Cross-modal Perceptual Learning: A Novel Shape Tasting Method for Sensory Discrimination of Wine

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Abstract

Traditionally, the wine industry relies on written descriptions of wine flavor to convey to consumers what the experience of tasting that wine is like. Patrick Reuter of Dominio IV wines has created a novel "shape tasting" method, in which the acid, tannin, fruit, and length of a wine are represented visually with symbols. The present study sought to provide the first empirical analysis of the efficacy of this system in training intermediate wine drinkers to discriminate between and match wines to tasting notes. A final sample of 38 intermediate wine drinkers participated in 6 sessions over the course of 3 weeks. One group was trained with shape tasting notes (shape group), a second group was trained with linguistic tasting notes (linguistic), and a final group was only given perceptual training with no tasting note information (control). At pre-test and post-test, participant discrimination and matching ability was measured. It was shown that the shape group improved significantly more in score than the linguistic group on an easy discrimination task (at pre-test), and novel triangle test (at post-test). For the difficult discrimination task, a verbal overshadowing effect occurred in which the control group improved in score but the linguistic group declined. Lastly, across all three groups, score on the shape tasting note matching tasks was positively correlated with participant mental imagery ability.

For my grandmother and her only daughter.

Introduction

In our daily lives, we perceive and distinguish a large number of stimuli from various sensory modalities. However, we are generally better at perceiving the world through some senses than others. Vision is the dominant sensory modality in humans. We learn from an early age to describe visual attributes (e.g., color, shape, texture) by using linguistic labels (e.g., red, round, smooth). In vision and in other modalities, we often engage in "perceptual translations," using linguistic terms to convey perceptual or emotional experiences (e.g., white noise, loud dress, feeling blue, etc.). Thus, our perceptual experience in one sensory modality may often be influenced by another modality, especially as it is communicated verbally.

In some sensory modalities, such as the gustatory (taste) and olfactory (smell) systems, our ability to describe sensory attributes using precise linguistic labels is limited. With the gustatory system, we are confined to only 4 basic terms (sweet, salty, sour, bitter); olfactory attributes are even more difficult to verbalize (Ackerman, 1990). Further, through retronasal stimulation, olfactory cues often influence gustatory cues to create "flavor" perception (Shepherd, 2006). Retronasal stimulation is the release of volatile molecules from food in the mouth through the back of the oral cavity and ultimately to the olfactory epithelium. These molecules are judged to be part of the taste of the food and have been shown to be necessary for flavor identification; however, we are often unaware that these molecules are influencing our perception (Murphy, Cain, & Barishuk, 1977; Mozell, Smith, Smith, Sullivan, & Swender, 1969). Thus, our gustatory and olfactory systems interact in such a way that they are conflated, adding another level of difficultly in attempting to describe individual sensations during flavor identification and discrimination.

Differences in our ability to describe sensations with language have been shown to correspond to underlying neuroanatomical differences. For example, in most sensory systems, the primary afferent pathways include early synapses in the thalamus (Sherman & Guillery, 2006). Thalamic nuclei are known to have extensive connections to wide-spread cortical areas including those involved in language processing (e.g., Broca's area, Wernicke's area). The human olfactory pathway, on the other hand, does not contain direct thalamic connections, which may help explain our difficulty in linking olfactory sensations to language (Kay & Sherman, 2007).

When describing an olfactory experience, we often resort to using labels that refer to the odor-eliciting stimulus rather than its sensory attributes (e.g., the smell of a rose, a peach, cedar, gasoline) (Berglund, Berglund, Engen, & Ekman, 1993; Engen, 1987; Lawless & Engen, 1977). Most people can easily refer to the positive experience of smelling a rose, but have no linguistic tools to say exactly what it is like to have that sensory experience (e.g., "qualia," such as the "redness of red"). In order to capture the conscious experience, we often refer to our preferences for olfactory sensations (e.g., pleasurable scents, foul smells) and their intensity (Engen, 1982; Yeshurun & Sobel, 2010). When asked if they can identify common smells, such as bananas, chocolate, lemon, or cinnamon, most people answer "yes". However, the majority of people are in fact able to identify fewer than half of these odor stimuli (Desor & Beachamp, 1974; Cain & Krause, 1979; Cain, 1982). Similar to how people experience a difficult trivia question, the name of the item might feel almost accessible, as if on the tip of the tongue, and perhaps may be available at a later point in time (Lawless & Engen, 1977). Therefore, we often encounter situations where, in spite of a rich and detailed olfactory perceptual experience, we find ourselves unable to describe such an experience in abstract terms (e.g., linguistic description).

Limits of flavor description: wine tasting

One interesting example of this difficulty in describing olfactory and gustatory sensations with linguistic labels is wine tasting. Multiple studies have confirmed that wine experts, who have a high level of domain-specific knowledge, are much more successful than novices in discriminating between, recognizing, or matching wine on the basis of wine description (Lawless, 1984; Solomon, 1990; Valentin, 2007). Without extensive training, most individuals find it very difficult to describe the sensory attributes of wine using linguistic terms (Urdapilleta, Parr, Dacremont, & Green, 2011; Parr, Heatherbell, & White, 2002). Those with beginner or even intermediate-level wine experience are unable to generate precise linguistic labels to match the sensations they perceive while drinking wine, and many individuals find the paragraph-long linguistic descriptions of wine (i.e., tasting notes) to be quite obtuse and often obscure. There is even evidence suggesting that verbal descriptions are not only unhelpful to the lay wine taster, but they can even be detrimental to one's ability to recognize a particular wine tasted moments before (Melcher & Schooler, 1996; Parr, Heatherbell, & White, 2002).

Verbal overshadowing. In an experiment by Melcher and Schooler (1996), wine experts, intermediates, and novices were asked to taste a wine and describe it in as much detail as possible, and then identify it from a set of four distracters. Compared to a control condition in which subjects did not describe the wine using linguistic terms, it was found that experts and novices did well on this task, but intermediates did very poorly. This pattern of results has been termed "verbal overshadowing," because the generation of a verbal description of complex non-verbal stimuli seems to interfere with recognition performance, at least for individuals with certain levels of perceptual expertise. Verbal overshadowing is hypothesized to occur in situations in which domain-specific (i.e., perceptual) expertise is greater than verbal expertise. Novices and experts in this study were not affected by verbal overshadowing because their perceptual and verbal expertise is equivalent (both low or both high, respectively). On the other hand, intermediates drink wine often, and thus their perceptual knowledge is high but their verbal knowledge is low. Unlike experts, they have not been trained to associate linguistic labels with wine stimuli; they have previously relied only on their perceptual ability. This effect may occur for many lay wine drinkers when reading wine reviews in an attempt to discriminate between wines using undeveloped verbal expertise, rather than relying on perceptual expertise alone. With this in mind, it seems unfortunate that written descriptions of wine are the common form of communication between wine expert and the lay drinker.

Traditional wine tasting notes. Wine reviewers are not charged with an easy task; they must use their perceptual expertise to translate their sensory experience of vision, smell, touch, and taste into a comprehensible linguistic description of the wine. The reviewer partially relies on the practice of referencing the temporal aspects of the wine tasting experience. Standard descriptions of the wine involve the sight of the wine, followed by the smell, flavor, and lastly the structure and length (Paradis & Hommerberg, 2016). Structure often refers to the mouth-feel, or tannin content of the wine, and length is a term used to describe the lingering of the wine flavors on the palate, even after the wine has been swallowed.

As previously addressed, the aroma and flavors of the wine are especially difficult to transcribe into linguistic terms. Accordingly, written descriptions of wine often refer to concrete objects, intended as a way to evoke rich mental imagery based on previous sensory experiences (Huang, Lee, & Federmeier, 2010). For example, reviewers often represent wine flavor with descriptions of objects that have the same color as the wine (Brochet & Dubourdieu, 2001). It should be noted that various descriptions of a given wine written by multiple experts are generally consistent with each other (Picard, Tempere, de Revel, & Marchand, 2015). In other words, individual wines have distinct flavor profiles that can be reliably perceived and identified by those with enough training to do so (Brochet & Dubourdieu, 2001; Picard, Tempere, de Revel, & Marchand, 2015; Urdapilleta, Parr, Dacremont, & Green, 2011).

Expert and novice wine tasters

Perhaps the greatest obstacle that expert wine reviewers must overcome when communicating about wine is that olfactory stimuli often cannot be retrieved from memory in the absence of stimuli (Zucco, 2007). However, in an experiment in which experts and novices were asked to describe the attributes of a Sauvignon blanc wine, experts alone were able to conceptualize the wine from memory just as well as when tasting the wine (Urdapilleta, Parr, Dacremont, & Green, 2011). In other words, experts were able to describe the sensory properties just as effectively when doing so from memory as when tasting the wines in the present moment. Castriota-Scanderberg et al. (2005) compared brain activity of wine experts and novices while tasting three wines and a sugar substance. Participants were asked to identify the sugar substance or wines, and make evaluations about how it differed from the other samples. The sommeliers (but not the novices) showed activation in the amygdala-hippocampus area, indicating that they were most likely relying on memories of prior tastings. It seems that with enough experience, different strategies (that rely on different neural connections) can be invoked such that one can recall a flavor experience from memory in a way that may be near impossible for a novice taster.

Experts' prototypes. In another study, Brochet and Dubourdieu (2001) analyzed four corpora of wine reviews from experts, and found that their language was not based on detailed analytical description as might be predicted, but rather on prototypes; abstract mental impressions of a wine based on previous experience. It has also been found that lay wine consumers are less homogeneous than experts in their classifications, suggesting that they lack the same cognitive constructs, or prototypes, relating to wine knowledge (Urdapilleta, Parr, Dacremont, & Green, 2011). Thus, it has been suggested that experts' wine judgments are the results of top-down processes involving prototypes that are shared by all experts, which could explain the lower within-group variability amongst experts compared to the heterogeneous judgments of novices (Lawless, 1984; Gawel, 1997; Solomon, 1997; Urdapilleta, Parr, Dacremont, & Green, 2011). In other words, experts do not perform an analysis of separate sensory properties, but rather a comparison of the immediate cognitive associations that he or she has from the present wine with stored templates of prototypical impressions already developed from tasting previous wines.

The hypothesis of shared prototypal discrimination amongst experts is consistent with past research indicating that experts can recognize flavor blends even when they cannot analyze the content of the flavor; it seems that being able to recognize a wine using a conceptual prototype is sufficient, and perhaps even imperative, for experts to do their job (Livermore & Laing, 1998). From a practical wine tasting perspective, it has been suggested that attempting to perceive specific odors in order to give an analytic description of the wine interferes with the unity of the experience. This could play a significant role in novices' strife to describe and conceptualize wine stimuli, as they must rely on analytical tools because they do not possess prototypal knowledge (Herdenstam, 2004).

Language is analytical. Language is used to deconstruct and label our experiences of sensory stimuli. While verbally describing a wine, one evaluates a holistic experience using individual terms for specific sensations. As previously noted, such an analytical strategy may not allow for the strongest mental representation of olfactory stimuli. In a study by Peron & Allen (1988) groups of novice beer drinkers were either given information concerning beer-related descriptors (verbal), provided with taste experience (taste), or provided with a taste experience that was labeled with descriptive adjectives (verbal/taste). Only the taste experience, but not verbal experience or the combined verbal/taste experience, led to increased ability to detect similarities between beer flavors. In fact, as predicted by the verbal overshadowing effect, the verbal condition showed a decline in performance compared to before the training. It is hypothesized that these results occurred because the taste condition actually helped participants focus their attention on the process of discriminating flavors, rather than trying to apply somewhat arbitrary verbal descriptors.

Considering the difficulty of analyzing flavors, one can appreciate the depth of experience experts must have in order to maintain their holistic conception of a given wine while also deconstructing the experience in order to form linguistic descriptions. First, experts compare a present wine to a prototype, and only then do they use that comparison to apply specific, verbal descriptors to individual sensations. Intermediate wine drinkers cannot copy this process, as they do not have enough experience to have developed mental representations of wines from memory. With this in mind, it is no wonder intermediate wine drinkers are prone to suffer from a verbal overshadowing effect when asked to do the same.

A novel wine tasting note system

It is clear that while experts are very skilled at cross-modal (olfaction/taste to verbal) conceptual understanding of wine prototype, novices and intermediates do not possess the same ability to match linguistic descriptions with wine stimuli. This linguistic tasting note system, developed by and for wine experts, in turn creates barriers for beginners and intermediates interested in learning more about wine. From a business point of view, a large portion of potential wine consumers remains untapped due to the intimidation and disconnect created by this truly "experts-only" linguistic tasting note system.

Recently, an innovative wine maker in the Willamette Valley has developed an alternative method for communicating the sensory attributes of wine that challenges the traditional linguistic tasting note dogma. Patrick Reuter of Dominio IV wines in McMinnville has developed a visual "shape tasting" method in which an intuitive and novel symbolic system is used to visually depict what a wine tastes like (Figure 1).

Reuter developed this system after realizing that verbal descriptions were insufficient in conveying the richness of his tasting experience across time. His system attempts to depict the temporal, gustatory, olfactory, and somatosensory aspects of the wine tasting experience. Sets of visual symbols are plotted spatially on a graph-like plane, with time on the x-axis and intensity on the y-axis. The symbols used in this system represent various wine qualities: round, colored shapes represent fruit; sharp arrow-like shapes represent acidity; and small dot patterns depict tannins. When discussing the somatosensory properties of wine, tannin content gives rise to astringency, an aspect of dry wine that gives a sense of body and structure (e.g., a sense of roughness on the tongue).

Reuter has spent the last 3 years introducing wine consumers to his shape tasting method and anecdotal reports suggest that beginner and intermediate wine tasters often experience "eureka" moments upon *seeing* what a wine tastes like for the first time. After a brief introduction to Reuter's shape-tasting system, some wine tasters seem to finally overcome the disconnect that is often experienced with linguistic tasting notes (Walter, 2012). However, these observations are only informal, and no one has scientifically tested whether the use of visual (shape) tasting notes does in fact increase, or hinder, one's perceptual abilities.

A.

B.

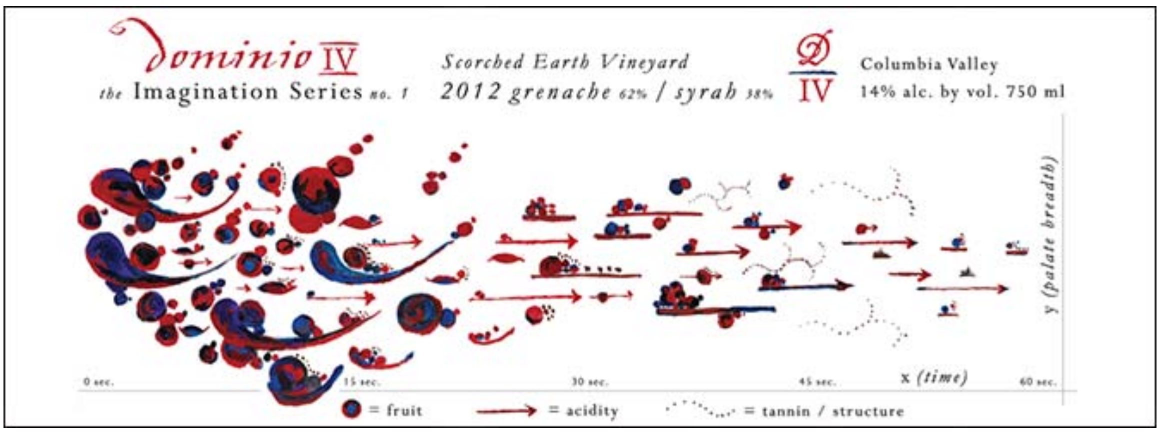


Figure 1. Two example shape tasting notes from the Dominio IV Imagination Series, painted by Patrick Reuter.
Figure 1A depicts a 2013 viogner/syrah, and Figure 1B depicts a 2012 grenache/syrah. On both tasting notes, the x-axis represents time (seconds) and the y-axis represents the intensity of the wine on the palate. Circles represent fruit, arrows represent acid, and small dots represent tannin.

Reuter's intuitions about his shape tasting method are not unprecedented; prior research has shown that under certain conditions, humans are capable of using one modality to process perceptual information conveyed by another modality (Brown, Macpherson, & Ward, 2011; Hanson-Vaux, Crisinel, & Spence, 2013; Howes, 2006). A common example is the use of tactile information by blind individuals, using a cane to guide them in spatial navigation (Hitomi & Mori, 2008). In our own lab, we have found evidence suggesting that sighted individuals can learn to extract shape information provided via sound (Reed Magazine, Brain Wave; Graulty et al., under review). Other labs have reported similar promising results of "sensory substitution" using visual-to-auditory and visual-to-tactile conversion systems (Haigh, Brown, Meijer, & Proulx, 2013; Brown, Macpherson, & Ward, 2011; Lee et al., 2014; Ward & Wright, 2014).

