Recalling Taste Intensities in Sweetened and Salted Liquids

H. Tuorila[1], M.J.M. Theunissen[1,3] and R. Ahlström[2]

[1]Department of Food Technology, University of Helsinki, PO Box 27 (Viikki B), FIN-00014 Helsinki, Finland and [2]SIK—The Swedish Institute for Food Research, PO Box 5401, S-402 29 Gothenburg, Sweden

[3]Current address: Psychonomics Department, Utrecht University, Heidelberglaan 2, 3584 CS Utrecht, The Netherlands

Correspondence to be sent to: H. Tuorila, Department of Food Technology, University of Helsinki, PO Box 27 (Viikki B), FIN-00014 Helsinki, Finland

Abstract

The effect of training on recalling taste intensities over 6 weeks was studied using an *ad libitum* mixing procedure. Subjects tasted sweet and salty standards labeled as 'weak' and 'strong' (3 and 8% sucrose in redcurrant juice; 0.4 and 1.2% NaCl in beef broth). They subsequently mixed unsweetened and sweetened juice, and unsalted and salted broth, to produce taste intensities that corresponded to the standards. A minimum training (MT) group (n = 13) produced comparison stimuli by tasting and directly comparing with standards in one session only; an extensive training (ET) group (n = 13) did this in six sessions before producing comparison stimuli based on memory only at 1 h, 1 day, 1 week and 6 weeks. An upward bias (chemically determined concentrations of comparison stimuli exceeding those of standards) occurred at 1 day or 1 week in MT subjects for 'weak' and 'strong' sweetness, and for 'strong' saltiness, and sustained thereafter. The upward tendency was also observed in ET subjects but was significant only for 'strong' sweetness. It is important to recognize memory effects such as the one described, as they affect food perceptions and can be a major source of bias in sensory food research. **Chem. Senses 21: 29–34, 1996.**

Introduction

Human memory for perceived stimulus intensities has been predominantly investigated in the visual modality (e.g. Moyer *et al.*, 1978; Da Silva *et al.*, 1987). Research on olfactory memory has focused on odor recognition, not on intensity (see Richardson and Zucco, 1989). Research into the memory for taste intensities is even more limited.

Memory psychophysics addresses the representation and retrieval of perceptual information in memory (Kerst and Howard, 1978). Research in this area has been concerned with the determination of perceptual and memorial power functions. Memorial power functions tend to have lower exponents than those based on actual stimuli and two alternative hypotheses have been proposed to explain this discrepancy (for review see Algom *et al.*, 1985). (i) The reperceptual approach assumes that memorial intensity estimates relate to perceived intensities via a separate power function; the exponent of the memorial power function would be a square of the perceptual power function. Consequently, with an exponent < 1 (compressive power function), the memorial power function is flatter than the perceptual power function. (ii) The perceptual uncertainty hypothesis suggests that subjects, when making memorial judgements, either assume an enlarged stimulus range or constrict their response range, both again leading to a flat power function (compared with the perceptual power function).

Moyer *et al.* (1982) studied memorial and perceptual power functions in different modalities, among them taste. They observed an attenuated memory exponent for saccharine (compressive function, exponent < 1) and a fairly unchanged exponent for sucrose (expansive function, exponent > 1). They do not give details of experimental conditions, except for a few remarks on the difficulty of the research task on taste.

Barker and Weaver (1983) asked their subjects to taste and remember the strength of an aqueous solution of 15% sucrose (standard). After a time delay of 1, 5 or 15 min, or 72 h, subjects tasted one of the aqueous solutions containing 5, 10, 15 or 20% sucrose, and reported its strength (weaker, stronger or the same as standard). Subjects tended to remember the standard as weaker than it was, so that the sample with 10% sucrose was frequently identified as the standard.

