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Controlled Continuous Flow Delivery System for Investigating Taste–Aroma Interactions

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A multichannel flavor delivery system, Dynataste, was developed. Controlled amounts of isoamyl acetate (100 ppm) and sucrose (0−3%) solution was administered to experienced and naïve assessors who used time intensity techniques to record perceived 'fruit' flavor intensity. In-nose volatile delivery was monitored using atmospheric pressure chemical ionization-mass spectrometry. Results indicated that sucrose is a key driver of fruit flavor intensity but that the magnitude of the effect varies between individuals. The combined temporal analysis of chemical stimuli in vivo and sensory data indicate evidence of interactions at a perceptual level. Comparison of experienced and naïve assessors revealed cross-modal interactions in each group, although a subgroup of experienced assessors was unaffected by changes in sucrose concentration. This raises the question of the selected use of experienced panels in cross modal investigations.

KEYWORDS: Sensory interactions; taste; aroma; flow delivery

INTRODUCTION

One contemporary view is that all aspects of human perception are based upon the integration of multiple, concurrent sensations (*1*). In the past researchers investigated flavor through separate modalities but, as Noble (*2*) summarized in a recent review, the literature is now laden with accounts of taste-aroma interactions. A key question to emerge is whether it is a change in flavor release that affects perception, or whether interactions occur at the neural (*3*) or cognitive level (*4*).

Aroma-taste interactions in fruit flavor systems have been widely investigated (*2*, *5*−*8*) although much conflicting evidence remains as to the mechanism/cause behind reported enhancement effects. More often than not some degree of flavor enhancement has been observed and a range of explanations has been proposed to explain the occurrence of this phenomenon. Analysis of headspace composition appears to have ruled out any physicochemical effects in these particular types of system (*8*, *9*) and, consequently, attention has now focused on cognitive explanations (*4*).

Murphy et al. (*10*) explained enhancement on the basis of taste−odor confusions. McBurney (*11*) concluded that flavor was a 'fusion' of its component parts but that the individual stimuli could be perceived independently with training. Frank et al. (*12*) attributed enhancement effects to rating biases commonly referred to as "dumping" (*13*). Prescott (*14*) ruled out the dumping effect from his work, suggesting that evidence of enhancement depended on what particular questions were posed. A commonly held conclusion is that enhancement is dependent on the congruency of the taste and aroma stimulus (*6*, *15*, *16*). Stevenson et al. (*6*) found that certain odors enhanced the tasted sweetness when added to sucrose solutions while others suppressed it. More recently, working at sub-threshold levels, Dalton et al. (*7*) have shown that tastes and smells interact additively. Thus, a sub-threshold taste (saccharin) and a sub-threshold odor (benzaldehyde) were detected when presented together at approximately 63% of their individual detection thresholds. Dalton's data suggest direct neural integration of the two modalities rather than the intentional or cognitive mechanisms engaged with supra-threshold stimuli.

As attention turns to the cross-modal nature of flavor perception, new methodologies are required to enable researchers to decouple all these possible enhancement effects. At the perceptual level, fMRI brings us a step closer to understanding how signals are being processed and techniques such as breath by breath analysis using atmospheric pressure ionization mass spectrometry (APIMS) (*17*) enable us to measure proximal stimuli in vivo, in real time. Research from many of the authors cited above has also highlighted the need for attention to the effects of sensory protocols. Two further areas for consideration include the nature of stimulus delivery and the type of assessors to be employed.

Previous methods of sampling when investigating taste aroma interactions include, sipping (*15*, *18*), sip and sniff (*19*, *20*), and sip and spitting (*21*, *22*). Such methods may enable decoupling of the stimuli but are not wholly comparable to the natural eating event that involves oral delivery of both stimuli, with mouth movements, swallowing, and larger volumes over a longer length of time. Methods closer to normal consumption, but which allow controlled delivery of stimuli, will enable interactions to be studied over longer periods of consumption, in addition to other sensory phenomena such as adaptation and the order and nature of stimulus delivery.

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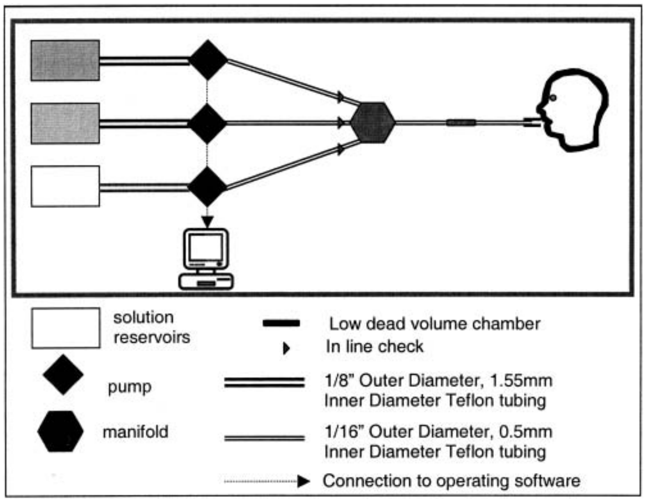

Figure 1. Schematic of the Dynataste multichannel flavor delivery system. Pumps dispense solution from the solution reservoirs according to flow rates preprogrammed in the operating software. The solutions combine at the manifold and are delivered to the assessor at a constant flow rate.

Bingham et al. (*23*) observed that trained assessors did not perceive enhanced flavor intensity measures in taste-aroma mixtures. Indeed, the purpose of training is often geared toward enabling assessors to recognize and subsequently measure the discrete attributes of a model system or food product—an analytic approach. Stevenson (*24*) investigated the effects of exposure and training on sweetness taste enhancement and although he observed some reduction in enhancement, he concluded that much lengthier training or previous experience of components in isolation may be required to remove the effect.

Whether assessors have been trained to ignore such interactions becomes a critical consideration when embarking on investigations concerning multimodal flavor perception. If training has enabled assessors to disassociate such effects then a different approach using naïve judges is required.

The objectives of this research were essentially threefold: to develop a system that would enable controlled delivery of a mixture closer to normal consumption conditions; to use the system to investigate the occurrence of taste-aroma interactions; and to compare responses between naïve and more experienced assessors. Prior to experimentation, it was hypothesized that decreases in tastant concentration, either when removed completely or to different degrees, during stimulus delivery would cause a reduction in flavor intensity perception for naïve assessors but not in the case of experienced assessors.