Cross-modal correspondences

The term "cross-modal correspondence" refers to a normally occurring tendency to match certain sensory features or dimensions across sensory modalities (Deroy & Spence, 2013). For example, most people associate high auditory notes with a relatively higher location in visual space compared to low notes with a relatively lower location in visual space. Related to this is synaesthesia, in which a vivid perception in one sensory modality is spontaneously evoked by stimulation in another modality (Martino & Marks, 2001; Howes, 2006; Melara & O'Brian, 1987). For example, many synaesthetes see specific colors when viewing specific letters, or see different colors when hearing different musical notes (Deroy & Spence, 2013). Synaesthesia and cross-modal correspondences are often considered two sides of the same coin, but this notion may be misleading. For cross-modal correspondences, the presentation of one sensory feature does not necessarily give rise to the conscious experience of another, but rather they are frequently and more strongly associated when probed. Cross-modal correspondences exist in the general population, while synaesthesia affects 1 in 23 people (Simner et al., 2006). In this section, evidence for possible explanatory processes for cross-modal correspondences between olfaction, audition, and shapes, will be presented.

Olfaction and audition. Cross-modal correspondences have been found to exist between olfaction and audition (e.g., music stimuli), as well as olfaction and vision (see Deroy, Crisinel, & Spence, 2013, for a review). Perfumers often describe the composition of a fragrance in terms similar to those used to describe music (e.g., balance and harmony between high and low notes) (Deroy, Crisinel, & Spence, 2013; Crisinel & Spence, 2012). Piesse (1857), a renowned perfume expert, went so far as to express that odors appear in octaves, like musical notes; certain odors combine satisfactorily, as do the keys of an instrument. Not surprisingly, professional wine reviewers have also been known to describe wines through comparison to musical notes, musical styles, or pieces of music (see Spence, 2011b, for a review). Wang and Spence (2015) presented participants with a live musical performance and particular wine pairing, chosen for their shared attributes (e.g., high tempo and pace associated with sour taste and citrus flavors). They then assessed whether participants agreed that the pairings were congruent. The congruency of the wine-music pairings was indeed confirmed, and the congruency of the music had a significant effect on the perceived pleasantness, acidity, and fruitiness of the wines. The researchers suggest that this could be considered a cross-modal correspondence between music and flavor perception of wine.

Olfaction and shapes. Cross-modal correspondences have also been found to exist between olfactory stimuli and geometrical shapes (Hanson-Vaux, Crisinel, & Spence, 2013; Seo et al., 2010). Participants in a study by Seo et al. (2010) had to judge whether eight food odors (guava, honey melon, mint, parmesan cheese, pepper, truffle, vanilla, and violet) fit 19 distinct geometrical shapes or symbols; naïve participants reliably matched certain shapes to particular odors. Further, neural responses of the participants were measured when the stimuli were matched with a congruent or incongruent shape. Although behavioral responses showed no differences between these conditions, event-related potentials showed that this cross-modal correspondence between visual shapes and odors influenced the magnitude and latency of the early N1 olfactory component. These results suggest that the presentation of the abstract shape was affecting participants' perception of the odor, rather than their post-perceptual judgment of the olfactory experience.

Emotion. When considering the associations between odorants and music or odorants and shapes, one might find emotional similarities between the two modalities. In other words, cross-modal mappings could occur from "the affect produced by smell [being] similar to the affect produced by some other stimulus" (Kenneth, 1923, p. 77). Many perfumers seem guided by this insight when creating the right combination of odorants for a perfume, and this comparison may not be far off from the goals of a winemaker as well. Perfumer Sophia Grosjmas (interviews by Diane Ackerman, 1990) has said that:

> Creating a fragrance is similar to composing music, because there is also a similarity in finding the ‘proper’ accords. You don’t want anything being overpowering. You want it to be harmonious. One of the most important parts of putting a creation together is harmony. You could have layers of notes coming through the fragrance, but yet you still feel it’s pleasing.

An emotional interpretation of the associations between music and odors might imply a universality of these pairings amongst individuals within a given culture based on commonly shared associations. In Seo et al. (2010), the odors described as being pleasant (e.g., vanilla) were paired with circle or curve-shaped symbols, whereas the odors described as unpleasant (e.g., pepper) were paired with square or angular shaped symbols. Emotional responses for odors (i.e. whether an odor is pleasant or unpleasant) are learned rather than innate, thus, the findings of this study are based on subjective, perceived pleasantness, which may be consistent within a culture but not universal across cultures.

Interestingly, the opposite is true for gustatory perception: taste stimuli elicit the most basic human emotions of pleasure (sweet, salty, fat) and disgust (bitter), which are not learned but are present at birth (Steiner, 1974). The innateness of pleasurable and displeasurable associations with flavor cues indicates that there are structural (e.g., related to anatomy) determinants of these preferences. With this in mind, one might draw connections to Reuter’s shape tasting method, which has been described by Reuter and those whom he has taught the system as intuitive: sharp, angular shapes represent attributes like acid, round shapes represent those of fruit and bouquet, and clusters of dots represent gritty textures of tannins. Based on informal observations, Reuter’s shape system might be intuitive through its relation to emotional affect.

Metaphorical language. Another explanation given for why cross-modal correspondences commonly appear in certain domains is simply that perfumers, wine experts, and artists alike rely on metaphorical language in order to describe complex sensory experiences. That is, cross-modal attributes applied to smells can be thought of as a case of metaphorical transfer between concepts where the abstract experience of olfaction (e.g., smelling a rose) can be understood in terms of another (e.g., pleasure).

This explanation makes sense considering the difficulty of describing odor linguistically, as metaphor could help bridge the gap between perception and conceptual (i.e., linguistic) understanding. As previously discussed, verbal descriptions of wine often evoke metaphor as a way to help connect the reader to the experience of drinking the wine. However, this explanation implies that cross-modal mappings are only linguistic or conceptual, and cannot be explained in terms of perceptual and structural processes (Shen & Eisenman, 2008; Walker, Walker, & Francis, 2012). In other words, that cross-modal correspondences are a product of the convenience of metaphor rather than the product of direct neuroanatomical mappings between sensory modalities.

Sensory mappings. Many argue that cross-modal pairings are due to the organization of the perceptual system (e.g., innate neural connections, common coding) (Spence, 2011a; Deroy, Crisinel, & Spence, 2013). Deroy, Crisinel, and Spence (2013) propose a hypothesis that correspondences are transitive; if feature or dimension A corresponds to feature or dimension B in another sensory modality, and B corresponds to a feature or dimension C in a third sensory modality, then our perceptual system will generate a cross-modal correspondence between A and C. For example, in the case of Reuter's shape tasting notes, acid may have a direct correspondence to the stinging feeling we perceive when we taste high acid foods. This stinging feeling then corresponds to the image of something pointy, thus acid could intuitively correspond to an arrow shape. Thus, participants respond to an indirect relation between stimuli through a direct relation to a common stimulus (see Fields, Verhave, & Fath, 1984, for a review).

Vision and flavor. Findings by Morrot, Brochet, & Dubourdieu (2001) support the hypothesis that visual and flavor systems interact in the primary olfactory cortex. Naïve and experienced wine tasters tasted red and white wines and classified the wines according to different descriptors. However, hidden within the set of red wines was a white wine that had been artificially dyed red. Participants classified this white wine that appeared red using the same terms that commonly refer the other red wines, indicating that visual perception of color had an overriding effect on the perceived flavor. This effect occurred even for the expert wine drinkers, despite their advanced ability to discriminate flavors. One might guess that expert's advanced flavor discrimination would mediate the effect of conflicting visual information on taste perception, but this was not the case. With this finding in mind, it is suggested that the primary olfactory cortex is a "sensory packaging center" of the brain, where multiple systems (gustatory perception, olfaction, vision) interact (Shepherd, 2006). In other words, wine experts are trained to utilize all of their senses when perceiving a wine, so it makes sense that their perception may have been altered by the unexpected mis-coloring of the wine by the researchers. However, it is difficult to tell whether one's perception per se or the report of one's perception was altered by the red food coloring in this study.

Odor images. In the 1950s, it was first suggested that different odor molecules are represented by different patterns of spatial activity in the olfactory bulb (Adrian, 1953); the area to which sensory neurons in the nasal epithelium project. These spatial representations are "odor images" or "odor maps" (see Xu, Greer, & Shepherd, 2000, for a review). Odor images are relayed to the primary olfactory cortex in the orbitofrontal cortex which is a part of the prefrontal lobe. The existence of odor images is supported by the more recent finding that odor stimuli produce spatial patterns of activity in the rat brain that are overlapping but vary for distinct odors (Stewart, Kauer, & Shepherd, 1979). Considering this, the olfactory system is similar to other sensory pathways in that sensory attributes are represented by activity patterns in three-dimensional neural space. These images, unlike the conscious images we perceive through the visual system, however, appear to be are unconscious (Xu, Greer, & Shepherd, 2000). To many, the idea that when we perceive smells we are receiving a spatial image may seem entirely foreign. As previously mentioned, the human olfactory pathway is not in direct communication with the thalamus, which may contribute to the unconscious nature of odor maps, as thalamo-cortical loops have been hypothesized to play a role in conscious perception.

Recognizing complex patterns. An interesting comparison has been made between the identification of odor images and the identification of human faces, as both are examples of pattern recognition due to their complex nature (Shepherd, 2006). Importantly, face recognition has been shown to suffer the same negative effect of verbal overshadowing as wine discrimination. Participants who were asked to describe a face in linguistic terms performed worse on a recognition task (Schooler & Engstler-Schooler, 1990; Dodson, Johnson, & Schooler, 1997; Macrae & Lewis, 2002). Shepherd (2006) takes the stance that while it is true that the naming of odors is difficult, it may be no more difficult than verbally describing the features of a face; that is to say, not impossible. Both tasks require the difficult skill of matching language to complex spatial patterns or holistic arrangements of parts. However, we are very skilled in remembering and recognizing the visual patterns of faces even though we can't describe them quite as well. The same might be true for flavor mixtures, were we able to see them, as Reuter's system aims to accomplish. It is possible that by allowing a wine taster to attach visual labels rather than linguistic terms to the complex patterns of gustatory and olfactory cues, the wine taster might be better able to remember and recognize the pattern, just as we do when we recognize a new face.

Shape tasting notes: an effective system?

Reuter's shape tasting note system uses our primary sensory modality (vision) to represent the gustatory and olfactory sensations of drinking wine. While humans are very skilled at describing visual stimuli, our ability to describe flavor stimuli is limited, which can be at least partially explained by neuroanatomical structure. In order to overcome these barriers, we use labels that refer to the eliciting olfactory stimuli, their intensity, or our preferences for them. Wine experts write reviews and employ metaphor, such as describing the tasting experience in temporal detail, in order to evoke a mental image for the lay taster. Unlike novices, experts have shared prototypical representations of wine stimuli gained from experience and can retrieve these prototypes from memory as if tasting the wine in the present. Using vision, a modality for which we can form vivid mental imagery from memory, shape tasting notes might allow the naïve taster to form a mental image of the flavors of wine.

Interestingly, the idea that wine should be experienced holistically in order to develop prototypical knowledge is undermined by the nature of describing wine linguistically (e.g., analytically). Experts have gained enough experience to consider wine stimuli both holistically and analytically and to verbalize its constituent parts because they have vast conceptual and perceptual knowledge on which to rely. The occurrence of verbal overshadowing for the intermediate taster when asked to describe wine linguistically is a clear example of the shortcomings of applying language in certain circumstances. It is possible that the use of shape tasting notes rather than linguistic tasting notes would allow intermediate wine tasters to form (visual) descriptive representations of wine attributes faster, and more robustly. The use of shape tasting notes may in some ways make obsolete the need to communicate about wines verbally: language is clearly the dominant way to communicate ideas to others, but for the naïve individual's personal understanding of wine, it may be counterproductive.

Cross-modal correspondences—consistent associations between features in one sensory modality to features in a different sensory modality—have been shown to exist between many modalities (e.g., audition and vision, olfaction and audition, olfaction and vision). Possible explanations for these associations include metaphor, emotion, and structural determinants. Reuter's system draws on what he believes to be innate cross-modal correspondences between flavor sensation and shapes. An interesting finding is that incongruent shape and odor pairs may impact actual perception of the odor itself; the implications of this finding should be explored more in relation to how shape tasting notes might affect actual odor perception. Moreover, shape tasting notes represent flavor perception temporally, a dimension not often explicitly conveyed in traditional tasting notes. Visually, time may be represented as a continuous feature, but linguistically it can only be described as a discrete feature (i.e., short, long, medium length). Considering the visual, temporal, and cross-modal features of shape tasting notes, it is possible that this system could allow for better perceptual learning of the attributes of wine.

Research Questions

Perceptual learning is the process through which experts have gained their perceptual wine knowledge. It can be defined as a long-lasting change in perceptual ability produced by related experience. Gibson (1969) proposed a theory of perceptual learning in which exposure to two or more similar stimuli causes a differentiation process that allows the subject to more easily perceive the distinct features of each stimulus. Perceptual learning can occur from explicit instruction and deliberate practice in discriminating between samples, or from passive but extensive experience of various samples (Goldstone, 1998). More recently, a distinctiveness theory has been proposed, in which experience allows for efficient organizational processing that draws on information about similarities and differences of categorical properties on some dimension (Rawson & Van Overschelde, 2008).

The current proposal seeks to provide the first scientific test of whether perceptual training with shape tasting notes improves sensory discrimination of wine (compared to training with linguistic tasting notes and training through mere exposure to the same stimuli). Participants in the present study completed pre-training and post-training sensory tests, with 6 specifically designed training sessions (2 per week for three weeks) between the tests. Standard sensory triangle tests, common in the food and beverage industry, were used to quantify sensory discrimination abilities in the pre-test and post-tests (Davis & Hanson, 1954). The type of training was manipulated in a between-subjects manner. A third of the participants received training with shape tasting notes, a third with linguistic tasting notes, and a third with identical exposure to the wine stimuli but with neither visual nor linguistic training (control condition). In addition to the sensory triangle tests, participants were also tested for their ability to match a given wine with the appropriate visual or linguistic tasting notes via a 4-alternative- forced-choice matching task.

Specifically, the following questions were explored; 1) When given explicit perceptual training to associate either shape or linguistic tasting notes with wine stimuli, does one type of training lead to better discrimination of familiar or novel wines? 2) Do participants trained with shape versus linguistic tasting notes perform better on a 4-alternative-forced-choice matching task of the tasting note to the wine, and can these skills be transferred to matching performance in the opposite modality? 3) Lastly, will average score on shape tasting note matching tasks correlate with mental imagery ability?

Our main hypothesis is that training with either visual or linguistic tasting notes will improve sensory discrimination and matching abilities compared to the control group (assessed via differential accuracy on the post-test vs. pre-tests), but that training with the visual tasting notes will result in larger improvements than training with the linguistic tasting notes.

Methods

Participants

All procedures in this study have been approved by the Institutional Review Board at Reed College. A sample of 48 students at Reed College, ages 21 and above, were recruited to participate in the present study. Participants were intermediate wine drinkers (defined below); expert wine drinkers were excluded from participating. Throughout the course of the experiment, a total of 10 participants voluntarily ended their participation due to illness or scheduling conflicts which prevented them from completing the training protocol. The final sample was 38 students (14 males, 24 females) with a mean age of 21.5 years.

After invitation to participate, participants were randomly assigned to one of three conditions, initially with 16 participants in each group, but the final sample included: Shape training (n = 12), linguistic training (n = 13), or control (n = 13). The experimental conditions (visual and linguistic training) differed on which mode of tasting note the participants used during the training sessions. The visual training group was exclusively trained with shape tasting notes and the linguistic training group was exclusively trained with linguistic tasting notes. Participants in the control condition were given equal exposure to the identical wines as the two experimental groups, but were not trained with any tasting notes. Experimental sessions took place over 6 weeks, with a pre-test, six training sessions (2 per week for 3 weeks), and two post-tests.

