, 2010; Burns et al., 2011; Otgaar et al., 2010; Nairne and Pandeirada, 2011). Among the most intriguing are two studies suggesting that the survival advantage does not appear in implicit memory (Tse and Altarriba, 2010) or face recognition (Savine et al., 2011) and another that proposes a special form of iconic memory for threatening visual stimuli (Kuhbandner et al., 2011). These results underscore the importance of teaching memory as multi-modal and testing the possible survival advantages for different forms of memory across a wide variety of experimental situations.

Nairne et al. (2007) employed a grasslands scenario on the assumption that adaptive memory emerged during the Pleistocene era of human hunter-gatherers. Although dating the birth of adaptive memory is as difficult and speculative as dating the birth of modern human language, the two are often intertwined and certainly interdependent in any task that employs word recall. Therefore, it would be beneficial to develop an adaptive memory paradigm that does not use word lists or visual and auditory stimuli that can be linked to a participant's lexicon.

Unlike memory for word lists, taste memory has been studied within a functionalist evolutionary framework for decades (for review see Rozin and Kalat, 1971; Garcia et al., 1985) and the progress has been such that some researchers have proposed specific molecular mechanisms for specific taste memories (for review see Bermúdez-Rattoni, 2004). Building on the taste memory and adaptive memory literatures, we used a modification of the adaptive memory paradigm to develop a student exercise to explore survival coding for taste in human participants. We used a variety of non-sweetened teas as our stimulus set. Tea is inexpensive and comes in a wide variety of flavors that, with a few exceptions, defy lexical labels and are, therefore, not amenable to mnemonic devices. Tea is also typically bitter when unsweetened which may be beneficial for taste recall demonstrations since memory for deviations in bitter tastes is more accurate than memory for deviations in sweetness (Köster et al., 2004; Stevenson and Oaten, 2010). Additionally, the survival significance of detecting and remembering bitterness, a characteristic of alkaloid poisons, can be introduced to students at the behavioral, systems, or molecular levels (e.g., Rozin and Kalat, 1971; Garcia et al., 1985; Bermúdez-Rattoni, 2004; Fischer et al., 2004).

In one experiment, we asked individual student participants to imagine scenarios and rate tea flavors based on poison content, marketability, or bitterness. Like Nairne et al. (2007), we aimed to create conditions that would tap different "levels of processing" (Craik and Lockhart, 1972; Challis et al. 1996). Briefly, levels of processing theory predicts that memory will be better for items that are encoded while a participant relates them to other objects or events (deep processing) than it will be for items that are encoded while the participant only considers the item's features (shallow processing). We had one adaptive memory deep processing task, one non-adaptive deep processing task, and one shallow processing task. After completing a distracter task, our participants took a surprise taste recognition test in which we presented both previously encountered and novel stimuli. We hypothesized that, compared to those in the other two conditions, the participants in the imaginary poison content condition would be better at discriminating between recently encountered and novel teas. Additionally, recognition would be better for those who engaged in non-adaptive deep processing compared to those who engaged in shallow processing.

A second experiment employed a modified procedure suitable for testing students en masse. Using a similar but streamlined technique, we tested the hypothesis that a future-directed temporal orientation (planning) could enhance the survival processing effect (Klein et al., 2011).

PRIMARY LEARNING OBJECTIVES

Upon completion of this experiment, students should be able to:

1. Describe memory not as a single function, but as a collection of systems shaped by natural selection.
2. Describe the adaptive uses of the sensory systems and, with these in mind, propose experiments aimed at exploring the adaptive memory of each.
3. Describe how recall (and, presumably, encoding) can be difficult when the stimuli are not easily to label.
4. Compare and contrast the adaptive memory effect and levels-of-processing effect and consider whether or not they are, in fact, different effects or a common effect that can be exhibited by different techniques.

MATERIALS AND METHODS: EXPERIMENT 1

Participants

These experiments complied with the standards of Millersville University's Institutional Review Board. In the first experiment, fifty-three undergraduates participated in 30-minute sessions in exchange for course credit. Participants were tested individually in a classroom environment by fellow undergraduates.