MATERIALS AND METHODS

Multichannel Flavor Delivery System: Dynataste. To investigate the cross and intermodality of flavor perception/stimuli, a system where the composition of the sample could be varied was required. In addition, continuous delivery of a sample would enable consumption of food over more realistic time periods to be mimicked. To this end a system of computer-controlled pumps connected by Teflon tubing was developed and subsequently called Dynataste.

A schematic of the flavor delivery system constructed can be observed in **Figure 1**. Diaphragm Pumps (KNF, Switzerland), controlled via computer software (Measure, National Instruments Corp.), dispense solutions at a preprogrammed rate, which then combine at a manifold. The combined sample is delivered continuously to the assessor's mouth for a specified length of time. By adjusting the flow rate of each pump the composition of the sample can be varied with time, but the overall flow rate remains constant. Check valves ensure minimum back flow. The mixing efficiency of the system was evaluated by pumping and mixing different colored solutions. Initially, a pulsing effect was observed in the delivery tube but this was minimized by the addition of a low dead volume chamber in the feeder tube. Different flow rates into the mouth were evaluated and those between 10 and 15 mL/min were deemed comfortable for the assessor, to provide sufficient sample volume for evaluation purposes and enable "normal" swallowing action.

Sample. The fruit flavor sample (described as banana), administered to the panel using Dynataste, was derived from three separate reservoirs: 200 ppm isoamyl acetate (IAA) (Aldrich) dissolved in bottled mineral water (Brecon Carregg Natural Waters), 6% (w/v) sucrose (Fisher Scientific) dissolved in bottled mineral water and one containing only mineral water. The resulting 100 ppm isoamyl acetate 3% sucrose solution delivered to the assessors was chosen as these levels had been previously assessed by the experienced panel in our laboratory.

All assessors attended sessions where they were familiarized with the banana flavor and were introduced to a reference sample that represented an arbitrary level of "100" in terms of banana flavor intensity (100 ppm isoamyl acetate/3% sucrose). Practice sessions also took place in order to acquaint the assessors with the new flavor delivery system and the mode of time-intensity data collection in Fizz for Windows V2.00K (Biosystemes).

Panel. A total of 24 assessors, half with 1 and half with 5 years of sensory experience, were selected from the department's external panel to represent "experienced assessors" (age range: 34−65, mean 44, 3 males). This panel had received training in evaluating banana flavor and sweetness using magnitude estimation in previous projects, but they were not specifically trained for this investigation. A group of 30 staff and students were also recruited as naive assessors, that is, they had no previous training/experience, from within the Division of Food Sciences (University of Nottingham) (age range: 21−44, mean: 26. 12 males).

The assessors completed two experiments (due to availability only 23 of the experienced panelists and 26 of the naive assessors completed experiment 2.). Each naive assessor performed duplicate assessments of each experiment, randomized over several sessions on the basis of availability. A maximum of two evaluations was performed in any session. Experienced assessors performed duplicate assessments of each experiment, with a maximum of four evaluations in any session, as they were available for longer. During any session assessors observed at least a 15 min break between samples. A palate cleanser of water and a cracker were consumed between samples. Due to the logistics of testing and panel availability, anywhere between 15 min and 14 days elapsed between replicate judgments.

Experiment 1. To investigate the effect of the presence of sucrose on banana flavor intensity perception, Dynataste was programmed to deliver a solution of 100 ppm isoamyl acetate and 3% sucrose over a period of 150 s, except that during the middle 90 s the sucrose was replaced with water such that only the volatile was delivered (**Figure 2a**). Flow was maintained at a constant 10 mL/min.

Assessors were informed that the flavor intensity of the initial 10 s of flow would be the same as the reference, "100", and to start recording at this point on the time intensity scale (**Figure 3**) when the solution began to flow. Previous work in the lab indicated that no adaptation occurred during this short time, indeed, preliminary investigations in our lab using Dynataste with a constant sucrose/IAA level delivered indicated that even over 10 min only a 10−15% reduction in flavor intensity is observed. Consequently, we believe that it is unlikely that adaptation would have a large effect for the duration of this experiment. For the remainder of the time assessors were instructed to indicate the level of fruit flavor intensity that they perceived by moving the mouse up or down the scale relative to the reference value of '100'. Flow delivery and time-intensity measures were synchronized as assessors were instructed to click on the scale (which initiates data acquisition) as flow began; a verbal warning was also given to indicate this was about to happen. Assessors were instructed to swallow "normally". All assessments took place in sensory booths where assessors had no sight of the Dynataste system other than the feeder tube.

Experiment 2. To investigate how altering the level of sucrose present in a stimulus would affect banana flavor intensity perception,

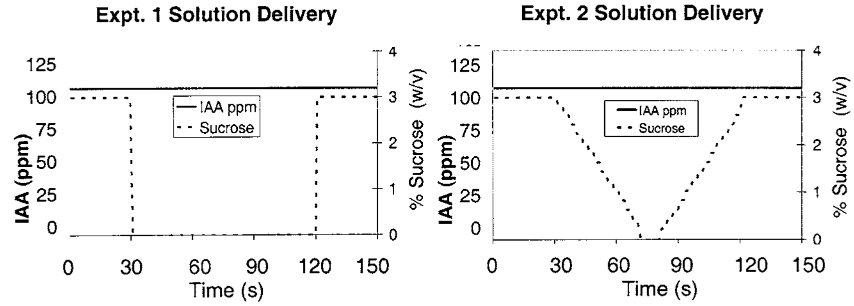

Figure 2. Pattern of solution delivery for experiments 1 and 2.

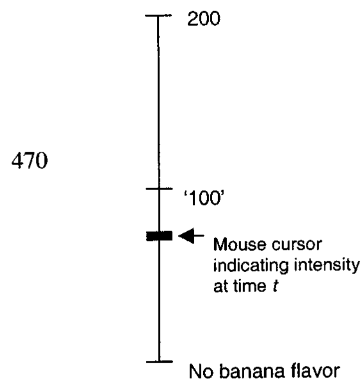

Figure 3. Flavor intensity scale.

the sample was administered as in experiment 1 but with one key difference during the middle 90 s. Instead of removing the sucrose completely, the pumps were programmed such that between 30 and 70 s the sucrose concentration decreased from 3% to 0 in a series of equal steps, remained at 0% for 10 s, and then increased from 0% to 3% over the remaining 40 s (**Figure 2b**).