Participants were allowed to consume at most 10 oz of wine in the pre and post-tests and 6 oz of wine during each training session (6 oz is approximately equivalent to one glass of wine), however most participants drank less than this. This amount of wine is unlikely to cause intoxication and has even been shown to provide potential health benefits (Angeles Pozo-Bayon et al., 2012; Markoski et al., 2016). Participants provided informed consent prior to the first session and were allowed to end their participation in the study at any point. If a participant missed a session without the ability to make it up at an available session, they were excluded from further participation.

Upon giving consent, participants indicated that they understood the following parameters for participation: participants must consent to bring their legal ID to each session; consent to not operate a vehicle or engage in other behaviors that could be dangerous under the effects of alcohol until 2 hours have passed after each session; consent to eat a meal before participating; consent to stay hydrated the day of and prior to a session; consent to not discuss the study with others; consent to not change their wine consumption during the course of the study; consent to record the amount of wine they drink on a weekly log. Additionally, participants were given reading materials from the Center for Disease Control on moderate drinking and the health effects of drinking alcohol, which were read to them immediately after they gave formal consent. Further, water was provided at every session and participants were encouraged to consume equal amounts of water to wine.

Measures

Level of wine expertise was determined using General Wine Knowledge measure from Melcher & Schooler (1996), which classifies novices as those who drink wine less than once a month, and intermediates as those who drink wine at least once a month (Appendix A). Hughson and Boakes (2009) performed an experiment very similar to that of Melcher and Schooler (1996), however they modified the parameters for measuring expertise. Rather than measure the frequency with which participants drank wine each month, they measured for how long participants had been drinking wine. Previous studies of expert performance have shown that long-term practice is crucial to skill development (Ericsson & Crutcher, 1990). Thus, Hughson and Boakes (2009) classified intermediates as those who had been drinking wine for at least 5 years, and anyone else as novices.

Participants in this study were ages 21 and above and still enrolled in college, thus most had turned 21 quite recently. Because of the recent turn to legal status and small range in age, it was unlikely that there would be variation in length of experience with wine greater than a few years. Thus, the Hughson and Boakes (2009) classification of intermediates as those who had been drinking wine for 5 years or more would be too stringent for the present sample studied. The present study measured level of expertise by asking participants to report both the frequency (number of times per month) with which they drank wine as well as the length of time (months) they had been consuming wine at that frequency. Participants who reported drinking wine at least once a month for one month or longer, were classified as intermediates. On average, participants reported consuming wine 5 times per month (SD= 4.0). 17 participants reported having been drinking wine at this amount for 1-11 months, 8 for 12-24 months, and 13 for more than 24 months.

Other items in the Melcher and Schooler (1996) questionnaire included in the present study were questions related to wine expertise (i.e., have you ever had formal wine training?). Only those who did not have formal wine training were invited to participate. Additionally, this measure includes four questions related to general wine knowledge, (i.e., What color is most German wine; what is the principle grape in Bordeaux wine; what is the aroma in wine; what is the bouquet in wine?). Each question was given a 1-point value for a correct response, totaling 4 possible points. Potential participants who received more than 2 points on this measure were excluded from participating (n = 2), even if they had not previously had any formal wine training.

Mental Imagery recall ability was measured using the Vividness of Visual Imagery Questionnaire (VVIQ), and was administered prior to the first training (Marks, 1973). Participants are instructed to think of a person or object from memory (i.e., think of some relative or friend whom you frequently see, and consider the picture that comes before your mind's eye). Then, a specific list of features is given for the participant to consider individually (i.e., the exact contour of face, head, shoulders and body/ the different colors worn in some similar clothes). The participant must rate the vividness of the mental image on a scale from 1 (perfectly clear and as vivid as normal vision) to 5 (no image at all). For the purpose of analyses, scores on each of the questions were summed and re-weighted such that low scores (high mental imagery ability) were high scores and high scores (low mental imagery ability) became low scores.

Ability to Discriminate between same and different wine samples was measured using a modified Sensory Triangle Test. The triangle test is widely used to test an individual's ability to discriminate between different stimuli (Davis & Hanson, 1954). In the triangle test, participants are presented with three samples of wine, identical in appearance. Two of the samples are the same wine, and one is different. Participants were instructed to taste the first, second, and third sample, and cleanse their palate between each. It is necessary that samples be tasted in this order, and participants are not allowed to taste any sample twice. After all samples were tasted, participants indicated which of the three samples is the odd one out. In the standard triangle tests, participants are asked to verbalize exactly what distinguishes the sample they have selected as the odd one out, however this step was omitted from the present study as the requirement of applying linguistic terms to the attributes of the sample would undermine some of the experimental goals.

Ability to match a sample of wine to the corresponding tasting note was measured using a 4-alternative-force-choice matching task. In the matching task, participants were given a sample of wine to taste and shown four tasting notes on a computer screen. They were then instructed to choose which tasting note best matched with the sample. Participants often perform better when they are presented with a set of options to select the correct answer, thus this format was used in the present study (Tulving, 1983; Schab & Crowder, 1995). This task was completed by all participants with both shape tasting notes and linguistic tasting notes, the order of which was counterbalanced across participants.

Procedure

Online survey was distributed to participants via flyer and online recruitment statements through email and social media. Potential participants who met the inclusion criteria (21 years of age or older and intermediate wine drinkers) were invited by email to participate in the experiment. The email invitation included the consent form for the study so that participants could be informed about the expectations for participating. After expressing interest in attending the first session, participants were randomly assigned to one of the three conditions, and given schedule options for when to attend the first testing session and subsequent sessions each week for 6 weeks. If participants could not attend any of the available sessions for the condition to which they were assigned, they were re-assigned to one of the other sessions and given different scheduling options until they could attend a session. It was made clear to participants that they would be asked to give or deny formal consent at the first session prior to participating in the session.

The Pre-Test was the first session for participants to attend (week 1). After arrival to the laboratory, all participant's legal ID cards with date of birth were checked to ensure that they were 21 years or older. This was repeated at every session. The experimenter distributed and read the consent form to participants to ensure that they understood the expectations for participating. Participants were then asked to give or deny formal consent. Additionally, two resources from the Center for Disease Control (CDC) were distributed and read aloud by the experimenter: a fact sheet on moderate drinking, and an infographic on the health effects associated with consuming alcohol. These forms were available for participants at every session. Participants took a quick questionnaire to ensure that they understood the expectations for participation as well as what would be safe and unsafe behavior prior to and after the sessions. If they did not score 80% accuracy or more, they were given the opportunity to retake the quiz. Participants retook the quiz prior to each session to ensure that they remembered the information. After the comprehension quiz, participants were given a brief demonstration on how to smell and taste a sample of wine. Then, instructions were given and participants completed the triangle test tasks.

All stimuli used in this experiment were red wines. The Pre-Test included two triangle tests with two different sets of wines; Set 1 and Set 2. Set 1 included wine1 (2014 Powers Malbec) and wine2 (2014 Acrobat Pinot Noir). Set 2 included wine3 (2012 Dominio IV "flow" Pinot Noir) and wine4 (2012 Dominio IV Stermer Vineyard "rain on leaves" Pinot Noir). These sets were selected such that wine1 and wine2 were easier to discriminate than wine3 and wine4. Wine3 and wine4 were selected to be the most difficult to tell apart, as they are the same year, varietal, and from the same winemaker.

Wine1 and wine2 were easier to tell apart because they were a different varietal and winemaker. Difficulty of distinguishing between sets was asessed by wine professional Patrick Reuter.

Each triangle test was composed of three 1-ounce samples of wine (two identical, one unique). Participants were instructed to taste the first, second, and third sample, and cleanse their palate with water between each. Samples were tasted only in this order, and participants were not allowed to taste any sample twice. After all samples had been tasted, participants indicated on an answer sheet which of the three samples was not included in the matched pair, thus, was the odd one out. The order that the sets appeared and the order of the samples within each set was counterbalanced across participants in each condition. There were a total of 24 possible permutations of sample orders across Set 1 and Set 2 (Appendix B). Because each group initially consisted of 16 participants, we sampled from the first 16 of these possible permutations, ensuring order matched across the three groups. In each condition, 8 participants were presented with Set 1 first, and the other 8 were presented with Set 2 first.

After participants completed the triangle test Set 1 and Set 2, they completed the 4-alternative-force-choice matching tasks. First, they were shown an example of a linguistic and a shape tasting note, and given a brief description of the shape tasting note system (i.e., "circles represent fruit, arrows represent acid, dots represent tannin, length is represented on the x-axis in seconds from swallow to finish of the flavor").

Then, samples of the four distinct wines in Set 1 and 2 were presented. Participants were instructed to taste the first sample. Simultaneously, they were shown four tasting notes on a computer screen, and instructed to choose which tasting note on the screen was the best match for the given sample. All participants completed the matching task with both types of tasting notes (shape and linguistic) (see tasting note stimuli: Appendix C). Once they had selected the tasting note for the first sample of wine (shape or linguistic), they opened a new screen with four tasting notes in the opposite modality. Participants then tasted the same sample again and were instructed to select the best match. Participants repeated this task with the second, third, and fourth wines. The order in which wines were tested and tasting notes presented was counterbalanced across participants (Appendix D).

In total, each participant was presented with 10 ounces of wine at pre-test, but were only asked to consume enough to complete the tests (which was almost always less than 10 ounces). All visual and linguistic tasting notes for this experiment were created by Patrick Reuter of Dominio IV wines.

Perceptual Training or Exposure sessions began the week following the pre-test, and were composed of 6 sessions; two each week for three weeks (Monday/Wednesday or Tuesday/Thursday). The control group attended the same number of sessions as the experimental groups, but was not provided with tasting note training. However, control group participants received exposure to the wines. They were given the same wines in the same amounts as the visual and linguistic groups, but they were not given any information about the wines in the form of tasting notes. All trainings were approximately half an hour in length. All sessions were led as a group (5-10 participants) with verbal instructions. If participants had a scheduling conflict, they were allowed to attend the other session for that week's training for their condition.

Research on perceptual learning has suggested that alternating exposure of the two distinct stimuli (ABAB) is more effective than blocked exposure (AABB) because there is greater opportunity to compare the two stimuli and detect differences (Mondrago'n & Hall, 2002; Symonds and Hall, 1995). The sessions were formatted to allow for alternating comparison of samples in order to enhance participants' ability to distinguish between samples in the post-tests. In other words, participants were asked to alternate tasting each wine so that each wine was immediately compared to the other two wines.

First Training. The first training session was a passive training, in which participants were presented with wine stimuli (with or without corresponding tasting notes). Stimuli used in this training were wine9 (2012 Lagone Aia Vecchia), wine10 (2013 Vin de Tabula Rasa), and wine11 (2011 Dominio IV Pinot Noir "The Hedgehog") (See full stimuli list: Appendix E). Participants were presented with three 2-ounce samples, each a distinct wine, totaling 6 ounces. This training was intended to passively familiarize participants with the given tasting note system. Wine9, wine10, and wine11 were selected based on their diverse representation of the aspects of wine, intended to train for holistic understanding of the taste note system. The three wines are different years, varietals, and from different wine makers. Before beginning the training, participants spent the first 10 minutes of the session completing the VVIQ individually.

For all three training conditions (shape, linguistic, control), the training began with an explanation of tannin, acid, fruit, length, balance, and body. For the linguistic group and shape group, participants were also given example words or shapes, respectively, that represent these various aspects. All participants initially tasted each wine in unison, given timed instructions to swirl, smell, take the wine into their mouths, and swallow. Participants in the experimental groups were shown the wine number and corresponding tasting note (shape or linguistic) displayed on a screen in the front of the room while they did this. The control group was only shown the wine number. During the first taste in unison, the shape group was also presented with a vertical bar that moved across the screen with each passing second, to help participants visualize the passing of time represented on the x-axis of the shape tasting note.

After tasting all the wines once, participants were instructed to taste the wines on their own, at their own pace. At every training all participants were instructed to focus on the flavors they experienced and the way they change over time. The experimental groups were given paper tasting notes to look at while doing so (Appendix F). The experimenter paused at various points throughout the session to take questions from participants, and answer them with the group.

Second Training. In the second training, participants were presented with three 2 ounce distinct samples of wine15 (2015 Subduction Red Syncline), wine16 (2014 De Forville Barbera d'Alba), and wine17 (2015 Vietti "Tre Vigne" Barbera d'Asti) (6 ounces total). These wines were selected because of their variation in acid: wine15 was selected to be a low acid wine, wine16 a high acid wine, and wine17 a slightly higher acid wine. Thus, participants were exposed to both a large and subtle difference in acid between wines. This training was intended to help participants identify differences in the acid content of wines. All participants were given a review of the information they received on acid in the first training to ensure recollection of the information. Participants in the experimental conditions were shown the wine number, acid information (low, high, higher), and corresponding tasting note (shape or linguistic). The control group was only shown the wine number and acid information. As in the first training, participants first tasted the wines as a group and then passively and individually compared the samples to each other. The experimental conditions were given paper tasting notes (Appendix G).

Third Training. In the third training, participants were presented with three 2-ounce distinct samples of wine18 (2014 Les Capucins Languedoc), wine19 (2013 Jean Pierre Gaussen Vin de Pays Du Mont-Caume), and wine20 (2012 Irouleguy Domain Llarria) (6 ounces total). These wines were selected because of their variation in tannin: wine18 was selected to be a low tannic wine, wine19 a high tannic wine, and wine20 a slightly higher tannic wine. Thus, participants were exposed to both a large and subtle difference in tannin content between wines. All participants were given a review of the information they received on tannin in the first training to remind them of the basic necessary information concerning tannins. Participants in the experimental groups were shown the wine number, tannin information (low, high, higher), and corresponding tasting note. The control group was only shown the wine number and tannin information. Participants first tasted the wines as a group and then passively and individually compared the samples to each other. The experimental groups were given paper tasting notes (Appendix H).

Fourth Training. In the fourth training, participants were presented with three 2 ounce distinct samples of wine12 (2014 Ex Umbria Syrah), wine13 (2014 A to Z Oregon Pinot Noir), and wine14 (2012 Domain Mucyn Les Entrecoeurs Croze-Hermitage) (6 ounces total). These wines were selected because of their variation in dominant fruit: blueberry (wine12), cherry (wine13), blackberry (wine14). All participants were given a review of the information they received on fruit in the first training. Participants in the experimental groups were shown the wine number, fruit information (blueberry, cherry, blackberry), and corresponding tasting note. The control group was only shown the wine number and fruit information. Participants first tasted the wines as a group and then passively and individually compared the samples to each other. The experimental groups were given paper tasting notes (Appendix I).

Fifth Training. The fifth training was a 2-alternative forced choice matching training, in which participants in the experimental groups were presented with a wine, and then asked to identify with which of two tasting notes best corresponded to it. Participants were presented with three 2-ounce samples of distinct wine (wine9, wine10, wine11), totaling 6 ounces. All participants were told that they had been presented with these wines previously, but would not be told which specifically. Participants received feedback after responding to all the questions, and were given time to discuss what was challenging or easy about the task. This session was intended to more closely train participants for success in the post-test, as participants practiced recognition of tasting notes. In place of the matching task, the control group was told to taste each of the three wines one by one, individually, and to focus on the flavors they were experiencing.

Sixth Training. The last training was a note-creating training, in which participants were presented with three 2 ounce samples of distinct wine (wine9, wine10, wine11), totaling 6 ounces. Again, participants were told that they had been presented with these wines before, but would not be told which specifically. Participants in the experimental groups were given three minutes to taste a given wine and create a tasting note (shape or linguistic) (for each of the three wines). They were instructed to not merely guess which wine it was and imitate the tasting from there, but to creatively come up with the tasting note based on their present flavor experience. In other words, they were asked to create the tasting note from the bottom up, not identify one aspect, assign it to a wine, and fill in the rest from memory. Participants were encouraged to be as creative as they wished, include novel elements, and reminded that there was no "correct" answer. After creating the three tasting notes, participants were shown the tasting note for each wine that they had seen before. They were then given the opportunity to discuss what they had created, why, and how it did or didn't match with the original tasting note. In place of creating tasting notes, the control group was told to taste each of the three wines one by one, individually, and to focus on the flavors they were experiencing.

The Post-Test was completed in two parts in order to avoid participants drinking more than 10 ounces of wine in a given session. Post-test session 1 occurred one week after the last training, and post-test session 2 occurred the subsequent week. The two post-tests were identical to the pre-test in procedure. At each post-test session, participants completed the triangle test and matching task for a familiar set of wines (from the pre-test) and a novel set of wines. The first post-test included the familiar easy triangle test and a novel set (Set 3). This novel set included 2010 Dominio IV Tempranillo of the Earth (wine5) and 2013 Dominio IV Vita Springs Pinor Noir (wine6).