Algom and Marks (1989) determined power functions based on perceived and remembered taste intensities of 1–24% sucrose in aqueous solutions. Subjects underwent a training period during which they learnt to associate five sucrose concentrations with certain colors. In the 'memory' condition 24 h later they gave magnitude estimates to the samples that were symbolically represented by colors. The power functions based on perceived and remembered intensities were almost identical.

Remembered taste intensities are worth more attention. Understanding the rules of the recall phenomenon is methodologically crucial for the discipline of sensory food science, which is engaged in quantifying food characteristics and which, in long-term studies, has to rely on human assessors' stable perceptions over time (cf. Lawless, 1990). Further, understanding how taste memories act as the frame of reference in human responses to food would give us the means to interpret food acceptance data (Barker, 1982).

As the available research is scarce and conflicting, the present experiment was designed to determine (i) the extent to which remembered taste intensities may be over- or underestimated during a period of 6 weeks and (ii) to what extent the possible bias can be overcome by training. Sucrose and sodium chloride in 'natural' food media (juice and broth respectively) were used as stimuli.

Materials and methods

Subjects

Twenty-six female volunteers, students or staff members, were recruited at the University of Helsinki and divided into two equal-sized groups. Only individuals without previous experience of sensory testing qualified. One group (mean age 22 years, range 19–30) participated in one training session only ('minimum training'; MT) while the other group (mean age 25 years, range 20–35) participated in six identical training sessions conducted over a period of 8 days ('extensive training'; ET).

Testing method

The testing method was *ad libitum* mixing. In experimental psychology this method is called the method of average error or the method of adjustment (Pangborn, 1984). The subject receives a standard stimulus (ST) and her task is to manipulate the intensity of another stimulus (comparison stimulus; CO) so that it matches that of the ST. In the case of taste stimuli, the subject receives a standard at a fixed concentration level for tasting, and produces the perceived intensity equal to the standard by mixing low and high concentrations of the taste substance. The actual concentration of the CO is then determined chemically or physically. With the choice of *ad libitum* mixing, we aimed to minimize context effects [that are produced, for example, by a fixed concentration range (Riskey *et al.*, 1979; Schifferstein, 1995)]. Compared with traditional scaling methods, *ad libitum* mixing is easy to administer and understand, and evaluations of its reliability and validity have been encouraging (for a review see Mattes and Lawless, 1985).

Samples

The stimuli were solutions of sucrose (household quality, manufactured by Suomen Sokeri Oy, Helsinki) in unsweetened redcurrant juice (Saarioinen Oy, Tampere; dilution ratio 1 + 4) and sodium chloride (household quality, manufacturer/distributor Jozo, The Netherlands) in beef broth (manufactured in the pilot plant of the Department of Food Technology, University of Helsinki). Each ST was prepared at two concentrations: 3 and 8% (w/v) sucrose in redcurrant juice, and 0.4 and 1.2% (w/v) NaCl in broth. These concentrations were labeled 'weak' and 'strong' respectively. The juice samples were served at room temperature (21°C) and the broth samples hot at 60°C.

The samples to be mixed to achieve the intensities of the standards were 0 and 20% sucrose in juice, and 0 and 3% NaCl in broth. All were presented in 500 ml thermos bottles, from which subjects delivered them by pushing a lid. In this way, the samples remained at constant temperature and subjects could not see how much liquid they had used. The COs were prepared in 50 ml plastic cups (juice) or glass beakers (broth) with a prefill (juice or broth) of 20 ml. The prefills were used to keep the procedure unaffected by visual cues (volumes of start concentrations), and were randomly sweetened with 0–20% sucrose (all concentrations with 2% intervals, $n = 11$) or salted with 0–3% NaCl (all concentrations with 0.3% intervals, $n = 11$). The broth prefills were kept at 60°C in water baths in tasting booths.

The obtained COs were kept frozen at –20°C until all sessions were completed, then thawed and brought to room temperature (21°C) for the analyses. The sucrose contents were analyzed refractometrically. The soluble solids of redcurrant juice (1.9%) were subtracted from the total to obtain the amount of sucrose added in the *ad libitum* procedure. The NaCl contents were determined using a sodium specific electrode. According to analyses, the unsalted broth contained 0.075% NaCl, which was subtracted from the total to obtain the amount of added NaCl.