API-MS Analysis of in Vivo Volatile Release. A subset of 15 assessors (a mixture of experienced and naïve) repeated both experiments in duplicate while positioning a nostril on the MS-Nose (Micromass, Manchester, U.K.) nasal sampling tube and breathing normally. This real-time in-nose release of isoamyl acetate was measured to determine if the level of volatile reaching olfactory receptors varied during each experiment. No concurrent sensory assessment was performed due to the need to concentrate on the positioning of the tube. Air was sampled directly to the source of the API-MS at 30 mL/min (*17*) and the release of isoamyl acetate determined by monitoring *m*/*z* 131, which is the mass-to-charge ratio for this molecular ion.

Data Analysis. Time-intensity data were exported into Excel 2002 (Microsoft Inc.) and the time−intensity curves for each assessor, for each experiment, were assessed for any inconsistencies between replicates. Where inconsistent patterns were observed, that is, the shape of the flavor perception curve was considerably different from one replicate to the next, this was noted and the data removed from subsequent analysis. Mean time−intensity curves were calculated for each assessor. To determine if the pattern of response differed between different assessors, the time-intensity data, for each experiment and each panel (experienced/naive), were subjected to principal component analysis (PCA) (Unscrambler v8.0, Camo Process AS) using individual time points as variables. This enabled the key time points that differentiated between the assessors' perceived levels of banana flavor intensity to be identified. Subsequently, plots of individual assessor component scores were used to identify groups of assessors who responded similarly to each experiment and to describe the nature of their response. For each group, an average time-flavor intensity curve (± 1 standard deviation) was calculated to enable comparisons of the different response patterns.

The pattern of in nose isoamyl acetate delivery was determined from the breath by breath time-peak height chromatograms obtained from the MS-Nose.

RESULTS

Experiment 1. *Naive Assessors*. Of the 30 assessors, only 2 produced inconsistent duplicate judgments. PCA analysis indicated that 2 components accounted for 72% of the variation in the data (**Figure 4**) with a third component contributing 16% (not shown). Time points in the period just after the sucrose was reintroduced ($t = 126-134$ s) correlated most highly with the first principal component. Indeed, increasing assessor scores on principal component (PC) 1 related to higher flavor intensity scores between 126 and 134 s. Time points between 135 and 145 s, that is, intensities measured at the very end of the experiment, correlated most highly with PC2. Time points between 40 and 65, that is, the period after which the sucrose was removed, also showed high negative correlation with PC2. Increasing assessor scores on PC2 related to relatively lower intensity levels recorded toward the end of the experiment and higher intensity levels recorded following the point at which sucrose was removed ($t = 40-65$ s). When assessor scores from the PCA were plotted on the two components (**Figure 5**) four groups could be observed, leaving two individual assessors at outlying points. As one group, group 3, covered a broad range of scores on PC1 and PC2, scores on PC3 were investigated to determine if variation in this component helped in the identification of assessors groups.

Figure 6 plots assessor scores on PC1 and PC3. It showed that most assessors remain in their previously identified groups but that assessors in group 3 could be divided into 3 subsets when the impact of their scores for the third principal component, which was highly correlated with time points 140−150, were observed. Observations of the individual assessor curves in group 3 indicated that their responses were indeed very similar apart from the final perceived level of intensity.

In summary, the naive assessor responses for experiment 1 could be grouped according to the extent of the drop in perceived flavor intensity when the sugar was removed, and the level of intensity perceived as the sucrose had been reintroduced. This is evident when the average response curves for the different groups are observed (**Figure 7**). Group 1 perceived a gradual decrease in banana flavor intensity when the sucrose was removed. The remaining groups all perceived a more immediate drop in banana flavor intensity but to different levels. Group 2 appeared to perceive no or very little banana flavor whereas group 4 only perceived a drop in intensity of around 25%.

Experienced Assessors. Only one experienced assessor yielded inconsistent replicate results and was removed from the analysis. PCA analysis of the time-intensity data indicated that two components accounted for 97% of the variation in the data and in fact, PC1 accounted for 92% on its own (**Figure 8**). Time points between 70 and 110 s, that is, halfway through the sucrose being removed to just before its reintroduction, correlated most highly with the first principal component. Increasing assessor

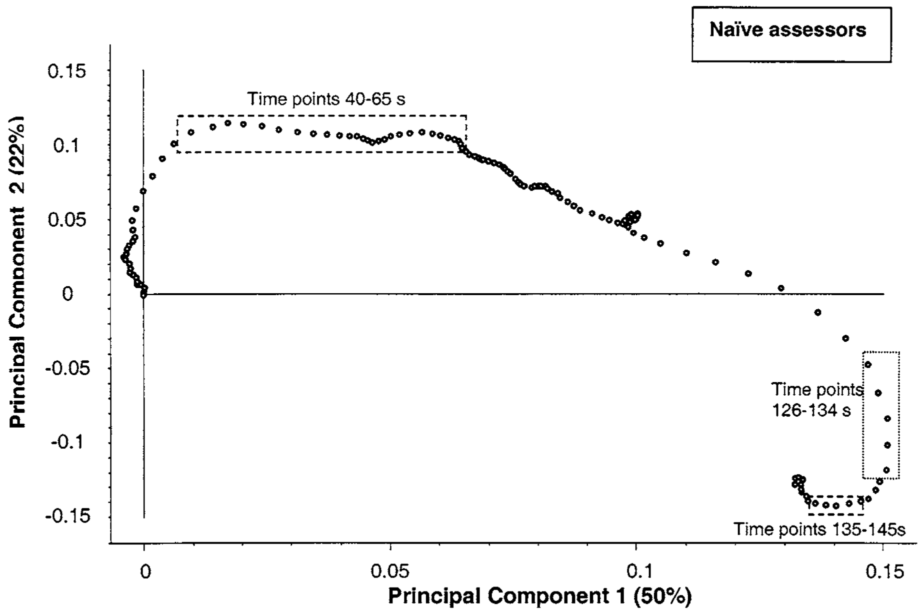

Figure 4. Loading plots of time point variables on first two principal components from PCA of experiment 1 time–intensity data (28 naive assessors). Open symbols o represent the individual time points from 1 to 150 s. Time points most highly correlated with PC1 (dotted box) and PC2 (dashed box) are highlighted.