The second post-test included the familiar difficult triangle test and a second novel set (Set 4). This novel set included 2014 Upper Eden Pinot Noir (wine7) and 2013 Dominio IV Pinot Noir “love lies bleeding” (wine8). Both sets of novel wines were chosen for their similarity to one another. Set 3 was intended to be an easier triangle test (the wines are different varietals), while Set 4 was intended to be medium difficulty (the wines are from different wine makers but the same varietal).

The post-tests were both identical in procedure to the pre-test. Because the final sample only included 38 participants, the original counterbalancing plan could no longer be applied at post-test. Thus, participants were assigned the same counterbalanced condition at post-test that they were randomly assigned at pre-test (Appendix K). Thus, performance on the post-test would be directly comparable to performance on the pre-test and not confounded by order in which the samples appeared being different at pre- and post-testing. In the counterbalancing permutations, Set 3 replaced Set2 order, and Set 4 replaced Set 1 order (see Appendix J for details).

Following the post-test, participants were given a short form to offer feedback on the study to help inform future experimental endeavors. As they exited the lab, they were handed a form that described the goals and methods of the experiment in detail, and listed the wines used (number, name, vendor, price). Participants were told that if they had any more questions about the study, they could ask the experimenter over email.

Results

Triangle Tests

Preliminary analyses revealed that the three training groups varied in their performance on the triangle test at pre-test, prior to any experimental manipulations. Performance on both the easy triangle task (Control M= 76.9%, Linguistic Training M= 69.2%, Shape Training M= 41.7%) and the difficult triangle test (Control M= 23.1%, Linguistic Training M= 61.5%, Shape Training M=50%) varied across these randomly assigned groups. Thus, all subsequent comparisons were based on the observed changes in performance from pre-test to post-test as a categorical variable (performance improved, stayed the same, or declined), when assessing post versus pre-test differences statistically. Figures in this section present performance as a percentage of participants in each group who completed each task correctly, at pre-test and post-test. Thus, decrease, consistency, or improvement in mean score is clearly observable. Ratios of participants who declined, stayed the same, or improved score (as analyzed by various Chi-square tests of independence) are presented in Appendix L. Additionally, preliminary analyses on the pre-test data also revealed that participant scores on the triangle tests varied by test difficulty (easy or difficult), thus triangle test 1 (easy) and 2 (difficult) scores were analyzed separately.

For the easy triangle test, in which the same exact wine stimuli were used in the pre and post-training tests, the shape group appeared to improve from pre to post-test, while the control and linguistic groups did not (Figure 2; Appendix L, Table 1). This pattern of results was assessed via a Chi-square test of independence, however, did not reach statistical significance, $\chi^2(4, 38) = 3.97$, $p = 0.409$. Further exploratory analyses were performed to determine if the difference between the control and shape group, which visually appeared to show a clear difference, would differ statistically. A Chi-square test of independence for control and shape groups revealed a slight trend, $\chi^2(2, 25) = 3.22$, $p = 0.199$. If the sample size had been larger, it is likely that this pattern of results would have reached significance. The trends indicated an improvement from pre to post-test for the shape group, and little change in the linguistic and control groups.

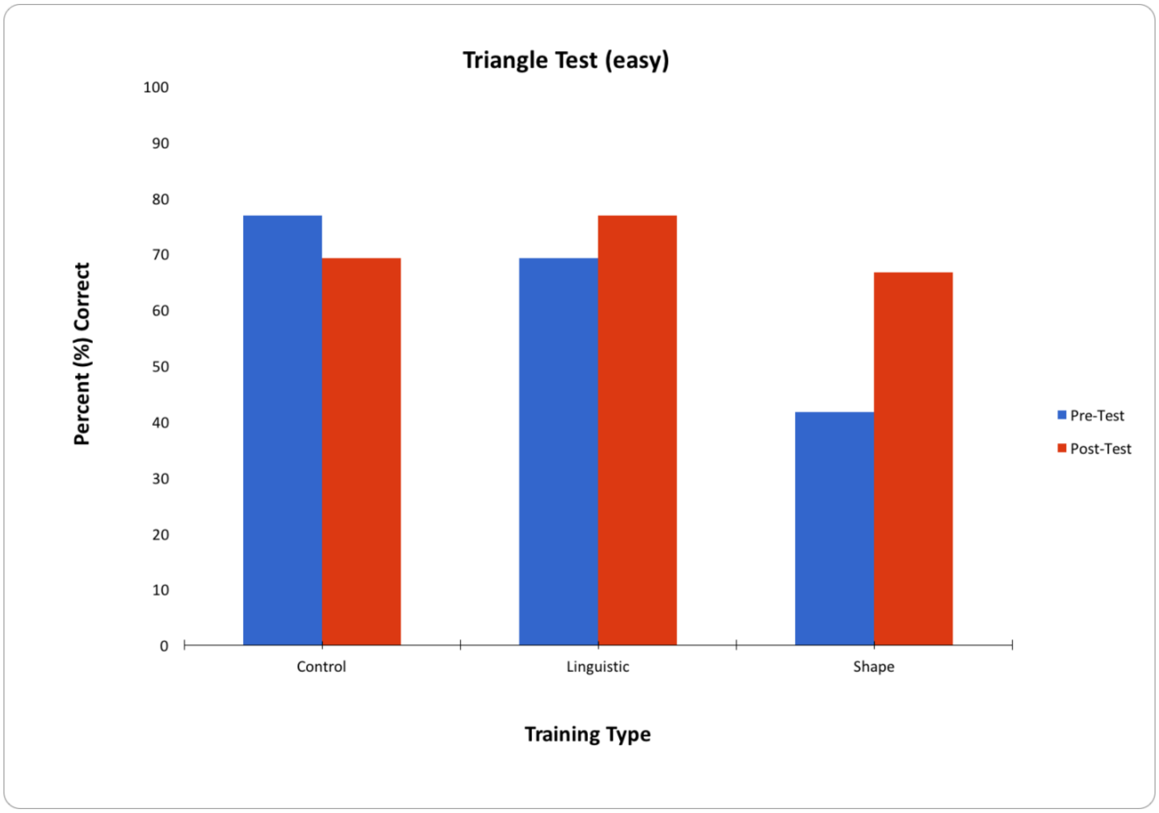


Figure 2. Mean percent correct on pre-test and post-test easy triangle test for the three training groups (control, linguistic, shape).

To further evaluate whether the shape group showed greater improvement on the triangle tests compared to the other two groups, scores from the easy triangle test at pre-test were compared to the scores on the triangle tests for novel wines at post-test (Set 3 and 4) (Figure 3; Appendix L, Table 2). Set 3 and Set4 were designed to fall at an intermediate-level of difficulty (slightly more difficult than Set1, but clearly easier than Set4). A Chi-square test of independence showed significant differences in how performance changed from pre to post-test across the three groups, chi2(4, 38) = 9.51, p = 0.049. A second Chi-square test confirmed that this result was driven by the significant difference between linguistic and shape groups, chi2(2, 25) = 7.37, p = 0.025, while the differences between the control and shape groups (chi2(2, 25) = 2.24, p = 0.325) and between the control and linguistic groups (chi2(2, 26) = 3.85, p = 0.146) were not significant. A greater proportion of participants in the shape group (n = 5) improved from pre to post-test than the linguistic (n = 0) or control group (n = 2). Similarly, the smallest proportion of participants who did worse on the post-training task were in the shape tasting group (n = 6), whereas the linguistic group (n = 9) and control group (n = 10) had similar proportions.

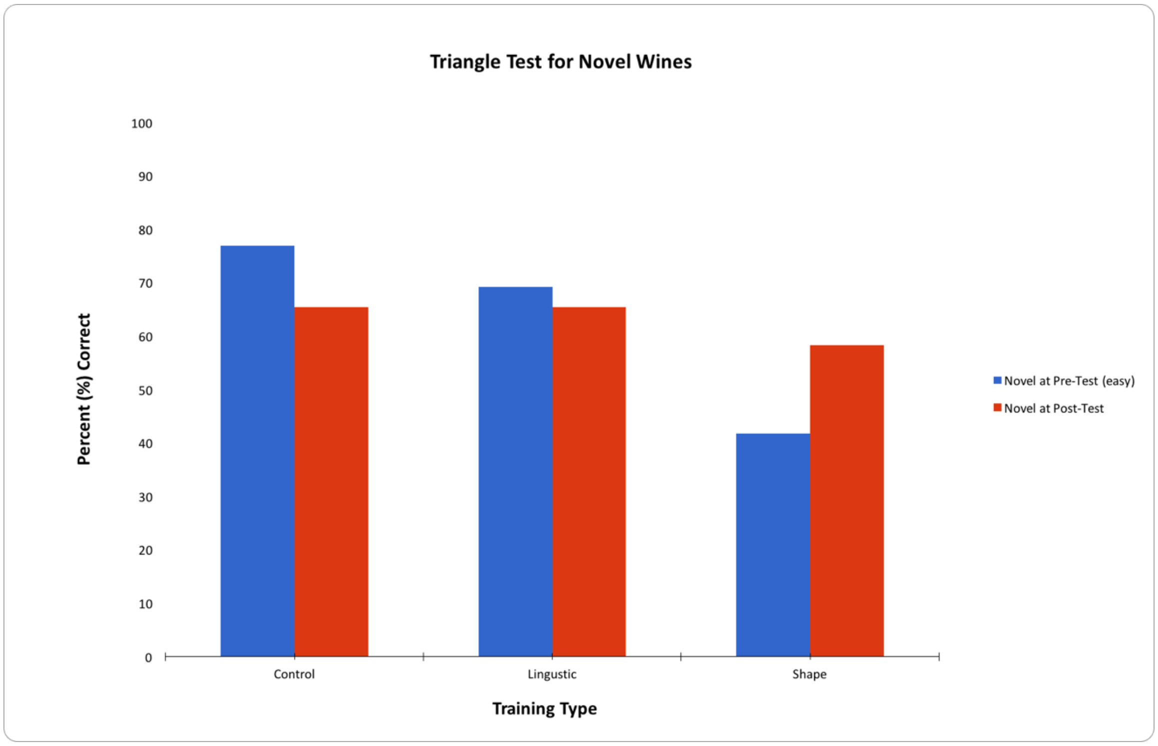


Figure 3. Mean percent correct on pre-test novel triangle test (easy) and post-test novel triangle test (set 3 and set 4) for the three conditions (control, linguistic, shape).

For the difficult triangle test, in which the same exact wine stimuli were tested in the pre and post-test, a Chi-square test of independence was run to determine whether the three training groups performed systematically different from one another (Figure 4; Appendix L, Table 3). This Chi-squared test revealed a trend toward significance, chi2(4, 38) = 8.5385, $p = 0.074$. A second chi-square tested for differences between the linguistic and control groups, revealing a significant difference which was driving the previously observed trend, chi2(2, 26) = 7.833, $p < 0.02$. This difference seems to occur due to a larger number of participants decreasing in score from pre to post-test in the linguistic tasting group (n = 6) than in the control group (n = 0). A third Chi-square tested for differences between the shape and control group, revealing a modest trend, chi2(2, 25) = 4.3193 $p < 0.115$. This can be explained by a smaller difference between proportion of participants in the shape group who performed worse (n = 3) and proportion of participants the control group who did worse (n = 0) than that observed between linguistic and control groups. A final Chi-square test revealed no significant difference between the linguistic and shape group, chi2(2, 25) = 1.9814, p = 0.371.

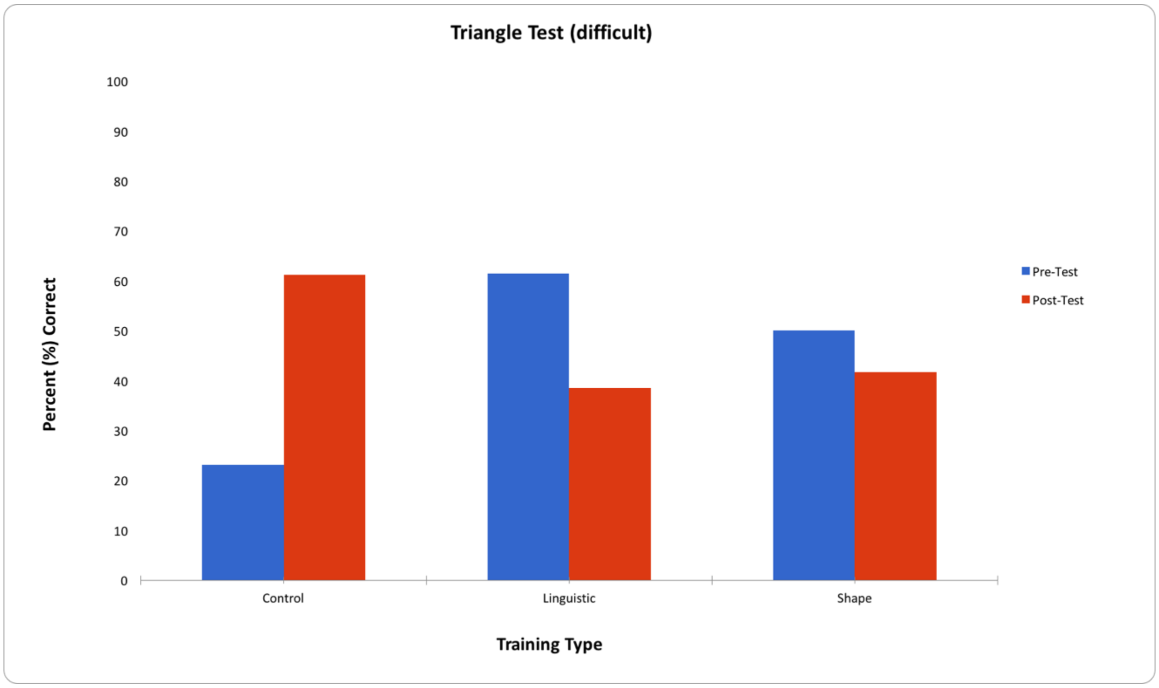


Figure 4. Mean percent correct on pre-test and post-test difficult triangle test for the three training groups (control, linguistic, shape).

Matching Tasks

Preliminary analyses suggested that at pre-test the groups scored around chance on the matching tasks for both the shape and linguistic tasting notes (Figure 5), and none of the groups changed (improved or worsened) significantly at post-test (Figure 6; Figure 7; Appendix L, Table 4 & 5). Chi-square tests of independence were run to ensure that proportions of participants whose score improved, stayed the same, or became worse were not significantly different between groups, for both the linguistic and matching tasks. There were no significant changes in score across the three groups for the shape tasting note matching task (chi2(4, 38) = 3.90, p = 0.42), nor for the linguistic tasting note matching task (chi2(4, 38) = 1.60, p = 0.81).

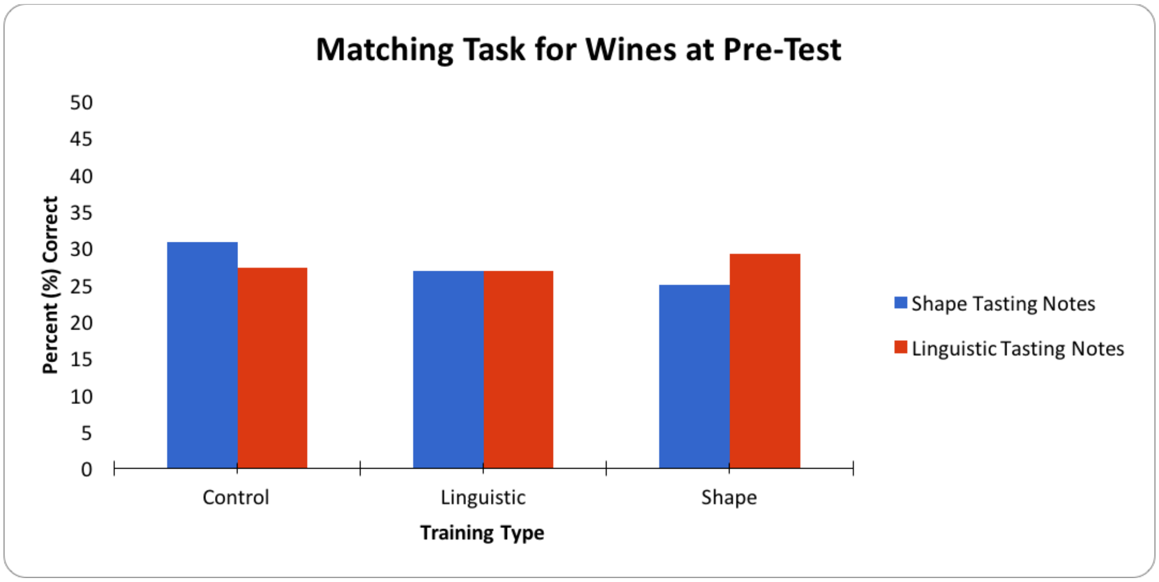


Figure 5. Mean percent correct on pre-test linguistic tasting note and shape tasting note matching task for the three conditions (control, linguistic, shape).
Chance performance on this test is 25%. All groups performed approximately at chance for both linguistic and shape tasting note matching tasks.