Sessions

Subjects were exposed to the four labeled STs in one (MT) or six (ET) training sessions. Their task was to reproduce these intensities in duplicate, by adding portions of the start concentrations to a prefill, and by tasting and retasting the ST and CO as much as they wished. Half of the subjects in each subgroup started with juice and the other half with broth; this order was randomized over sessions. Within a taste quality, the order of the four STs (two 'weak' and two 'strong') was randomized. Subjects rinsed with tap water every time they had completed a sample. Once a CO was completed it was removed from the tasting booth to prevent retasting during the preparation of the replicate. A 1 min break was held between the juice and broth series.

During training sessions subjects were requested to carefully memorize the intensities of each labeled ST as they would need this information to produce a similar intensity in later sessions without having the ST available. Thus, subjects were fully aware of what they were expected to learn, and were encouraged to maximal performance. However, no feedback was offered on individual performance during training.

Both subgroups participated in experimental sessions at 1 h, 1 day, 1 week and 6 weeks after the last training session. The procedure was identical with that in the training sessions, except that STs were not available. Thus, the subjects were requested to prepare COs that corresponded to the images of the 'weak' and 'strong' stimuli that they had adopted during training.

All sessions were conducted in a sensory laboratory, in partitioned tasting booths with basins in which to spit the taste samples and rinsing water.

Data analysis

Repeated measures analysis of variance was performed on juice and broth data separately. The training group (MT versus ET), the strength of ST ('weak' versus 'strong'), time (five time points: the last training session plus four experimental sessions) and replication were used as sources of variance. Main effects and interactions were examined. Subjects' performance in experimental sessions was compared with that during training using pairwise *t*-tests at $P < 0.05$ with the Bonferroni correction (no. of comparisons in each set = 4) (see e.g. Howell, 1995).

Results

Mean sucrose and NaCl contents of the COs produced by each training group are shown in Figure 1. Expectedly, the strength of ST (weak versus strong) was a major source of variance for both juice and broth [$F(1,24) = 237.8$ and $F(1,24) = 326.0$ respectively, $P < 0.001$ in both cases]. The MT group produced significantly higher COs than the ET group [juice $F(1,24) = 11.6$, $P < 0.001$ and broth $F(1,24) = 7.4$, $P = 0.012$]. This tendency held true equally at both strengths of ST (*group* × *strength of standard* non-significant for both juice and broth) and in the course of the time (*group* × *time* non-significant for both juice and broth).

The COs went up with time [$F(4,96) = 19.1$ for juice and $F(4,96) = 9.9$ for broth, both significant at $P < 0.001$]. The shape of the upward curve was somewhat different at weak versus strong level of the ST [*time* × *strength of standard* for juice $F(4,96) = 6.0$, $P < 0.001$ and for broth $F(4,96) = 3.5$, $P < 0.010$]. The MT group produced significantly heightened NaCl and sucrose concentrations of