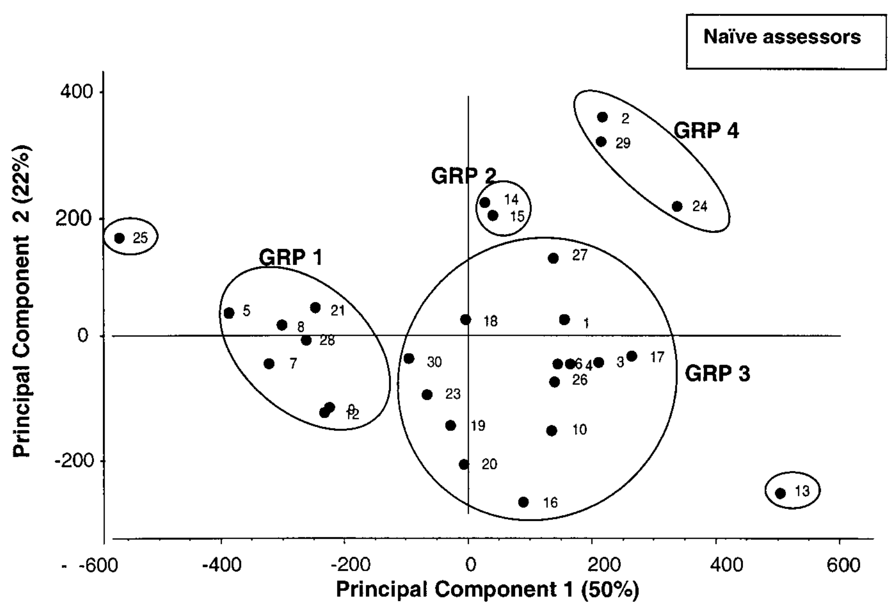

Figure 5. Naïve assessor sample scores on first (50%) and second (22%) principal components following PCA analysis of time intensity data from experiment 1. Numbers 1–29 represent naive assessor identification number. Four groupings of assessors and two outliers are suggested.

scores on this component related to increased flavor intensity scores during this time period. Time points between 130 and 140, that is, intensities measured toward the very end of the experiment, correlated most highly with PC2 and increasing assessor scores on this component related to relatively higher intensity levels recorded toward the end of the experiment. When assessor scores from the PCA were plotted on the two components (**Figure 9**) five separate groups could be observed, with one outlying assessor. The variation in perceived flavor intensity when the sucrose was removed is clearly demonstrated in the average time intensity curves of the grouped assessors (**Figure 10**). In fact, assessors in group 1 exhibited an increase in perceived intensity. Groups 3 and 4 showed an approximate 50% drop in intensity but were differentiated by a difference in the level perceived once the sugar was reintroduced. Finally, group 5 perceived very little banana flavor while the sucrose was absent but perceived it to return to the original level once the sucrose was reinstated.

Experiment 2. The second experiment served to investigate the effect of a gradual change in sucrose level on perceived banana flavor. PCA analysis of the data for both naïve and experienced assessors (not shown) proceeded as for experiment 1 and the key findings are summarized below.

Naive Assessors. PCA analysis of the time-intensity data indicated that two components accounted for 86% of the variation in the data. On PC1 (59%) key time points accounting for the variation in perceived flavor intensity related to the period toward the end of the increasing concentration of sucrose (t = 100−120 s). Variation on PC2 was related to time points around 60, that is, the level at the end of decreasing sucrose gradient

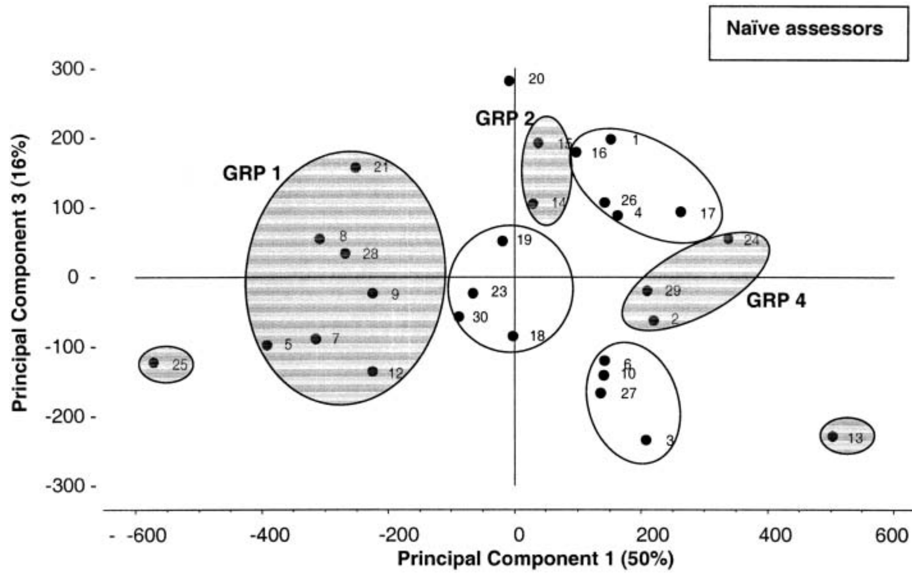

Figure 6. Naive assessor sample scores on first (50%) and third (16%) principal components following PCA analysis of time intensity data from experiment 1. Previously identified outliers and groups 1, 2, and 4 are grayed out highlighting 3 possible subsets of assessors and an outlier (20) from the former Group 3.