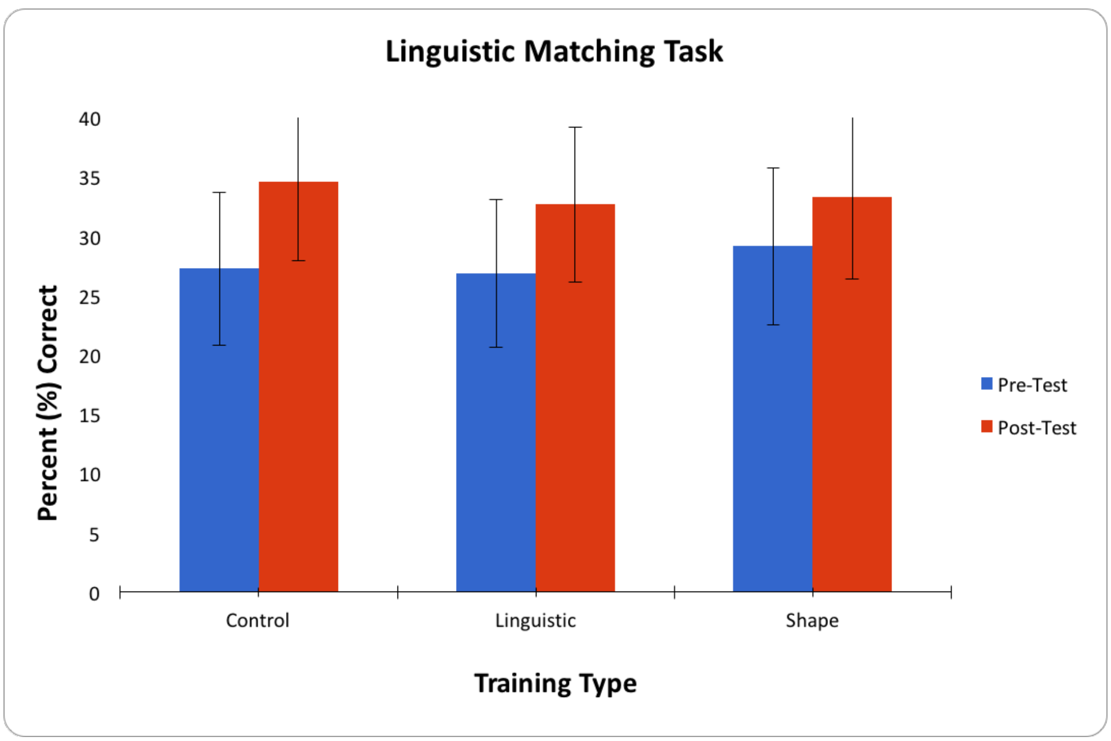


Figure 6. Mean percent correct on pre-test and post-test linguistic tasting note matching task for the three conditions (control, linguistic, shape).

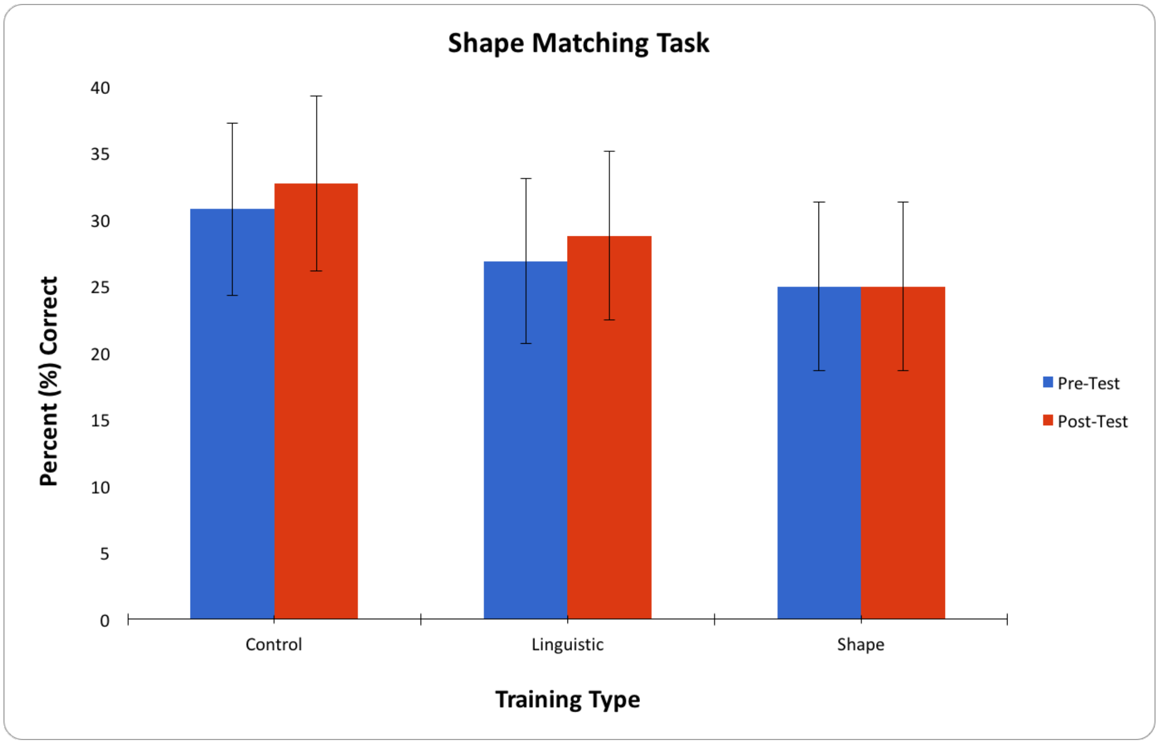


Figure 7. Mean percent correct on pre-test and post-test shape tasting note matching task for the three conditions (control, linguistic, shape).

Vividness of Visual Imagery

A Pearson's correlation revealed a significant positive correlation between vividness of participant visual imagery and total average percent correct on all of the shape tasting note matching tasks presented at pre-test and post-test, across all participants, $r = 0.3834$, $n = 38$, $p = 0.0175$ (Figure 8). High scores on the Vividness of Visual Imagery Questionnaire (VVIQ) were correlated with high overall scores on all of the shape tasting matching tasks, suggesting a relationship.

Figure 8. Scatterplot of average percent correct across all shape matching tasks and vividness of visual imagery questionnaire score.

Discussion

Summary of Findings

In the present study, participants received perceptual training for discriminating and matching wine stimuli with either shape tasting notes, linguistic tasting notes, or no tasting notes. Participant's discrimination, matching, and mental imagery abilities were measured prior to training, and again after training. The primary findings are summarized below.

1. A trend toward improvement in score on the easy discrimination task was observed for the group trained with shape tasting notes, but not for the other two groups (see Figure 2). One interpretation of this finding is that training with the shape tasting system allows one to better categorize basic wine attributes. Thus, it is possible subjects in this training condition improved in their ability to notice the three major attributes of wine (acid, tannin, and fruit), and this helped them when making broad discriminations.

2. A significantly greater improvement in the shape group was observed for discriminations of novel wines (Figure 3). More specifically, participants in the shape group showed larger improvements than the other two groups on discriminating novel wines at post-test (when their scores on the easy discrimination task at pre-test were used as a baseline). This mirrors the pattern of results found for the easy discrimination task that was repeated at pre- and post-test.

3. For difficult discriminations, a linguistic overshadowing effect was observed, in which generation of a detailed, language-based, description of complex non-verbal stimuli lead to poorer recognition performance (Figure 4). Specifically, for the difficult discrimination test that was repeated at pre- and post-test, the linguistically trained group performed worse at post-test compared to the pre-test, whereas the control group performed better at post-test versus pre-test. Verbal overshadowing is hypothesized to occur in situations in which an individual's domain-specific (i.e., perceptual) expertise is greater than his or her verbal expertise. A similar trend was observed for the shape group, but “visual overshadowing” appeared to be less detrimental to performance compared to verbal overshadowing.

4. A significant positive correlation was found between participants’ ability to visualize images from memory and performance on the shape tasting note matching tests (Figure 8). A possible interpretation of this finding is that the shape tasting system is more intuitive for participants who are better at visual imagery to begin with.

These findings and their relation to the three research questions explored in this study, as well as possible limitations, are expanded on in the next section.

Research Questions

Question 1. When given explicit perceptual training to associate either shape or linguistic tasting notes with wine stimuli, does one type of training lead to better discrimination of familiar or novel wines? First, it is important to keep in mind that there were two discrimination tasks varying in difficulty: easy (pinot noir versus Malbec) or difficult (two pinot noirs made by the same winemaker). Although our findings for the easy triangle test failed to reach statistical significance, the shape group showed clear improvement from pre-test to post-test, while the linguistic group and control groups did not improve. Importantly, this pattern of results was confirmed by a comparison of the scores on the easy triangle test at pre-test to the scores on the novel triangle tests are post-test (intermediate in difficulty). Here, the shape group improved significantly more than the linguistic group, whose score declines. These results can be interpreted in terms of the type of information contained in the linguistic versus shape tasting notes, and the type of information the participant is likely to utilize when making more basic discriminations.

The difficulty levels of these discrimination tasks were classified based on the degree of difference between the various wine attributes. The two wines used in the easy discrimination task were from different grapes and wine makers, thus, had larger-scale differences between acid, fruit, and tannin. These differences correspond nicely with those that the shape group was trained to perceive, as the notes focused on depicting information about length, fruit, acid, and tannin. Moreover, the visual format of the information provided more quantifiable comparisons between specific attributes and between wines (e.g. “this wine clearly has more fruit, this wine is balanced, this wine is more acidic than that wine”).

On the other hand, the linguistic tasting notes did not communicate so clearly these larger differences in fruit, acid, and tannin. The linguistic tasting notes certainly expressed some of these differences (i.e., medium tannin, high tannin, etc.) but the visual tasting notes allowed more degrees of freedom in terms of representing how each wine varies across these primary dimensions. Participants in the linguistic group were given useful words that appeared often, for example, “grippy” to mean high tannin; however, the meaning of these words as it relates to the wine may be less clear and quantifiable than the symbolic system used in the shape tasting notes. For example, even if taught the difference between “medium-grained tannin” and “firm tannin,” the distinctions between these two must be conceptualized, and may vary much more across individuals based on memorized reference points. The shape group on the other hand needed to only memorize the sensory conversion rules for the system, which allows for continuous comparison of attributes (i.e., less versus more; no arrows (acid) displayed versus lots of arrows displayed). In other words, the linguistic tasting note system may not have provided clear comparisons between fruit, acid, and tannin in the same way that the shape tasting note system was visually able to do. This interpretation is supported by Rawson & Van Overschelde’s (2008) distinctiveness theory of perceptual learning, in which experience allows for efficient organizational processing that draws on information about similarities and differences of categorical properties on some dimension. Here, the shape tasting notes better provided for this efficient comparison.

Thus, it is possible that participants in the linguistic group were not trained as effectively as the shape tasting group in perceiving large differences between the main attributes of wine. From these results we can propose the hypothesis that if the goal is to improve basic discrimination of large differences in acid, fruit, and tannin, shape tasting notes are a more effective training tool than linguistic tasting notes, or simple perceptual exposure.

On the other hand, the results for the difficult discrimination task looked very different. For the difficult task, the mean score of the control group increased, while the mean score for the linguistic group decreased. The shape group's score decreased slightly, but not as much as the linguistic group. Only the comparison between the control group and the linguistic group revealed a statistically significant difference. This pattern of results can be described as a verbal shadowing effect, occurring after a training in which participants were taught to rely on verbal descriptions of wine to aid them in making discriminations. It is likely that participants utilized the tactics they learned during training when performing the discrimination tasks at post-test, even though they were not explicitly prompted to use visual or verbal descriptors. Rather than relying on their perceptual knowledge to make discriminations, participants in the experimental groups were trained to use visual or linguistic descriptions to help identify differences between wines, leading to a verbal overshadowing effect (and a slight visual overshadowing effect). Importantly, this only occurred for the difficult triangle test. It is possible that the difficulty of the test caused participants in the experimental training groups to "over think" their discriminations, applying incomplete or inaccurate labels (or images) to hard-to-discern differences, which led them to perform worse. Controls, on the other hand, did not attempt to override their perceptual discrimination ability with their underdeveloped linguistic or visual discrimination ability, thus their post-test scores reflect their improved perceptual ability (based on simply being exposed to more wine during the training period).

Comparing these results to those of Melcher and Schooler (1996), our control group would correspond to their intermediate participants who were not asked to describe the wine linguistically, and thus did well on the discrimination task. Our experimental training groups would be analogous to their participants who were asked to describe the wine, thus did worse on the discrimination task because they relied on their underdeveloped conceptual ability (visual or linguistic), rather than their perceptual ability. Perhaps at pre-test, all groups reflect the condition from Melcher and Schooler's (1996) design in which novice and intermediate wine drinkers were asked to discriminate without applying descriptors. A strength of the present design is that participants completed all triangle tests prior to matching tasks, so the matching tasks would not have primed participants to use the descriptors they were presented with to the stimuli they discriminated between in the triangle test.

One possible question of interest is the initial range of expertise across participants at the beginning of the study, and how this may have affected the extent of a verbal overshadowing effect at post-test. At the pre-test, we see large variation in discrimination skills across groups (which were semi-randomly assigned). Importantly, verbal overshadowing has previously been found to occur only for intermediate wine drinkers, and our method to classify our participants as at an intermediate level of expertise was sourced from Melcher and Schooler (1996).

Melcher and School (1996) classify an intermediate as an individual who drinks wine at least once a month. In contrast, Hughson and Boakes (2009) classify an intermediate as an individual who has been drinking wine for at least 5 years. We did not use the stringent classification of the latter (no minimum number of months necessary). The participants in the present study reported consuming wine an average of 5 times per month (SD = 4). 17 participants reported having been drinking wine at this amount for 1-11 months, 8 for 12-24 months, and 13 for more than 24 months. It is highly unlikely that a participant who reported drinking wine for more than 24 months would have been doing so for 5 years, as participants were an average of 21.5 years of age. Thus, none of the participants in this study explicitly meet the criteria for Hughson and Boake's (2009) intermediates, although they do meet the criteria for Melcher and Schooler's (1996). It is possible that there were participants in this study who had only begun drinking wine one-month prior- does that really classify them as an intermediate wine drinker?

One way to consider this ambiguity might be that novice and expert wine drinkers may fall into very discreet categories based on experience and skill level. Intermediates, on the other hand, may differ greatly across measures of perceptual and conceptual ability. Perhaps intermediates may gain skills at different rates depending on their involvement and active or passive learning. For example, an intermediate who has been drinking wine for two years and never reads the back of the label to learn tasting notes may have greatly different expertise than an intermediate who has been drinking wine for the same amount of time but actively pays attention to tasting notes and attempts to perceive them.

The possibility of varying skill levels amongst our intermediate sample is confirmed by varying performance on the triangle test at pre-test. It is difficult to know, but perhaps the training had different effects on participants depending on their individual ratio of perceptual and conceptual (linguistic or visual), knowledge of wine. Importantly, it has been shown that semantic knowledge for describing wine takes longer to develop than perceptual knowledge, which may be rapidly acquired (Zucco, Carassai, Baroni, & Stevenson, 2011). Thus, the linguistic group may have been disadvantaged in this way. Ultimately, the training was not sufficient to raise any participant from intermediate ability to expert ability, but perhaps there are subtler improvements made for novices and intermediates. For example, a novice control participant (incorrectly labeled an intermediate by the methods used in this study) might have improved perceptual skill enough to become an intermediate. The control condition seems the most likely candidate for a condition that raised perceptual skills.