Materials

We obtained 32 different loose-leaf teas from a local market and brewed each one by steeping 3 tablespoons in 32 ounces of hot water for four minutes. We allowed them to cool, numbered them, and then stored them at room temperature (21°C), in sealable plastic containers for at least 12 hours before use.

Procedure

Prior to data collection, a group of eleven undergraduates volunteered to screen the 32 teas. We gave them 5 ml of each tea to taste and consume and asked each to describe or label them according to as many characteristics as they could subjectively identify (e.g., tastes minty, smells like lemon, tastes very bitter). We were concerned that tea recognition could be confounded by labeling; for example, one could report recognizing a particular tea flavor because they originally encoded the stimulus with a label, such as "lemony" or "unusually bitter," and not because they recognized the actual stimulus. To minimize labeling effects, we chose the 16 teas that the volunteers described or labeled most inconsistently.

Set A	**Set B**
Chai*	Apricot
China Black*	Assam
Darjeeling	Ceylon Ultima
Earl Grey	English Breakfast
Lemon Spice*	Giulia*
Mango*	Imperial Green
Oolong	Turk Caravan*
Russian Ancai	Yorkshire Gold**

*Table 1. Teas Used. Teas were made by White Coffee (Long Island City, NY) except *Metropolitan Tea Company (Cheektowaga, NY) and **Brands of Britain (San Ramon, CA).*

We divided the selected teas into two sets of eight (Table 1) and presented each participant with one of the two sets (Set A, n = 29; Set B, n = 24) to taste and swallow for the encoding phase.

After selecting a tea set, we randomly assigned participants to one of three encoding conditions and an experimenter read the corresponding scenario aloud. The three scenarios were as follows:

Condition 1
(Survival Condition, n = 18): Imagine that all tea leaves naturally contain a certain amount of poison and that, even though the poisonous properties of these teas have been neutralized during processing for human consumption, some taste of the original poison remains. You are at a prime age for tasting the poison present in the tea leaves, even though the tea is no longer toxic. Please rate each tea on a scale of 0 to 10 based on how much poison you think was in the tea leaves prior to processing, with 0 signifying no poison, 5 signifying a moderate amount of poison, and 10 signifying a large amount of poison.

Condition 2
(Marketing Condition, n = 16): Imagine that the university is instituting a new program which will have students grow teas in the university greenhouse and then sell them to the community in a new campus store. You have been chosen to rate a selection of teas based on how well you think each one will sell. Please rate each tea on a scale of 0 to 10 based on how well you think each tea will sell with 0 signifying that the tea will not sell at all, 5 signifying that the tea will sell moderately well, and 10 signifying that the tea will sell very well.

Condition 3
(Bitterness Condition, n = 19): Please rate each tea on a scale of 0 to 10 based on how bitter you think it is, with a 0 signifying that the tea is not bitter at all, 5 signifying that that the tea is moderately bitter, and 10 signifying that the tea is extremely bitter.

We used an alternating strategy to assign participants to the sets and we counterbalanced presentation sequences within sets. We then blindfolded the participant and presented the eight teas in individual plastic cups containing 5 ml of liquid at room temperature (21°C). After tasting and rating a tea, the participant rinsed their mouth with 100 ml of water, spit the water out, and waited 30 seconds for the next tea. At the conclusion of the rating phase, we instructed the participant to remove the blindfold and complete a ten-minute digit recall task similar to the one used by Nairne et al. (2008). Then we surprised them by asking them to put the blindfold back over their eyes and taste the full set of 16 teas, which included the eight teas from the rating phase as well as eight novel ones. Again, we instructed the participant to taste, swallow, and rinse but this time, instead of assigning a rating to each tea, the participant responded to a forced-choice, yes or no, to indicate if they had tasted the tea in the rating phase. After tasting all 16 teas, the participant removed the blindfold and completed a tea familiarity questionnaire which simply asked how often they drank tea (0, 1-3, 4-6, or more than 6 times/week) and how many different flavors they typically sampled each week.