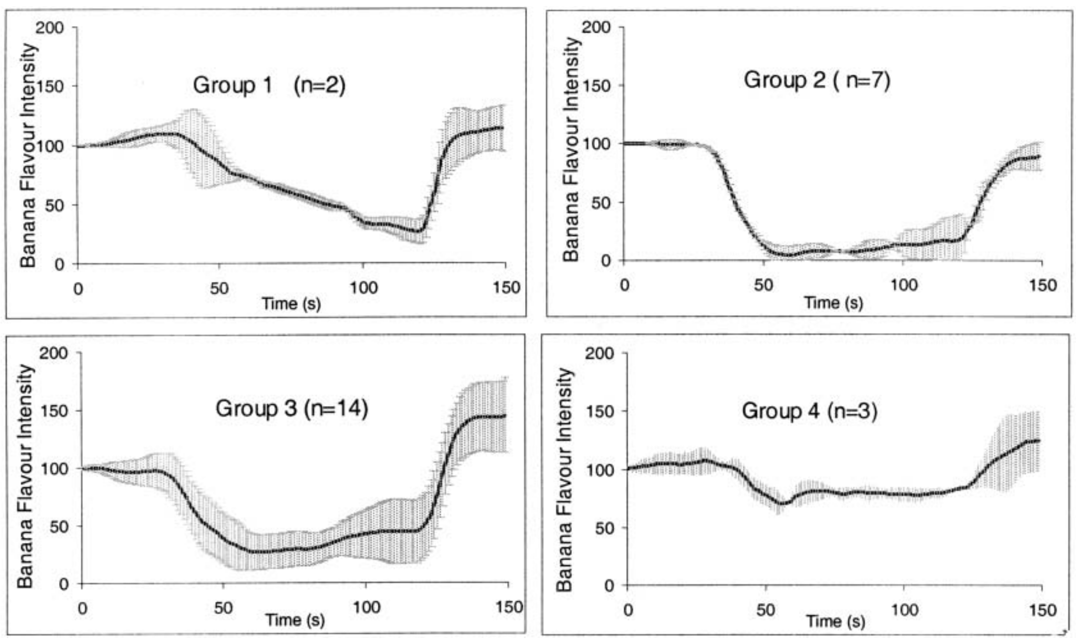

Figure 7. Average time–intensity curves (±1 SD) for observed groups of naïve assessors: experiment 1 (outliers not shown).

and the perceived flavor intensity toward the end of the experiment. Bi-plots (not shown) of assessor scores indicated four groupings of assessors and four outliers. The average time-intensity curves of the four groups are shown in **Figure 11**. Again, perceived flavor intensity appeared to be driven by sucrose levels albeit to different levels and once more there were groups of individuals who perceived very little banana flavor when the sucrose levels were close to or at zero.

Experienced Assessors. PCA analysis of the time-intensity data indicated that two components accounted for 92% of the variation in the data. On PC1 (85%) key time points accounting for the variation in perceived intensity related to the middle time period when sucrose concentration was decreasing and then increased ($t = 60-90$ s). Variation on PC2 (8%) was related to time points just after the sucrose began to decrease ($t = 80$) indicating variation in the magnitude of response to this event. Bi-plots (not shown) of assessor scores indicated three groupings of assessors and four outliers. The average time-intensity curves of the four groups are shown in **Figure 12**. Group 1 perceived a slight increase in banana flavor toward the end of the decreasing sucrose gradient, which tended to remain elevated as the sucrose gradually increased to its original level. The perception of the two remaining groups appeared to be driven by the sucrose level, albeit to very different extents. The largest group (group 3) perceived very little banana flavor at low levels of sucrose concentration.

Breath by Breath Analysis. For all assessors the pattern of delivery followed a consistent "lower level" of volatile interrupted by occasional spikes that corresponded to swallowing action. Examples of a typical MS-Nose chromatograms for each experiment are shown in **Figure 13**. The magnitude of the difference between the lower level and the spike varied considerably from assessor to assessor as did the relative concentrations at the lower levels. Nevertheless, this general pattern of

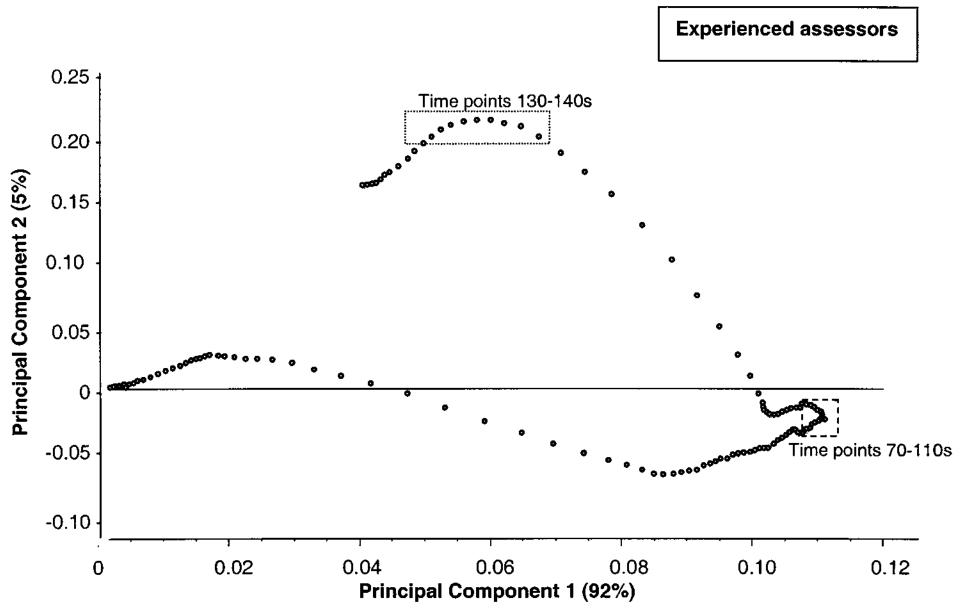

Figure 8. Loading plots of time-point variables on first two principal components from PCA of experiment 1 time-intensity data (23 experienced assessors). Open symbols o represent the individual time points from 1 to 150 s. Time points most highly correlated with PC1 (dashed box) and PC2 (dotted box) are highlighted.