The linguistic and shape tasting conditions aimed to improve both skills sets, but the results from the difficult triangle indicates they were not successful enough to overcome verbal overshadowing. Perhaps an intermediate in the experimental conditions improved perceptual and conceptual abilities equally, but maintained lower conceptual skill than perceptual, thus still suffered from overshadowing. Perhaps, the less severe trend of verbal overshadowing for the shape tasting condition implies that for this group, perceptual ability was raised slightly more than descriptive ability, thus the difference between the two skill sets was smaller, and overshadowing was less likely to occur. One way to conceptualize this effect would be that it is the *linguistic* description that is critical for overshadowing to occur. Another explanation could be that the shape tasting system is simply easier to learn and match to perceptual stimuli. Thus, there is less of a gap between what one perceives and how one is expected to describe that experience, because the two are intuitively linked at a perceptual level. This possibility returns to the fact that gustatory and olfactory cues are difficult to describe, and experts spend a very long time learning to do so; perhaps shape tasting notes are slightly more approachable for distinguishing differences.

Additionally, the observed verbal overshadowing effect prompts again the question of what kind of information was conveyed to each of the three groups, and how that may have affected their performance on this task. The shape tasting group received comparative information on general, primary, attributes of wine, but no detailed information. For example, a wine with a smoky aftertaste would have been described as such to the linguistic tasting note group, but the shape tasting group would not have been informed of this detail. In contrast, the linguistic group's attention was brought to specific, detailed attributes of the wine; sometimes subtle, other times prominent. Interestingly, this did not seem to help them on either of the two discrimination tasks (easy or difficult) as they performed equal to or significantly worse than the control group. Perhaps, the fine detailed descriptive language that they were taught was of a greater hindrance than the broader visual categories provided to the shape group. Again, another possibility is that the shape tasting note group improved in their descriptive ability more than the linguistic group, and thus had a less severe gap between a high perceptual and low descriptive ability, therefore experiencing a slightly less severe overshadowing effect.

Because of the differences between tasting note types, it should be noted that we were perhaps not performing a controlled comparison between learning with either visual or linguistic modalities, but also comparing other differences that could not be controlled for. A major difference is that the shape tasting notes present a labeled temporal axis that measures the length of the wine, which the linguistic tasting notes do not describe. The shape tasting notes allow for a more fine-grained quantification of amount of acid or tannin, while the linguistic tasting notes do not. Linguistic tasting notes describe fruit by the name of the fruit, or the presentation of the fruit (e.g. fruit forward, big fruit, bright fruit), whereas the shape tasting notes convey the size of the fruit and the density (both of which change over time), but not the type or fruit.

Another interesting aspect of the present findings is what appears to be a trend toward an overshadowing effect due to a visual description rather than a verbal one. A verbal overshadowing effect has been found to occur when describing visual stimuli, specifically faces: Participants who are asked to describe a face in linguistic terms perform worse on a face recognition task (Schooler & Engstler-Schooler, 1990; Dodson, Johnson, & Schooler, 1997; Macrae & Lewis, 2002). In contrast, this study explores the possibility of an overshadowing effect for taste stimuli, due to a visual description. It should be noted that we can only guess that participants were imagining, or considering the shape tasting notes while completing this task. However, there are qualitative data that support this proposition. In the post-experiment questionnaires, many participants reported imagining the tasting notes during the triangle task and participants in the linguistic tasting note condition reported trying to describe verbal tasting notes during the triangle test. However, even assuming that participants in the shape tasting group were visualizing the notes during the triangle test, it still cannot be assumed that these visualizations were completely absent from accompanying linguistic labels. Granted, these labels might be limited to acid, tannin, and fruit, but perhaps the trend observed is evidence for a verbal overshadowing effect caused by very simplistic verbal labels, rather than a visual overshadowing effect.

Considering the present finding and possible implications discussed, we can conclude that if the goal is to improve fine discrimination between subtle differences, perceptual training alone is better than training with linguistic or shape tasting notes.

Question 2. Do participants trained with shape versus linguistic tasting notes perform better on a 4-alternative-forced-choice matching task of the tasting note to the wine, and these skills be transferred to matching performance in the opposite modality? We found no significant effects in support of improvement or decrease in performance for all matching tasks (linguistic and visual) across the three groups. In other words, no group significantly improved or declined in score on either matching task modality from pre to post-test, nor did they score well above chance. This lack of significant findings leaves much open to interpretation.

One possibility is that the training itself, for all groups, was simply not effective enough to improve participants' ability to match a wine with a given description, in either modality. There are a number of reasons why this could be the case. One possibility is that the training was not sufficient in length (twice a week for three weeks). It's possible participants in the experimental conditions did not have enough time to fully learn the given tasting note systems enough to be able to perform successfully on a 4-alternative-forced-choice matching task. Additionally, training was limited by the number of times a week participants were available to participate; it would have been unreasonable to ask participants to attend a session more than twice a week, but perhaps the training would have yielded more robust improvements if they had. A second possibility is that the training did not include enough variety in terms of training activities (e.g. matching, discrimination, drawing/verbalizing, direct comparisons between wines, etc).

Based on wine logs that participants were asked to keep during the experiment, it appears as though most participants stopped drinking wine outside of the study. This makes logistical sense; if you are a student who drinks wine about 5 times a month, and now you are drinking wine in a study 8 times a month, it doesn't seem reasonable that you would drink another 5 times a month outside of the study. It seems as though the wine provided for free during the study replaced the wine that participants had previously been drinking (presumably not for free) when they were not participating in the study.

Another possibility is that the methods used in the matching task were unsuccessful; specifically, the way in which the task stimuli were selected and the type of instructions and reminders provided. Firstly, control and linguistic training group did not receive a refresher on what the shape tasting note system symbols meant. Thus, many of the participants in this condition were going into the test blind, maybe remembering one or two symbols. This was confirmed via qualitative participant feedback. The choice to not remind participants of the symbols in the shape tasting method was made in order to mirror the shape tasting condition, in which participants did not receive a reminder of what the linguistic tasting notes meant. The goal was to have post-test performance be solely dependent on information learned during training, but perhaps a quick reminder of the symbols would have been appropriate.

Additionally, the way that the wrong answers for each of the matching tasks were selected was likely problematic. For the shape tasting notes, each wine was modified using a photo editor, such that aspects were rearranged in time, deleted, or details were added. Additionally, the time axis might have been modified to be longer or shorter. A similar process was completed for the linguistic tasting notes, but instead, approximately half of the words were modified. Each wine had three alternate versions. Then, for the four wines that appeared in the pre-test, the three versions of each wine were each randomly paired with one of the other three distinct wines. Thus, every wine had three distracters, each of which was a modified version of one of the other three wines. This exact process was completed with the four novel wines that appeared in the post-test. For every wine, one of the distracters was a modified version of the other wine in its set- the wine that was chosen to be very similar (e.g. one of the distractors in the matching test with wine1 as the correct answer was a modified wine2). Thus, at least two tasting notes in each test looked very similar to one another; the changes we made were not drastic enough. It is believed that this occurred for both linguistic and shape tasting notes, contributing to chance performance at pre-test and post-test. Originally, we were concerned about a ceiling effect occurring at pre-test, thus, aimed to make the matching task difficult enough to see improvement at post-test. As it turns out, the data suggest a floor effect at both pre and post-test, indicating our targets were too similar to our distracters.

Question 3. Will improvement in wine discrimination or matching ability correlate with mental imagery ability? The data revealed a positive correlation between ability to visualize images from memory and overall performance on the shape tasting note matching tests. Those with better mental imagery may have better remembered, or found more intuitive, the rules for the symbolic system, thus, better applied the system to the matching task after (pre-test and post-test). In other words, this finding could be reflecting the robustness of participants' memory of the system, which would have allowed them to perform better because they had a clearer understanding of the meaning of the symbols.

General Limitations

Matching task stimuli. As previously described, the way in which the matching stimuli were selected likely led to a floor effect at both pre-test and post-test. This is an important limitation to note as sufficient matching ability is important for the wine consumer. Wine drinkers are often called upon to describe a wine using tasting notes, and thus matching skill is perhaps a more relevant skill than discrimination- at least to the lay taster.

Stimuli diversity. Due to financial and logistical constraints of the present study, wines used were limited to reds (i.e., no white or rose). Additionally, with 8 testing wines and 12 training wines, the overall diversity of the type of red wine presented was limited. Lastly, difficulty of discrimination tasks was limited to two easy, one intermediate, and one difficult task. A major constraint was the cost of wine, which greatly limited the variety and amount of wine we were able to provide. Similarly, participants could only drink a small amount of wine at each training session, so amount of wine presented was limited in this way as well.

Materials. All tastings during the tests at pre-test and post-test were blind, in that they were served in dark cups so participants would not be able to see the color of the wines and use that information to make their discriminations. However, some color differences may have been detectable if participants were aware of this possibility, and attempted to see them. Additionally, the cups were plastic, which can sometimes have a particular odor. Future studies should utilize black, glass, cups to avoid these present limitations.

Training. It is possible that the trainings may have limited learning in a variety of way. Firstly, as previously mentioned the diversity of wine type may have limited exposure. Moreover, frequency of exposure and repeated exposure to each wine might improve this training in the future. Training could have included more active forms of learning, such as drawing and writing tasting notes, rather than passively viewing notes while tasting.

Design constraints. Because of the nature of the 6-week long experiment and schedule coordination with a sample of participants who are busy college undergraduates, it was not possible to perform true random assignment to training condition. Participants were randomly assigned to conditions and given schedule options, but if none of the times worked with their schedule, they were assigned to a new condition and given new options until a time was found that worked. This method may have biased participants to select times in which they knew other participants would be participating. Groups varied in size from 5 to 10 participants, and also in “chattiness”, thus perhaps they also varied in engagement with, or distraction from the material. It is possible these differences were caused by intentional planning by some participants to be in the same sessions as their friends, unbeknownst to the experimenter. Moreover, it is possible there are other difficult-to-predict variables that may have affected available scheduling time, and thus, condition.

Related to possible differences between experimental groups is the way in which the training schedule was formatted. Because of the necessity to meet twice a week, one day apart, and at the same time, it was not possible to completely counterbalance the schedule such that every condition had a group that met at each possible time. To help account for training differences that might occur depending on the time of the day, the schedule was arranged such that every condition's two scheduling groups met at an average of 8-9pm. However, perfect counterbalancing was not possible. Additionally, participants were allowed to reschedule (within their condition) if they could not make a given session. While they would have experienced the exact same training in either session, it is possible that the different group of people or time between sessions might have affected their learning. However, participants in all groups utilized this option, so any effect would have appeared as noise in the data rather than as a systematic difference between groups.

Sample. Of course, one of the greatest limitations of the present study is the small sample size. The experiment began with 48 participants (16 in each condition), but ended with 38. Thus, it is difficult to draw meaningful interpretation from trends we observed, which otherwise might have been significant were we to have had a larger sample. Further, the small sample size contributed to differences across groups in discrimination and matching ability at pre-test. We attempted to overcome this limitation by comparing improvement from pre-test to post-test rather than raw score.

The limitations that have been described thus far would be important to consider in the pursuit of future research similar to the present study. A replication of the present study should address the key methodological issues we have identified, and explore how these changes affect interpretation and expansion of the present findings. In the following section, future questions and avenues for research are explored.

Future directions

Expertise. As previously discussed, future studies could attempt to parse out the different effects visual versus linguistic training would have on novices, intermediates, and experts. One interesting question might be, what is the sufficient amount of training experts would need to transfer their domain specific linguistic skill to the visual domain? Related, there seems to be a natural draw for novice and intermediate wine drinkers to try to describe wine linguistically- it is our most used form of description- even for participants in the shape tasting group. This is of course how we structured the training, as we were not training the shape group participants to recognize the symbols without first assigning verbal labels to those symbols. Perhaps there are varying degrees of combination of linguistic and visual descriptions that would be the most beneficial for learning. Future studies could explore how combining these systems would be useful or not for novice, intermediate, and expert wine drinkers.

Verbal description of shapes. Considering the verbal "key" for the symbols in the shape tasting notes, one might ask; can the system be entirely removed from verbal description and still (with enough training) be used as a tool for discrimination and matching? Previous sensory substitution studies yield promising results to this end, however the majority of these studies have used our primary senses (i.e. vision and audition). One way to approach this question would be to first train participants to make cross-modal associations between acid and arrows alone, fruit and circles alone, and tannin and dots alone. As participants master recognizing the different levels of these attributes, then they could be combined. It would be interesting to know if this analytical to holistic training approach would be more or less beneficial than an entirely holistic approach in improving discrimination ability (e.g. avoiding verbal overshadowing).

Individual differences. There are many ways in which the results of this study could be influenced by individual differences. As previously mentioned, individuals may differ in their expertise. Results from this study show a positive correlation between vividness of mental imagery and over all score on the matching tasks. Future research could expand on this finding, asking what exactly is it about mental imagery ability that led to improved matching performance. Additionally, learning styles could be analyzed; Specifically, individual cross-sensory perceptual ability. Perhaps some individuals are more prone to forming cross-modal correspondence than others, and would find the shape tasting note system more helpful (Deroy & Spence, 2013). Qualitative report from participants indicated a wide range in preference for and curiosity about the given systems.

Wine prototypes. It has been found that experts use prototypal knowledge to recall wines from memory, compare them to a wine at present, and then identify the attributes of the present wine. In other words, they develop holistic representations of past wines, which they can remember as well as if they were drinking it in real time. As shown by verbal overshadowing, attempting to perceive specific flavors in order to give an analytic description of a wine interfered with the unity of the perceptual experience. Experts can maintain this unity, or expert prototype representation, and simultaneously analyze single components. Importantly, the prototype is what allows for the analysis. Perhaps one of the causes of verbal overshadowing is simply the act of breaking a holistic representation into details; linguistic description is simply the means by which this is done. In other words, perceptual ability on its own allows for holistic representation of a wine, without attempts to break it into further identifiable parts; it is broken when it is described.

Further, maybe a comparison could be made between the sort of prototypal knowledge that experts develop, and the holistic representation provided by the shape tasting notes. Perhaps the training the shape group was given allowed for improved prototypal knowledge of wines- at least more so than the linguistic group. Clearly, the control group didn’t experience a verbal overshadowing effect at all, but maybe absence of any verbal information would have allowed even greater perceptual advantage. The hypothesis that shape tasting notes allow for prototype generation is supported by the finding that only the shape group improved in ability to discriminate between novel wines. When faced with a novel stimulus, they could have called upon their previously formed prototypes of familiar wines, and used that to make the novel discrimination. Future studies could explore these questions.

An aspect of the training that attempted to help participants form personal wine prototypes was the self-generated tasting note training. In this training, linguistic and shape groups were asked to create their own tasting notes for three different wines. From participant feedback, it seems the shape tasting note group liked this much more than the linguistic tasting group. A possible interpretation of this is that the shape tasting group was successfully generating their own prototypes. Further, they felt comfortable using the symbolic system, which may have been due to the fact that it is simple and approachable. On the other hand, the linguistic group may have felt overwhelmed with an almost unending list of descriptive words they could have used (e.g. is this wine grippy or structured? Big fruit or bright fruit?). Informal observation by the experimenter revealed that the shape group expressed feeling much more confident about coming up with their own tasting notes than did the linguistic group. One reason the shape tasting notes could be effective at helping people create individualized prototypes is that they can be remembered visually. It doesn't matter that they are right or wrong; they provide an easily accessible representation of a wine from memory, which can be used by the lay consumer to later compare to other wines. Future studies might make creation of individualized shape or linguistic tasting notes a larger feature of a training.

Task modification. Future studies might attempt to modify the matching and discrimination tasks to observe different levels of verbal overshadowing. In the present study, we can only make an educated guess that most of the participants were trying to describe the wines in the triangle test while completing the task. This step could be manipulated by the experimenter. For example, would the effect have been stronger if participants had been asked to draw or describe the wine? Or, what if they had been asked to recall another wine from memory and compare the two, rather than describe it in isolation. What if in between tasting the wines, participants had been given an unrelated task, like filling out a crossword puzzle- would they have still experienced a verbal overshadowing effect, or would this attention demanding task prevented them from forming verbal descriptions of the wine?

ERP study. In a study by Seo et al. (2010), naïve participants judged whether eight odors matched certain shapes and symbols. These matches were made reliably across participants. Further, neural responses were measured when the stimuli were matched with a congruent or incongruent shape. Event-related potentials showed that this cross-modal correspondence between visual shapes and odors influenced the magnitude and latency of the early N1 olfactory component. A future study could use a similar method, but observe responses to incongruent and congruent shape tasting notes. It would be interesting to know if the same results would occur, and if the extent of trained association between wine and corresponding tasting notes would moderate the effect. While time-locking ERP recordings to sips of wine might be practically challenging, the reverse approach could be used in which subjects hold a given wine in the mouths while congruent or incongruent shape or linguistic tasting notes are presented and ERPs are time-locked to the onset of the visual stimuli.