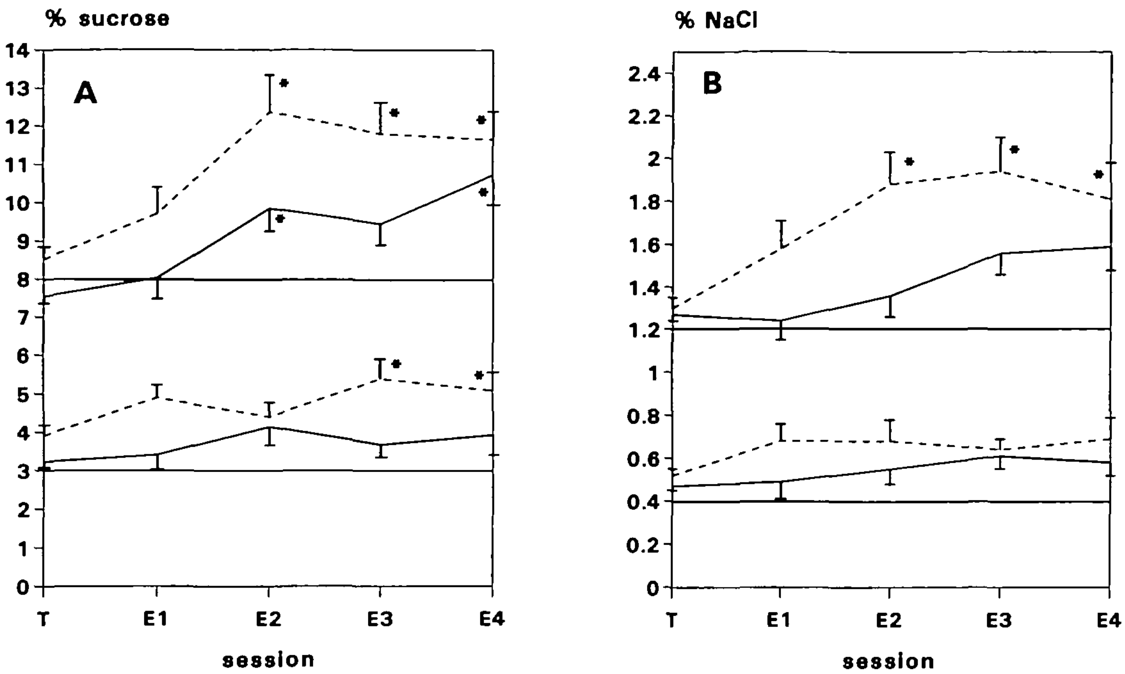

Figure 1 Mean concentrations (+ SEM), obtained in *ad libitum* mixing of **(A)** sucrose in redcurrant juice and **(B)** NaCl in beef broth in MT (dashed lines) and ET (solid lines) groups of 13 subjects. SEMs are represented as vertical lines. The last (ET) or only (MT) training session is referred to as T, and experimental sessions as E1 (1 h), E2 (1 day = 24 h), E3 (1 week = 168 h) and E4 (6 weeks = 1008 h). Solid horizontal lines represent target concentrations present in the standard samples during the training sessions Asterisks refer to a significant ($P < 0.05$) difference of a concentration from the one prepared at T.

'strong' standards at 1 day (E2) and onwards, and of 'weak' sucrose at 1 week (E3) and 6 weeks (E4). The ET group produced significantly heightened concentrations of 'strong' sucrose at 1 day (E2) and at 6 weeks (E4), but for this group no other significant effects were observed. The replicates did not have a consistent impact on COs.

The mean deviations of CO from ST at different levels of prefills suggested that prefills had some effect on concentrations, particularly among MT subjects (Table 1). However, compared with the overall magnitude of deviation in the course of time, the effect of prefills was not major, nor statistically significant. In one-way analysis of variance among deviations at five prefill levels, the largest F ratio obtained was 1.20 ($P = 0.32$; NaCl in broth, MT group, 'weak' standard). It should also be noted that the deviation caused by prefills did not increase over time, thus the prefills do not play a role in the upward tendency in CO concentrations.

Discussion

Recalling sweetness and saltiness

Two notable and consistent findings emerged from this experiment. First, subjects tended to recall taste intensities as more intense than they had actually been. Second, this tendency was markedly suppressed by repeated exposures to standard stimuli, i.e. by training.

Stevens' power function exponents that are based on memory are generally smaller than those based on perception (Kerst and Howard, 1978; Algom *et al.*, 1985; Da Silva *et al.*, 1987). Based on the findings of Moyer *et al.* (1978, 1982), this results from overestimation of memorial intensities at low stimulus strengths; the perceptual and memorial power functions intersect only at very high stimulus intensities. Our standard concentrations, even the 'strong' ones, were not very high. Thus, overestimations observed in our study are in line with earlier studies on memorial power functions. Moreover, King (1963a, b), using the method of adjustment in visual and auditory modalities during 28 day memory experiments, also found slight upward biases in recalled intensities.