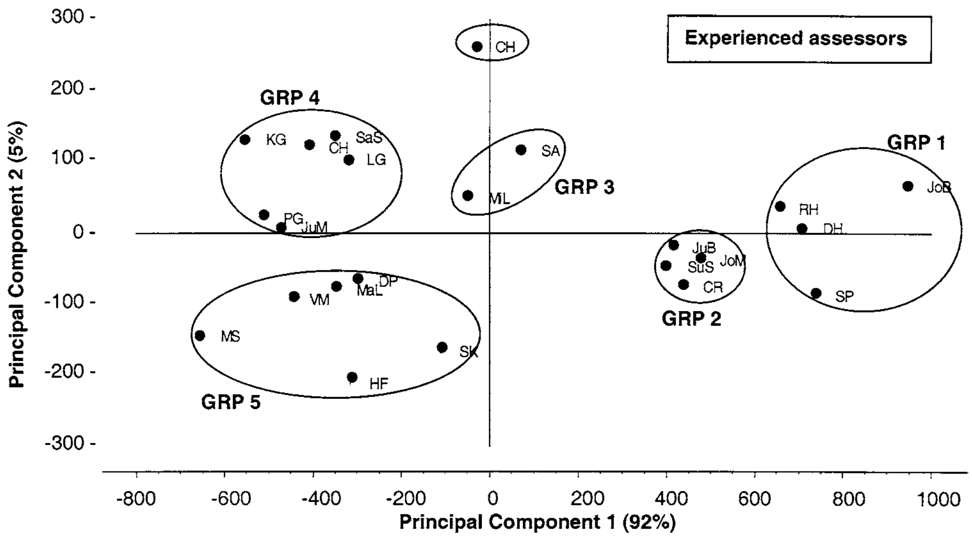

Figure 9. Experienced assessor sample scores on first (92%) and second (5%) principal components following PCA analysis of time intensity data from experiment 1. Letters represent assessor identification codes. Five groupings of assessors and one outlier are suggested.

delivery was consistent across assessors and across both experiments and demonstrated that in-nose levels of the volatile were unaffected by changes in sucrose concentration.

DISCUSSION

Dynataste provided a successful new approach in its ability to deliver a continuous sample consumed under conditions that represent the usual time period over which foods are eaten. The ability to manipulate the composition of the sample in a controlled manner while measuring the sensory response means that the effects of particular stimuli can be reliably investigated. The system also ensured that all assessors received the same sample composition over time and the same volume. In this investigation the only differences in consumption between assessors were associated with mouth movements and swallowing but these could be controlled in further research. Coupling Dynataste with the MS-Nose enables the in-nose volatile delivery to be monitored and, in this investigation, confirmed the elimination of any physicochemical effect on volatile release. The impact of mouth movements and swallowing on delivery were also highlighted and it is clear that this system could be used to investigate the impact of changes in nose volatile delivery and perception. Chromatograms regularly indicated increases in volatile delivery to the nose after swallowing but these plugs of aroma were not recorded as increases in perception by the panel. This could be likened to the brain integrating the blinking during vision such that it is not perceived unless particular attention is paid to it. The rapid plugs of increased volatile concentration appear to be integrated into perception over a longer time period, as previously proposed by Overbosch et al. (*25*).

The results from these experiments provide further evidence of the perceptual taste-aroma interactions previously reported in the literature (*2*) but using a different delivery system. Manipulating the sucrose resulted in changes in perceived banana flavor in most instances. PCA analyses demonstrated that variation in response to each experiment related to changes

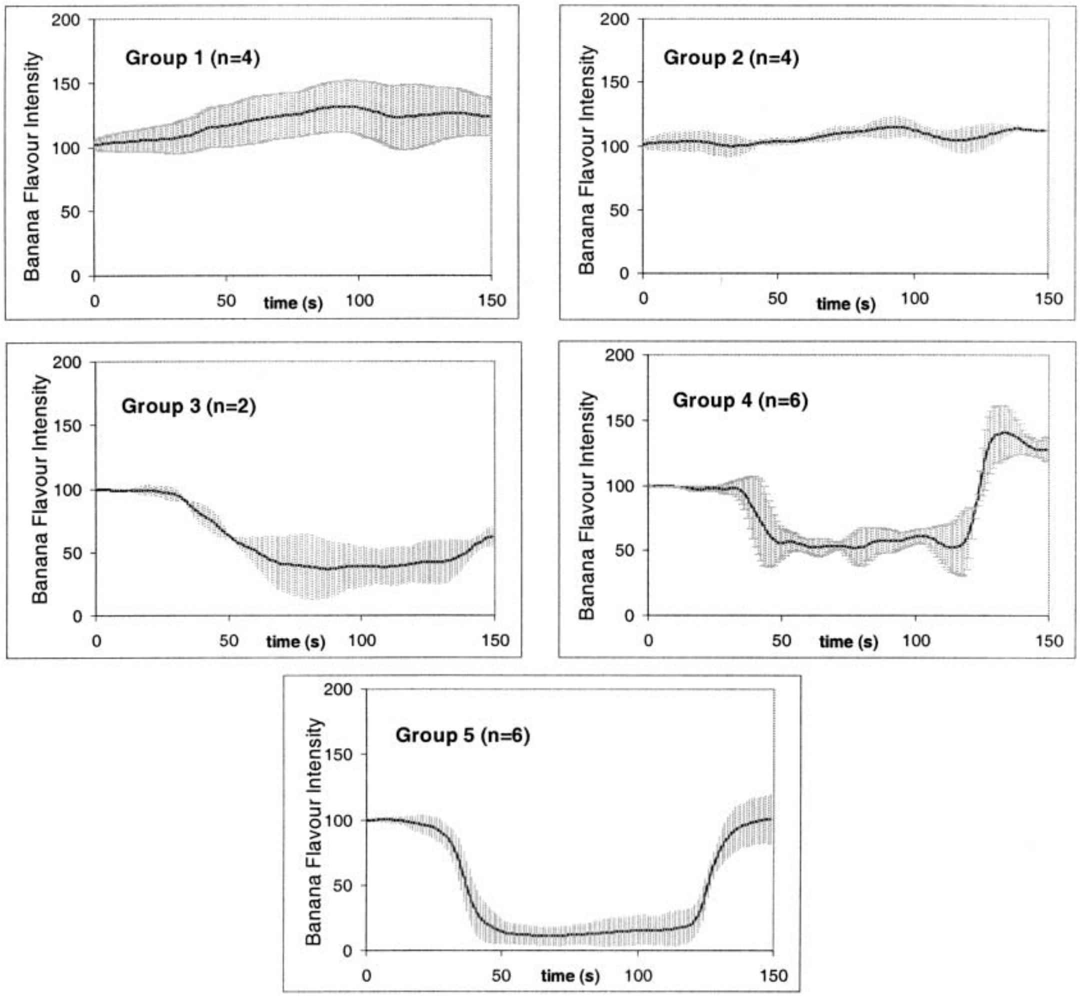

Figure 10. Average time–intensity curves (±1 SD) for observed groups of experienced assessors: experiment 1 (outlier not shown).