RESULTS: EXPERIMENT 1

We used an alpha level of 0.05 for all statistical tests. Figure 1 shows the mean recognition score, measured as d' per MacMillan and Creelman (1991), for the three conditions. One participant's score was more than two standard deviations above the mean for that condition and was therefore excluded from the analyses. Participants in the bitterness condition performed at chance level. A single factor analysis of variance (*ANOVA*) revealed a significant effect for condition, $F(2,49) = 7.15$, $MSE = 0.07$, $p = 0.002$, $\eta^2_p = 0.23$. Scheffé tests for multiple comparisons showed that while recognition scores differed significantly between the survival condition and the bitterness condition, $p = .011$, as well as between the marketing condition and the bitterness condition, $p = .006$, there was no significant difference between the survival and marketing condition scores, $p = 0.954$.

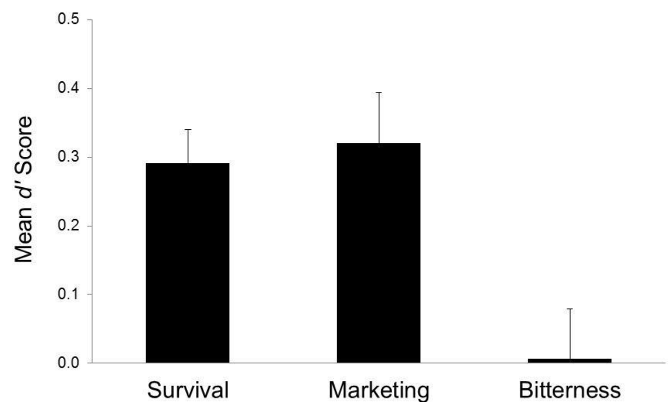

Figure 1. Mean (+*SEM*) d' scores for the three conditions used in Experiment 1. The mean score for Bitterness was significantly lower than that for Marketing ($p = 0.006$) as well as Survival ($p = 0.011$). Survival and Marketing scores did not differ significantly ($p = 0.954$).

We explored the possibility of a link between tea familiarity and recognition with a single factor *ANOVA* that revealed no significant differences among groups of participants who reported drinking tea 0 times/week, 1-3 times/week, and 4-6 times/week, $F(2,48) = 0.73$, $MSE = 0.10$, $p = 0.487$. (No participants reported consuming tea more than six times per week.) *ANOVA*s were also used to verify that the effect of condition seen across all participants existed within each of the two tea sets (A and B). Recognition (d') was compared for participants in the three conditions who tasted teas in Set A, $F(2,26) = 3.73$, $MSE = 0.06$, $p = 0.038$, as well as Set B, $F(2,20) = 7.18$, $MSE = 0.06$, $p = 0.005$. Post hoc analyses confirm the same effect of condition within both tea sets.

MATERIALS AND METHODS: EXPERIMENT 2

We modified the previous procedure to test the effect of planning on survival processing scenarios and streamline data collection for classroom situations.

Participants
One investigator tested forty-one undergraduates in two large groups as part of a demonstration for a cognitive psychology class. The students had studied the sensory systems and attention but had yet to study memory.

Materials
We reserved a single classroom and prepared individual desks for testing up to 25 participants. We prepared teas as described in Experiment 1 and distributed 5 ml quantities in opaque plastic 30ml cups. Single sheets of paper described one of two experimental scenarios as well as a common distractor task that instructed the students to calculate the mean of twenty single-digit numbers. Each desk had eight cups of tea and one instruction sheet placed face-down. The four teas to be consumed for the rating phase were labelled A-D and visible on the desktops while the four cups to be used in the recognition phase, also labelled A-D, were behind the other four and draped with paper towels. We used a Latin square method to create 16 unique rating sets. Two teas in each corresponding recognition set were randomly selected from the four in the rating set while the other two were selected from the remaining teas.

Procedure
Having prepared each desk with one of the 16 possible tea sets, the investigator led the students into the classroom, gave them pencils, and told them to read their individual instruction sheets which included one of the following scenarios:

Condition 1
(Survival without Planning Condition, *n* = 19): Imagine that you are lost in the wilderness, far from home and without any water. You have come across an abandoned campsite and find four heavy jars that appear to contain four different teas. You are not sure if the teas are safe to drink, but you are very thirsty now and need to drink something in order to survive. You decide to sample each tea and then immediately drink from the jar of the one that you believe is safest. Please taste and rate each tea on a scale of 0 to 10 based on how safe you think each tea is with 0 signifying unsafe, 5 signifying moderately safe, and 10 signifying that the tea is very safe.