Remembering taste intensities stronger than they were when actually tasted contrasts with the finding of Barker and Weaver (1983). Barker and Weaver used aqueous solutions, only one memory task per subject and, apart from a time interval of 72 h, very short time delays of 1–15 min. We used a different method and our subjects were presented with a fairly demanding task: reproduction of eight stimuli

Table 1 Mean deviations of comparison stimuli from 'weak' and 'strong' standards at different prefill levels

Prefill concentration (%)	Upward deviation (% sucrose/NaCl)			
	'Weak' standard		'Strong' standard	
	MT	ET	MT	ET
(A) Sucrose in juice				
0–2	1 6	0.5	2.3	0.9
4–6	1.7	0.6	3.1	0.9
8–10	1.4	0.4	2 1	1.3
12–14	2.1	0.8	3.1	1.2
16–20	1.9	1.0	3.5	1.4
(B) NaCl in broth				
0–0.3	0.15	0.03	0.29	0.16
0.6–0 9	0 25	0.17	0.50	0.25
1.2–1.5	0 26	0.12	0.44	0.19
1.8–2.1	0.22	0.19	0.57	0.22
2.4–3.0	0.32	0.20	0.60	0.18

Each mean is based on >20 values

in five (MT) or ten (ET) sessions over 6 weeks. Future research will hopefully indicate which aspects of the design might have led to converse results.

The upward bias in remembered stimulus intensities may cause problems in sensory food research in which subjects are often required to rate sensory intensities relative to reference concentrations that have been presented during a training period of a study. The observed effect of training emphasizes the importance of training in sensory analysis when a panel is used as a composite instrument. There is some literature available comparing the performance of naive and trained sensory panelists (e.g. Cardello *et al.*, 1982; McBride and Finlay, 1989), but the process of training, e.g. how memory acts and how improvements are monitored, has received very little attention (see Lawless, 1990). The performance of our trained subjects is in line with results by Algom and Marks (1989), whose well-trained group of subjects produced similar memorial and perceptual power functions.

Method

Basically, the *ad libitum* mixing was a flexible and useful tool for this study design. A problem was caused only by the prefills, which tended to affect the final concentrations. Fortunately the effect was not large enough to detract from the results. Mattes and Lawless (1985) demonstrated a considerable effect on final concentrations when the adjustment of sweetness and saltiness was done with ascending versus descending series of stimuli (prefills). According to their data, adaptation to the taste was not a major factor. They suggest that the observed effect resembles the error of anticipation—a premature change in response under a condition in which a subject expects that 'something will soon happen'.

Our within-subject design bears the risk that in the course of the experiment subjects may adopt a new image of the original standard via exposures to their own mixtures; thus, a previous mixture rather than the original standard may act as the target. This could perhaps explain the gradual increase observed in some reproduced concentrations, but not the fact that an upward rather than downward tendency originally took place.

The possible effect of our verbal descriptors needs attention, as individuals are likely to vary in their interpretation of intensity descriptors (Gacula and Washam, 1986). Subjects' personal views of 'weak' and 'strong' intensities may not have corresponded to the intensities of the labeled standards, and in the course of forgetting they may have started mixing according to their own view of 'weak' and 'strong'. However, compared with the sucrose and NaCl contents of ordinary foods, the target concentrations were labeled realistically, and a major conflict between labels and sensory stimuli seems unlikely. From the viewpoint of sensory methodology, combining labels and sensory stimuli was reasonable, as sensory panels are typically required to use intensity scales on which certain verbal descriptors represent certain stimulus intensities.

Conclusion

The present data suggest a marked tendency for memory effects in judgements of taste intensities. It would be risky to draw definite conclusions before more information is accumulated, but it is important to recognize the possibility of memory effects in food perceptions.