in sucrose concentration. A drop in perceived banana flavor was evident among all naive assessors and the majority of experienced assessors when sucrose was removed or decreased. Moreover, it highlights that among this sample population there were different patterns of response and that assessors could be grouped accordingly. Initially it was hypothesised that experienced assessors would demonstrate a more analytic approach to the task by separating the distinct stimuli, whereas the naïve assessors would demonstrate a synthetic approach. In fact, across the majority of assessors, the pattern of sucrose delivery was identified as the key driving force behind perceived fruit flavor intensity. This phenomenon has been observed previously (*8*) but here sample delivery over time using Dynataste provided a means of controlling the sucrose concentration and revealed the synergy of that relationship much more clearly for the majority of assessors.

It is apparent that the extent to which sucrose drives fruit flavor perception is variable. In experiment 1 the removal of sucrose eliminated fruitiness completely for many assessors, whereas for others it only reduced its intensity. As assessors were only asked to measure fruit flavor intensity it is possible that assessors "dumped" sweetness perception with fruit flavor but the fact that perception disappeared completely for some appears to discount this theory, at least for those assessors. It is plausible that the neural processing of the different stimuli is dealt with differently, which in turn could be due to either genetic or learnt responses. Past experiences of this fruit flavor and the associated level of sweetness at that time could also account for the different groups. Whatever the cause, the data support the findings of Kuo et al. (*26*) and Frank and Byram (*27*) who, when investigating taste-aroma interactions, concluded that enhancement was a question of individual interpretation. This research highlights the existence of the different groups within the population; the reasons behind this still require investigation. Interestingly, assessors demonstrating a particular response pattern in one experiment did not always demonstrate the similar response in experiment 2. That is, although many assessors recorded a 100% decrease in perceived fruit flavor intensity in experiment 1, this was not always the case in experiment 2 and vice versa. Consequently, the nature of the change in stimulus, whether that be temporal or in magnitude, could be important.

If training enables assessors to follow distinct stimuli/flavor attributes then flavor perception would be expected to follow volatile delivery. In each experiment there was a group of experienced assessors who perceived a continuous level of flavor intensity distinct from the sweetness. The members of this group were almost identical each time. As no such group was identified among the naïve panel it is possible that, as Bingham et al. (*23*) proposed, training could have led to a more analytic as opposed to synthetic assessment by these assessors. However, all the experienced assessors had extensive experience of measuring sweetness and fruit flavor and the majority demonstrated some form of interaction and did not differentiate between the tastants and aroma signal. Furthermore, no distinction could be made between assessors with 1 or 5 years of experience.

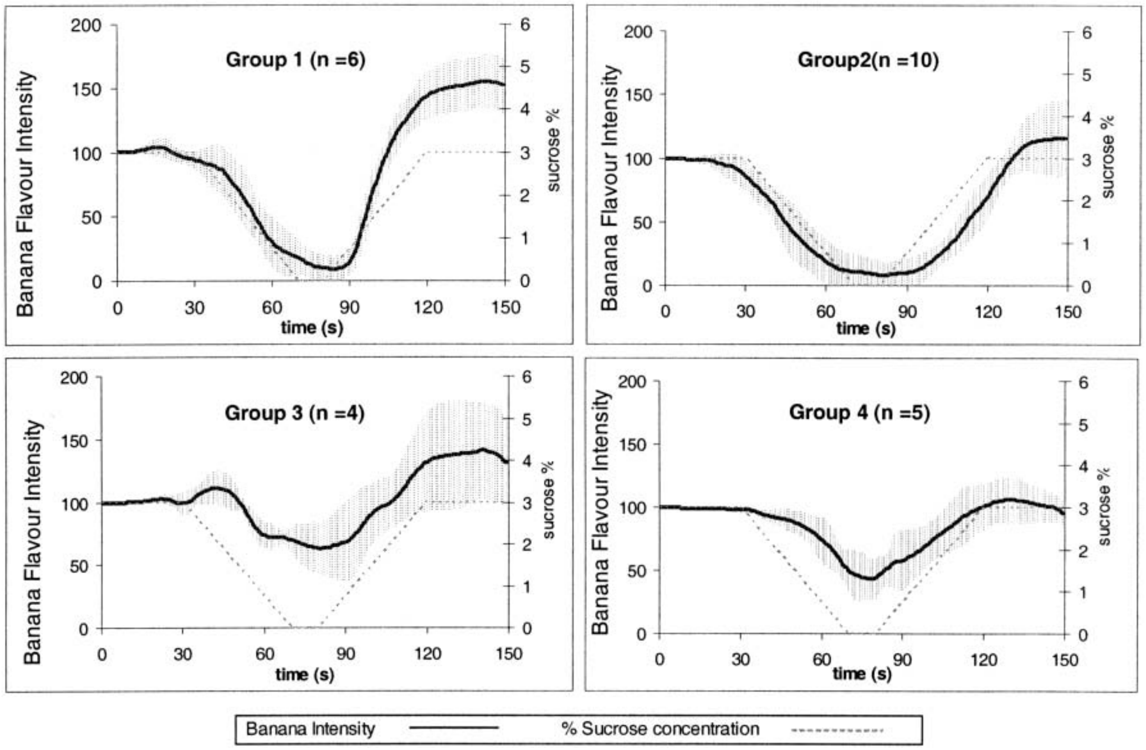

Figure 11. Average time–intensity curves (±1 SD) (and sucrose concentration of sample) for observed groups of naïve assessors: experiment 2 (four outliers not shown).