Conclusion

The present study sought to provide the first empirical analysis of the efficacy of Patrick Reuter's shape tasting note system in training intermediate wine drinkers to discriminate between and match wines to tasting notes. It was found that the shape group improved more than the linguistic group on easy and intermediate-level discrimination tasks. This finding can be interpreted to mean that shape tasting notes were an effective tool in training for discrimination of larger wine differences related to acid, fruit, tannin. For the difficult discrimination task, a verbal overshadowing effect occurred in which the control group improved in score but the linguistic group's performance declined. Here, the training that the linguistic group received most likely biased participants to utilize verbal descriptors, which interfered with their perceptual abilities. Lastly, across all three groups, performance on the shape tasting note matching tasks was positively correlated with participant's visual imagery ability.

These findings provide many avenues for future research. There exist a wide range of open questions concerning the specific types of training that might work best, the specific tests that might be used to measure perceptual abilities, and the interaction between training types and participants' levels of expertise. An important next step would be a replication of the present study with modifications of sample size, length and depth of training, and matching task stimuli. Taken together, the present findings provide a preliminary analysis of the effects of shape tasting note training (compared to linguistic and control) on discrimination of different wines, which could serve as the basis for future studies.

Appendix A: Participant Measure of Wine Expertise

General wine knowledge

(1) What color is most German wine? [White; 1 point]
(2) What is the principal grape in red Bordeaux wine? [Cabernet Sauvignon (then Merlot); 1 point]
(3) What is the difference between aroma and bouquet in wine? [Aroma: Odors from the grape; fruit odors; 1 point] [Bouquet: Odors from the wine: Reduction, flavors that develop during fermentation and aging; 1 point]

Other Questions:
Please write your date of birth.
How often do you drink wine each month? (Example answer: 6 times).
Are you a wine professional?
How many wine seminars or formal wine training events have you attended? (Example answer: 0).

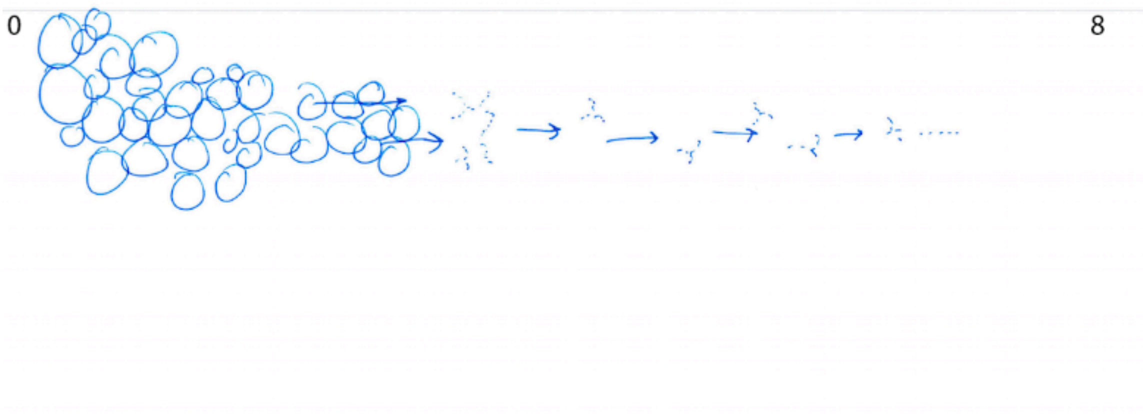
Appendix B: Pre-Test Triangle Test Counterbalancing

Permutation #	First Set Presented	Set1: Order of Wines	Set 2: Order of Wines
1	1	112	334
2	2	112	343
3	1	112	443
4	2	112	434
5	2	121	334
6	1	121	343
7	2	121	443
8	1	121	434
9	1	221	334
10	2	221	343
11	1	221	443
12	2	221	434
13	2	212	334
14	1	212	343
15	2	212	443
16	1	212	434

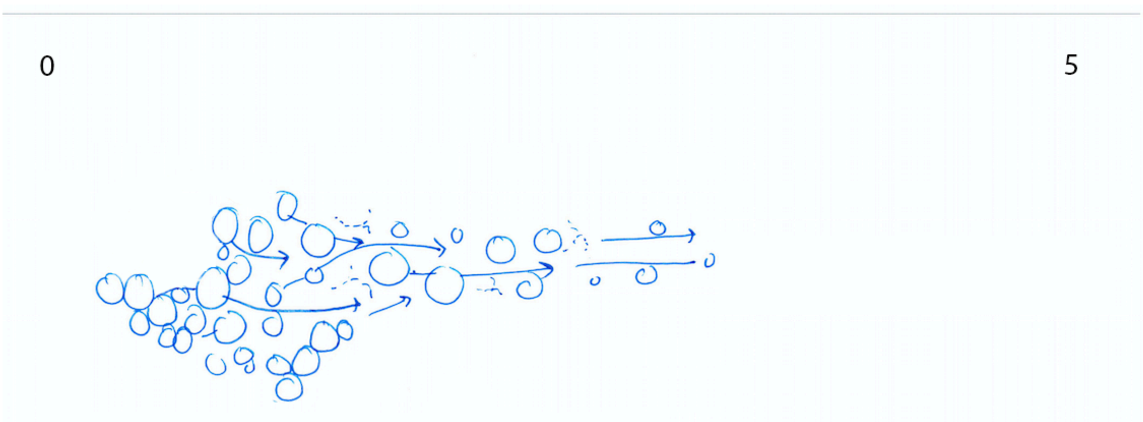
Appendix C: Pre-Test Matching Task Stimuli

Shape Tasting Notes

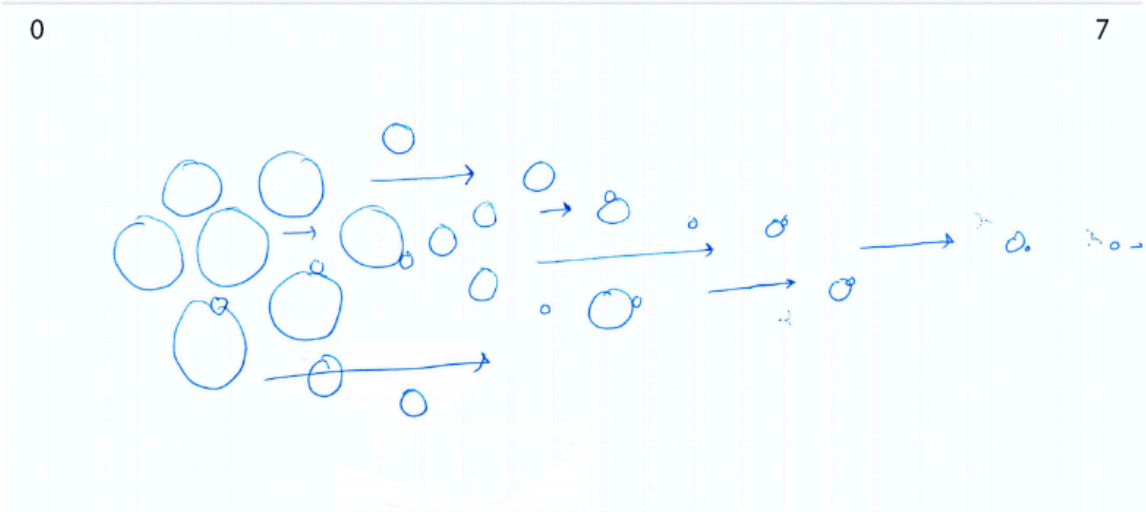
Wine 1



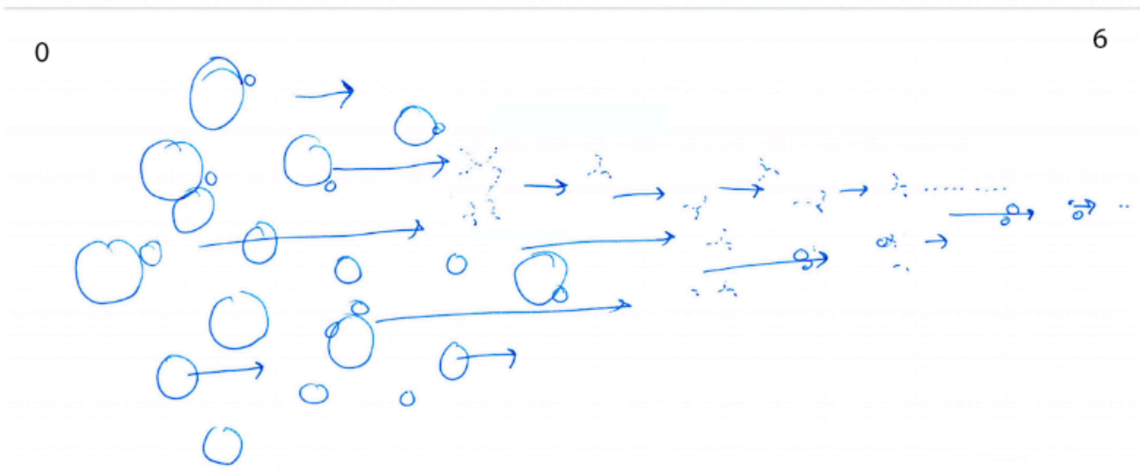
Distracter 1



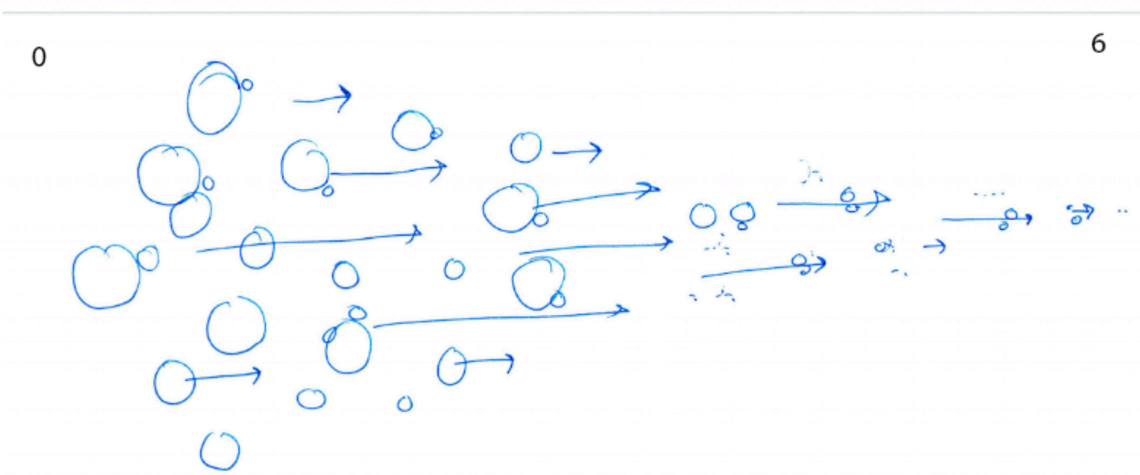
Distracter 2



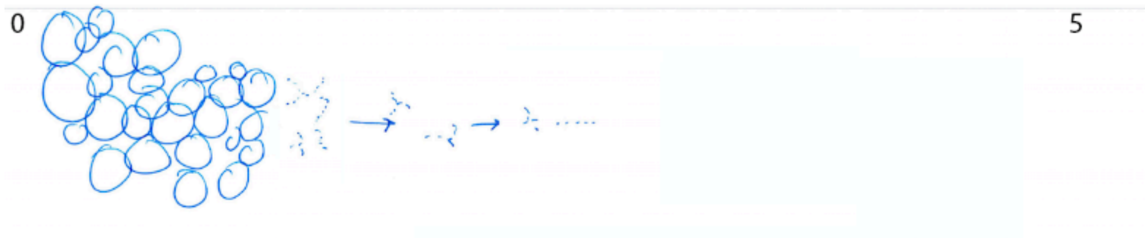
Distracter 4



Wine 2



Distracter 1



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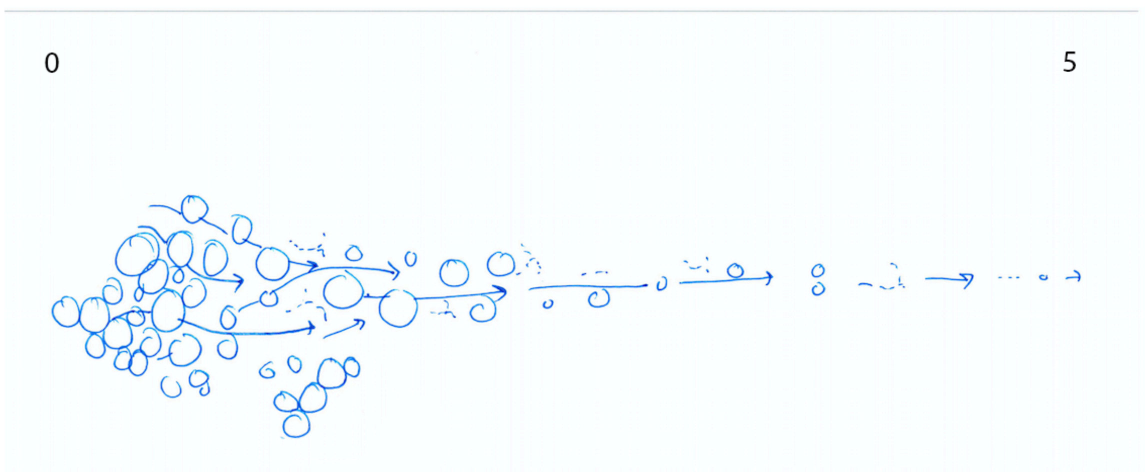

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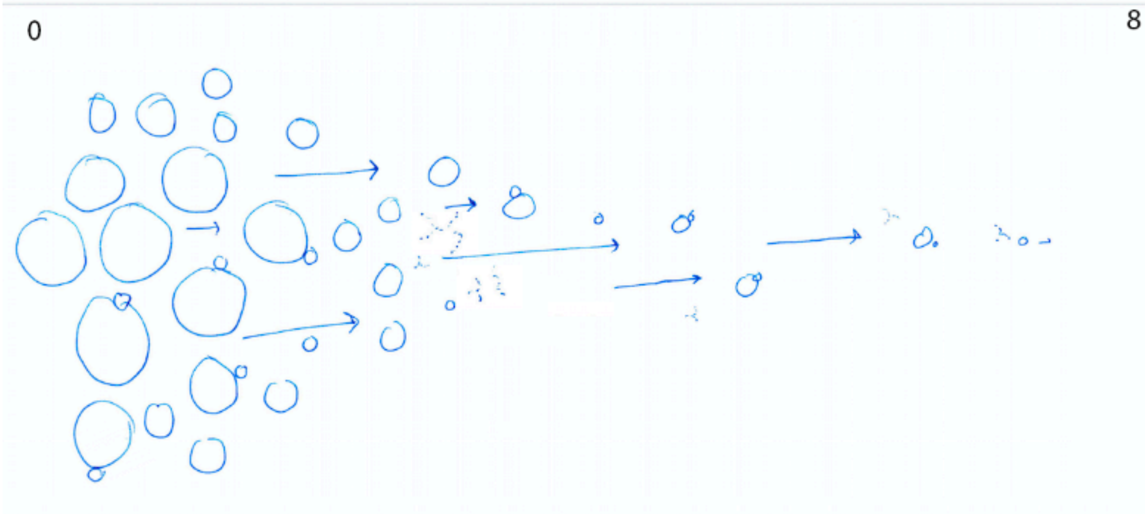
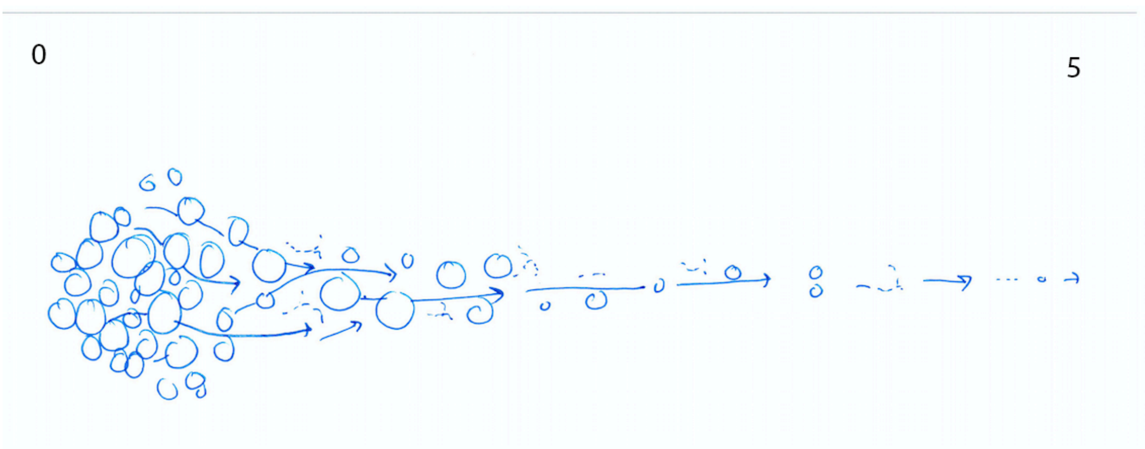