REFERENCES

Algom, D. and Marks, L.E. (1989) Memory psychophysics for taste. *Bull. Psychon. Soc.*, **27**, 257–259.

Algom, D., Wolf, Y. and Bergman, B. (1985) Integration of stimulus dimensions in perception and memory: composition rules and psychophysical relations. *J. Exp. Psychol.: Gen.*, **114**, 451–471.

Barker, L.M. (1982) Building memories for foods. In Barker, L.M. (ed.), *The Psychobiology of Human Food Selection*. AVI, Westport, CT, pp. 85–99.

Barker, L.M. and Weaver, C.A., III (1983) Rapid, permanent, loss of memory for absolute intensity of taste and smell. *Bull. Psychon. Soc.*, **21**, 281–284.

Cardello, A.V., Maller, O., Kapsalis, J.G., Segars, R.A., Sawyer, F.M., Murphy, C. and Moskowitz, H.R. (1982) Perception of texture by trained and consumer panelists. *J. Food Sci.*, **47**, 1186–1197.

Da Silva, J.A., Marques, S.L. and Ruiz, E.M. (1987) Subject differences in exponents of psychophysical power functions for inferred, remembered, and perceived area. *Bull. Psychon. Soc.*, **25**, 191–194.

Gacula, M.C., Jr and Washam, R.W., II (1986) Scaling word anchors for measuring off flavor. *J. Fd Qual.*, **9**, 57–65.

Howell, D.C. (1995) *Fundamental Statistics for the Behavioral Sciences*, 3rd edn. Duxbury Press, Belmont, CA, p. 310.

Kerst, S.M. and Howard, J.H. (1978) Memory psychophysics for visual area and length. *Memory Cognit.*, **6**, 327–335.

King, H.E. (1963a) The retention of sensory experience: I. Intensity. *J. Psychol.*, **56**, 283–290.

King, H.E. (1963b) The retention of sensory experience: II. Frequency. *J. Psychol.*, **56**, 291–298.

Lawless, H.T. (1990) Applications of experimental psychology in sensory evaluation. In McBride, R.L. and MacFie, H.J.H. (eds), *Psychological Basis of Sensory Evaluation*. Elsevier, London, pp. 69–91.

Mattes, R.D. and Lawless, H.T. (1985) An adjustment error in optimization of taste intensity. *Appetite*, **6**, 103–114.

McBride, R.L and Finlay, D.C. (1989) Perception of taste mixtures by experienced and novice assessors. *J. Sensory Stud.*, **3**, 237–248

Moyer, R.S., Bradley, D.R., Sorensen, M.H., Whiting, J.C. and Mansfield, D.P. (1978) Psychophysical functions for perceived and remembered size. *Science*, **200**, 330–332.

Moyer, R.S., Sklarew, P. and Whiting, J. (1982) Memory psychophysics. In Geissler, H.-G., Petzold, P., Buffart, H.F.J.M. and Zabrodin, Y.M. (eds), *Psychophysical Judgment and the Process of Perception*. North-Holland Publishing Company, Amsterdam, pp. 33–46.

Pangborn, R M. (1984) Sensory analysis as an analytical tool in food research. In Stewart, J.R. and Whitaker, J.R. (eds), *Modern Methods of Food Analysis*. AVI, Westport, CT, pp. 265–292.

Richardson, J.T.E. and Zucco, G.M. (1989) Cognition and olfaction: a review *Psychol. Bull.*, **105**, 352–360.

Riskey, D.R., Parducci, A. and Beauchamp, G.K. (1979) Effects of context in judgments of sweetness and pleasantness. *Percept. Psychophys.*, **26**, 171–176.

Schifferstein, H.N.J. (1995) Contextual effects in difference judgements. *Percept. Psychophys.*, **57**, 56–70.

Received on 6 February, 1995, accepted on 18 September, 1995