Condition 2
(Survival with Planning Condition, *n* = 22): Imagine that you are lost in the wilderness, far from home and without any water. You have come across an abandoned campsite and find four heavy jars that appear to contain four different teas. You are not sure if the teas are safe to drink and you are not thirsty now, but you are lost and will eventually need to drink something in order to survive. You decide to sample each tea and then carry the jar of tea that you believe is safest. Please taste and rate each tea on a scale of 0 to 10 based on how safe you think each tea is with 0 signifying unsafe, 5 signifying moderately safe, and 10 signifying that the tea is very safe.

Participants drank the teas at their own pace, provided scores on the instruction sheet on spaces labelled A-D, and completed the distractor task. The investigator then distributed a second sheet of paper that instructed them to "Gently remove the cover from the four remaining cups, try each one and indicate if this tea was in the first group of four or if it is a new tea. Circle the appropriate answer." A list of teas, A-D, followed along with the text: "This tea was in the first group of four. / This is a new tea." A third sheet asked a final question; "What strategies (if any) did you use to remember the teas?" The responses remained at the corresponding desks when the students were dismissed.

RESULTS: EXPERIMENT 2
Whereas Experiment 1 required participants to make sixteen binary decisions, Experiment 2 required them to make only four. Fourteen participants (34%) performed perfectly and the resultant ceiling effect, combined with the fact that four binary choices yield only five possible recognition score (d') values, precluded data analysis with parametric tests. Because of the low sample sizes, we collapsed the data into below chance ($d' < 0$), chance ($d' = 0$) and above chance ($d' > 0$) scores (Figure 2). A 2x3 Freeman-Halton Fisher exact test did not show a significant difference between the two conditions, $p = 0.282$.

When asked to describe the strategies used to recall the teas, 32 participants stated that they relied on taste and/or smell, but only five mentioned the use of descriptive labels like *bitter*, and *watered-down.* None stated that they recognized a specific tea. We saw no evidence of consistent labelling and nine participants reported having no strategy at all. Six of these nine performed at above chance and two of them performed perfectly despite having no insight to their ability.

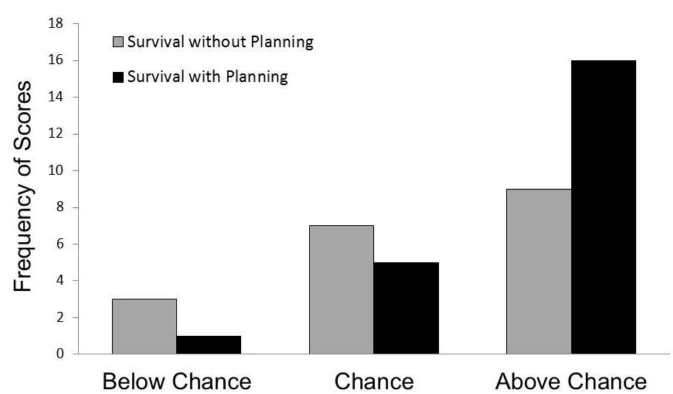

Figure 2. Frequency distributions of recognition scores for the participants in Experiment 2.

DISCUSSION
Student investigators and participants found these experiments simple and tolerable, if not enjoyable. Although most participants had performed some form of word recall memory task as part of a classroom demonstration in previous high school or college courses,

none had previously performed a memory task involving taste. The process, of course, presents opportunities to discuss methodological and analytical issues but the results should lend themselves to rich classroom discussions about the multi-modal nature of memory, levels-of-processing theory, and the challenge of recalling (and, presumably, encoding) stimuli that are not easily labelled.

Unfortunately, we still do not know if and how survival processing scenarios apply to taste recall. For example, in Experiment 1, contrary to previous findings, our adaptive memory (Survival) condition failed to produce superior recognition compared to a non-adaptive marketing condition. However, the poison and marketing conditions elicited much better recognition than the bitterness condition.