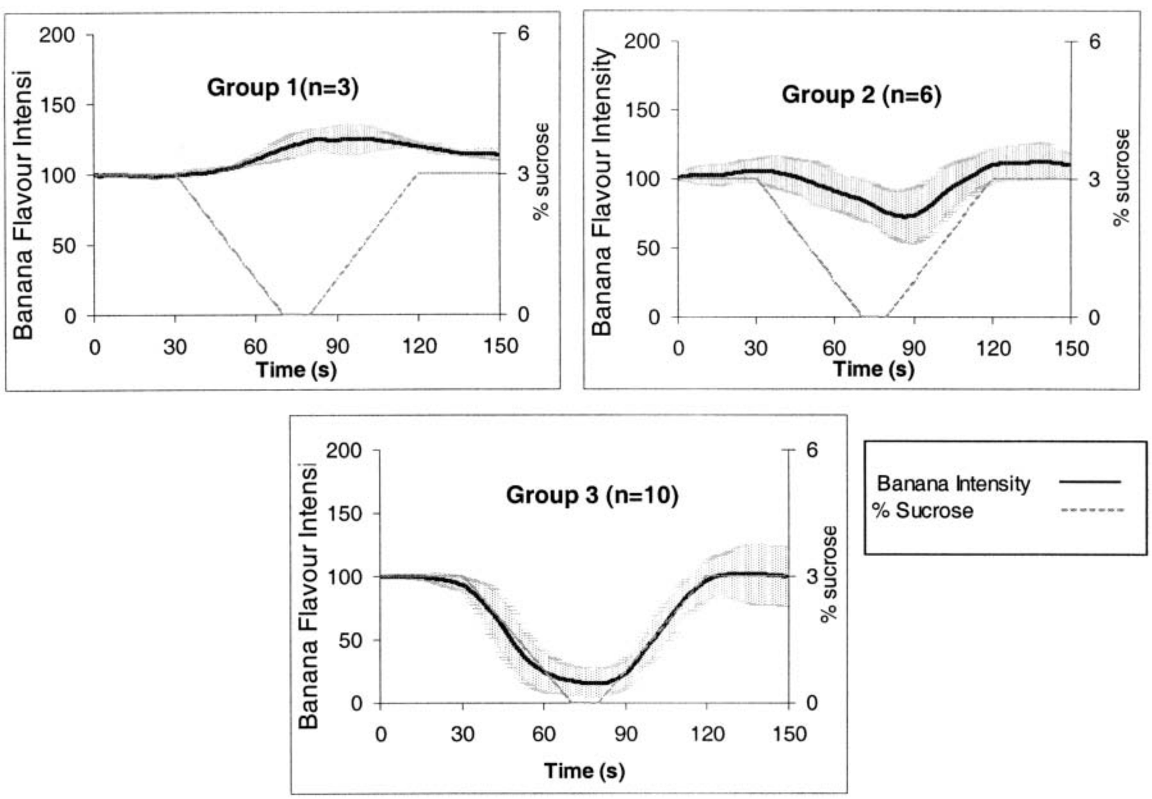

Figure 12. Average time–intensity curves (±1 SD) (and sucrose concentration of sample) for observed groups of experienced assessors: experiment 2 (four outliers not shown).

Clearly, the emergence of different groups within the experienced panel indicates that the use of experienced assessors when investigating and quantifying multimodal flavor perception needs great care and may not always be indicative of consumer perception; using consumers may be a better approach. However, within this type of model system it is evident that even with considerable experience, cross modal effects have not been trained out of the majority of assessors. Indeed it is not possible

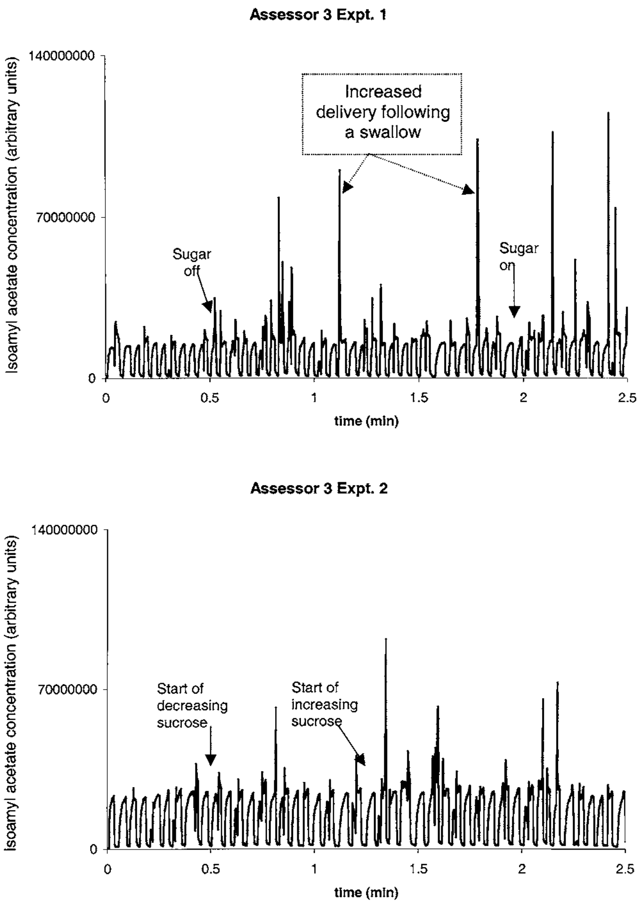

Figure 13. Typical breath-by-breath chromatograms showing in-nose delivery of isoamyl acetate during experiments 1 and 2 (naive assessor 3).

to conclude that the analytic approach observed in some is as much a result of training as in a larger study of naïve assessors, a similar group might be identified. It would appear that when investigating cross-modal perception using experienced assessors, some screening may be necessary.

Dynataste provides a new approach for the control of sample composition and delivery when investigating cross modal interactions. It has considerable potential in tandem with further techniques such as the MS-Nose, electromyography, larngography, and even fMRI to aid in determining the mechanism of cross-modal interactions. Furthermore, the potential to use Dynataste as a technique to investigate other areas such as adaptation, order of tastant, volatile delivery, and character impact compounds is evident.

Evidence for perceptual taste aroma interactions is apparent from the research presented, but of most interest is the emergence of different groups within the population. This has implications on a wide scale; from a commercial perspective it could account for the variety in responses to formulation changes. And, at a more fundamental level, begs the question, why? This investigation has revealed the existence of such groups and has suggested some possible explanations. However, much research is required to determine the cause.

In comparing experienced and naive assessors it is clear that although similar responses were generally observed, some experienced assessors have the potential to separate the stimuli involved in flavor perception, in this system at least, and would be inappropriate members of a panel used to investigate cross modality.

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