One interpretation of the Experiment 1 results, and perhaps the most parsimonious one, is that we have demonstrated a standard levels-of-processing effect (Craik and Lockhart, 1972; Challis et al., 1996). The survival and marketing conditions required imaginative elaboration (deep processing) whereas the bitterness condition required only sensory analysis (shallow processing). This interpretation suggests that while our data show no obvious adaptive memory effect, the levels-of-processing effect is robust.

Another possible explanation for the lack of an adaptive memory effect in Experiment 1 could be that the encoding processes for tastes and words are qualitatively different. For example, one recent study found that the adaptive memory advantage for words could be accounted for by fluctuations in both relational and item-specific processing (Burns et al. 2011). Relational processing between the tea flavors in our study and the encoding scenarios would have been difficult, given that the tea flavors were chosen because they defied labels. Congruency between encoded stimuli and processing tasks may also play a role in adaptive memory; recall is best when words are congruent with the encoding scenario (Butler et al., 2009; but see Nairne and Pandeirada, 2011). In Experiment 1, however, the scenario most congruent with the tea flavors was arguably the bitterness condition, in which recognition was no better than chance.

Another possibility is that both the poison and marketability conditions induced adaptive memory since financial stability can be thought of as fitness-relevant by modern day standards. While previous experiments (Kang et al., 2008; Nairne and Pandeirada, 2010; Weinstein et al., 2008) have shown that the survival advantage for words is linked to encoding scenarios that are ancestral (e.g., grasslands survival) as opposed to contemporary (e.g., city survival, planning a bank heist), Soderstrom and McCabe (2011) found no differences in recall between ancestral and modern scenarios. Although the personal acquisition of wealth could benefit survival in modern societies, our marketing scenario made no mention of direct personal gain. Our participants were working for the benefit of an institution and any expectation of reward would have been assumed and based on subjective interpretation alone. An adaptive memory benefit cannot be ruled out in the marketing condition but, if it is present, it should not be as large as it is in the survival condition, with its clear and direct link to personal fitness. Of course, any investigation of adaptive memory must consider the limited external validity of the lab where students, hopefully, don't feel endangered.

In Experiment 2, we aimed to test another hypothesis using a method suitable for classroom demonstrations. Klein et al. (2011) suggested that the future-directed temporal orientation of the survival scenarios used by Nairne et al., (2007) explained much of the survival advantage. That is, recall is enhanced when participants are encouraged to plan for the future (as they are in most survival scenarios). We found that, although our participants, who tasted only eight samples, had higher recognition scores than those in Experiment 1, who tasted 24, they failed to demonstrate a clear future-directed temporal orientation (planning) effect when the two groups were compared. Both of our Experiment 2 scenarios had explicit survival components and, perhaps, a "survival effect" lifted recognition to a common performance ceiling that masked the "planning effect." We can only conclude that we failed to detect a significant *additive* benefit for planning.

Like the original eleven volunteers who were invited to help us choose the teas, the experimental participants struggled to label the teas in a way that could possibly serve recall. We surveyed Experiment 2 participants to see if they could express any insight on how they were able to recognize the teas. Although most reported that they used olfaction and taste, and a few stated that they noted qualities like bitterness, none mentioned a label that could be attributed to a specific tea. These results can be used to illustrate how recall can be good - and sometimes perfect - in the absence of insight.

Exercises like these may lead cognitive psychology or perception students to a more comprehensive understanding of the various forms of memory and how they have been shaped by natural selection. Memory is multi-modal but, as a matter of convenience, most textbook examples and lab demonstrations employ visual or auditory/lexical stimuli. Students should understand that different forms of memory involve different mechanisms and serve many different purposes. We have developed a simple, inexpensive technique that illustrates memory in a seldom-explored sensory domain. To our knowledge, this investigation represents the first application of the Nairne et al., (2007) strategy to taste memory and we believe it holds great promise for both instruction and exploratory investigation. Instructors can easily simplify or expand the procedure or try other taste stimuli (flavored jelly beans are convenient, but we found them too easy to label). Instructors can also develop new imaginary scenarios to target specific cognitive tasks, like planning.

We still do not know if adaptive memory can be clearly demonstrated with taste stimuli, but this simple and cost-effective experimental technique shines a light on a seldom studied form of memory, it yields a levels-of-processing effect, and opens the door to discussions about the evolutionary origins of cognition.

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