Wine 3



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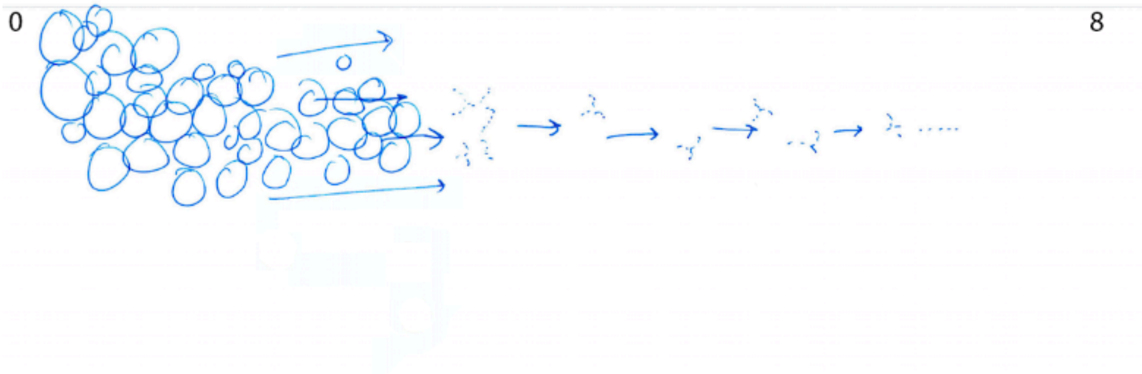

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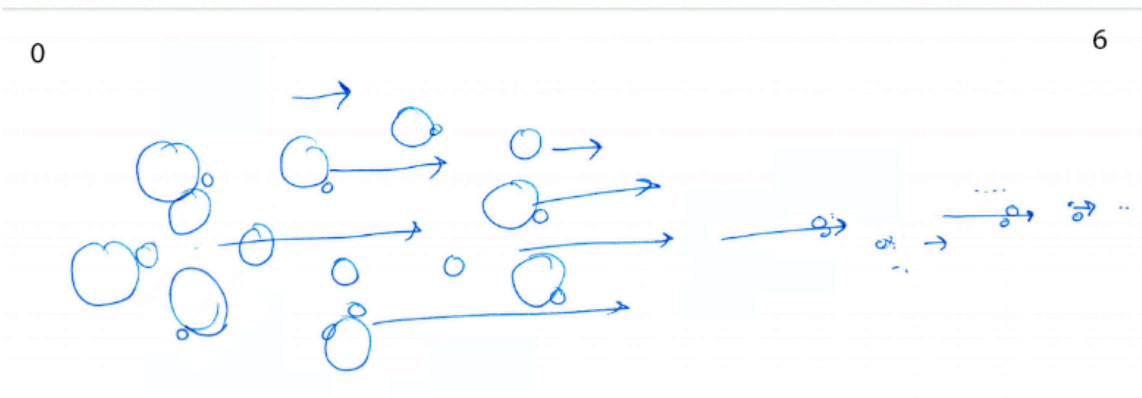

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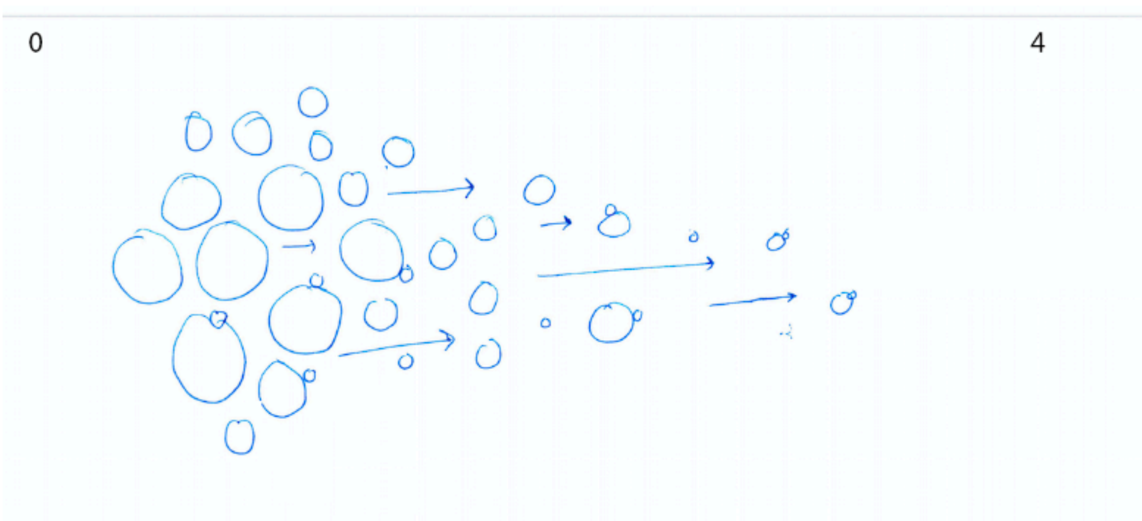
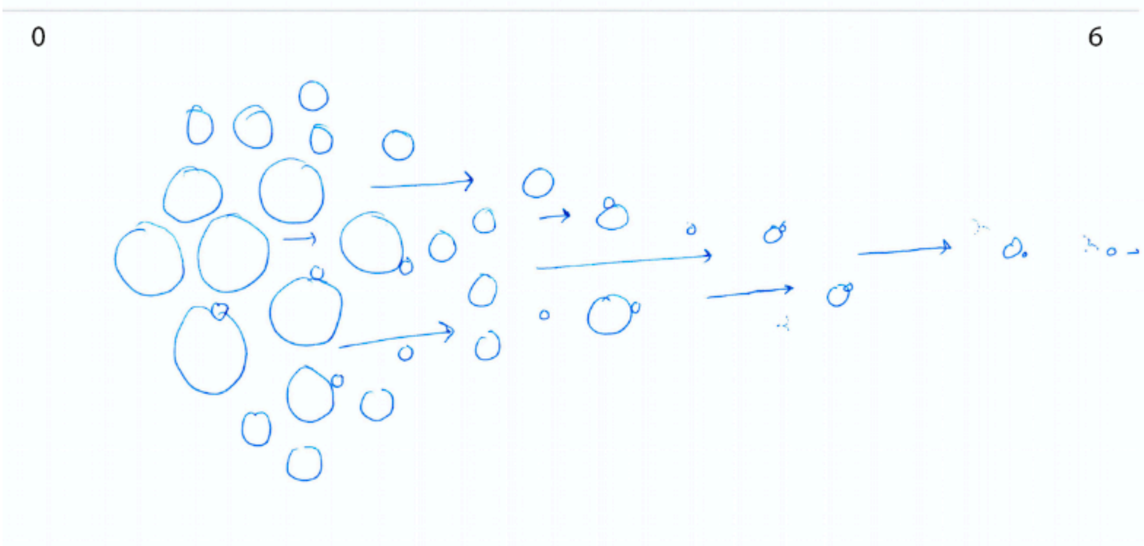


Wine 4



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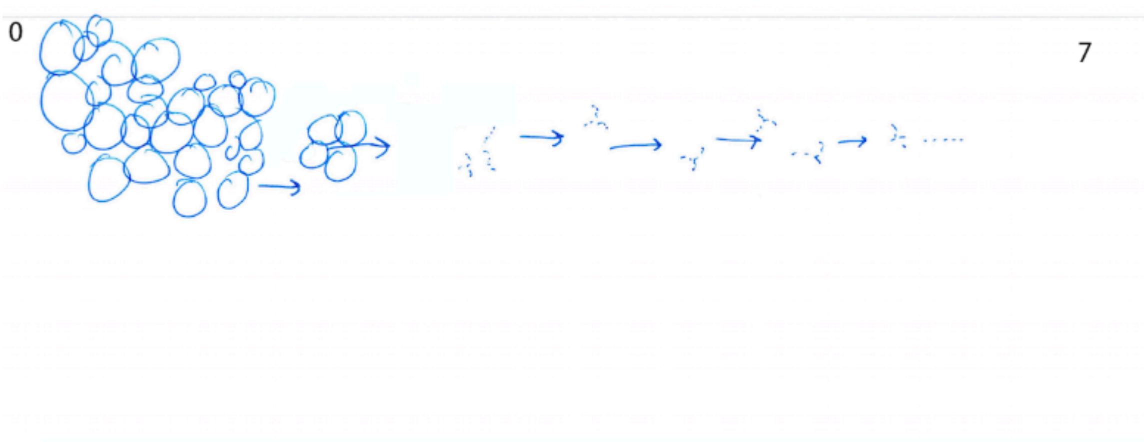
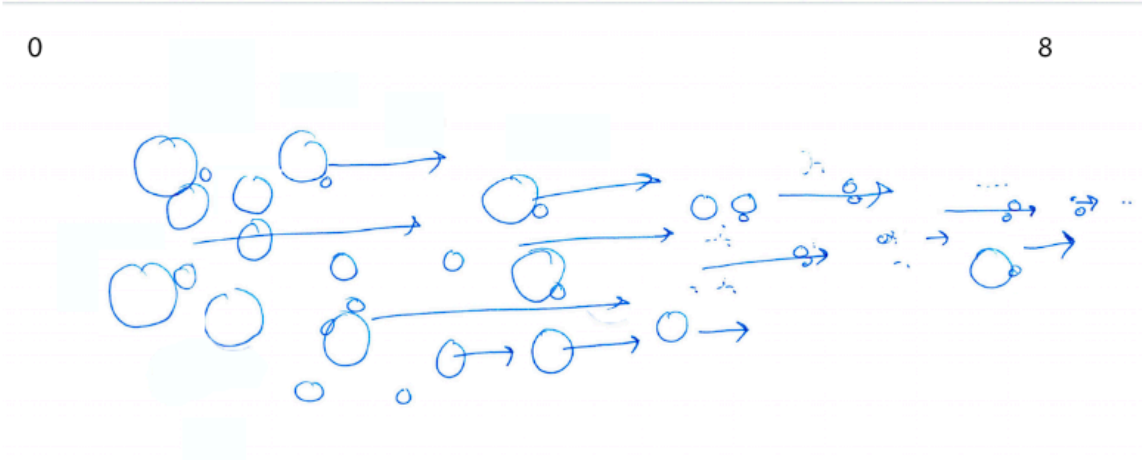
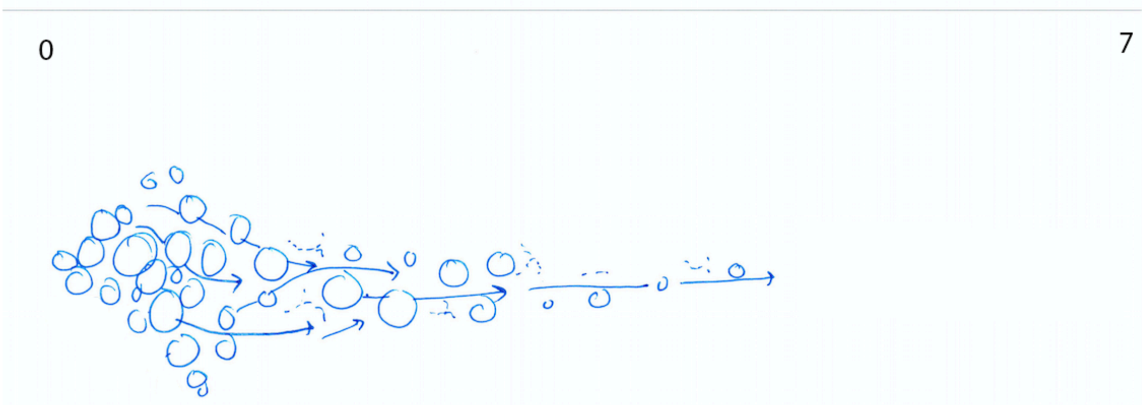


Distracter 2



Distracter 3



Linguistic Tasting Notes

Wine 1

Squash, green bean, pungent, grippy

Distracter 1

Vivid, bright fruit, fresh, lacey, dry

Distracter 2

Bright fruit, earthy, tropical wood, aged, fine-grained

Distracter 3

Dark, blueberry, racey, vivid, raspberry

Wine 2

Bright, red cherry, racey, polished, raspberry

Distracter 1

Dark, fruity, lacey, smooth

Distracter 2

Dark, bright fruit, fresh, grainy, dry

Distracter 3

Bright fruit, fresh, oak, vivid, grainy

Wine 3

Dark fruit, earthy, tropical wood, fresh, fine-grained

Distracter 1

Dark, green bean, pungent, smooth

Distracter 2

Dark, red cherry, grainy, polished, blackberry

Distracter 3

Dark, red fruit, spice, grainy, juicy

Wine 4

Vivid, red fruit, spice, lacey, juicy

Distracter 1

Squash, fruity, lacey, grippy

Distracter 2

Bright, blueberry, racey, vivid, blackberry

Distracter 3

Dark fruit, fresh, oak, grainy

Appendix D: Pre-Test Matching Counterbalancing

Permutation #	Type of Tasting Note Presented First	Order of Samples for Task
1	Shape	1234
2	Linguistic	1243
3	Shape	1324
4	Linguistic	1342
5	Linguistic	2134
6	Shape	2143
7	Linguistic	2314
8	Shape	2341
9	Shape	3124
10	Linguistic	3142
11	Shape	3214
12	Linguistic	3241
13	Linguistic	4123
14	Shape	4132
15	Linguistic	4213
16	Shape	4231

Appendix E: Wine List

Wine #	Session	Name
1	Pre/Post Test	2015 Powers Malbec
2	Pre/Post Test	2014 Acrobat Pinot Noir
3	Pre/Post Test	2012 Dominio IV flow pinot noir
4	Pre/Post Test	2012 Dominio IV Stermer Vineyard “rain on leaves”
5	Post Test	2010 Dominio IV Tempranillo of the Earth
6	Post Test	2013 Dominio IV Vitae Springs Pinot Noir
7	Post Test	Upper Eden Pinot Noir
8	Post Test	2013 Dominio IV Pinot Noir "love lies bleeding"
9/C/Y	Training	2012 Lagone Aia Vecchia
10/A/Z	Training	2013 Vin de Tabula Rasa
11/B/X	Training	2011 Dominio IV Pinot Noir “the hedgehog”
12	Fruit Training	2014 Ex Umbria Syrah
13	Fruit Training	2014 A to Z Oregon Pinot Noir
14	Fruit Training	2014 Domaine Mucyn Les Entrecoeurs Croze-Hermitage
15	Acid Training	2015 Subduction Red Syncline
16	Acid Training	2014 De Forville Barbera d'Alba
17	Acid Training	2015 Vietti "tre Vigne" Barbera d' Asti
18	Tanin Training	2012 Les Capucins Languedoc
19	Tanin Training	2013 Jean Pierre Gaussen Vin de Pays Du Mont-Caume
20	Tanin Training	2012 Irouleguy Domaine Ilarria

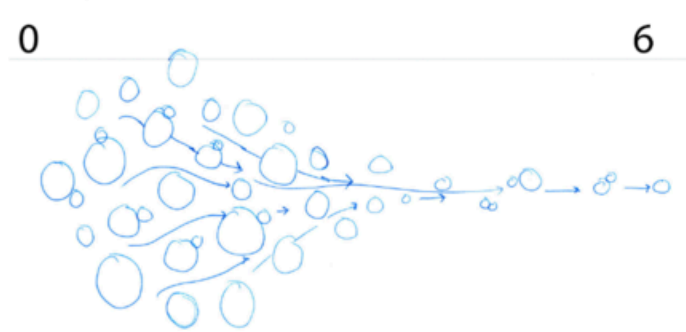
Appendix F: Training 1 Tasting Notes

Shape Tasting Notes

Wine 9:

Wine 10:

Wine 11:



Linguistic Tasting Notes

Wine 9:

Fresh wood, tangy, teriyaki, grippy

Wine 10:

Black fruit, dark, balanced, solid based, full-bodied

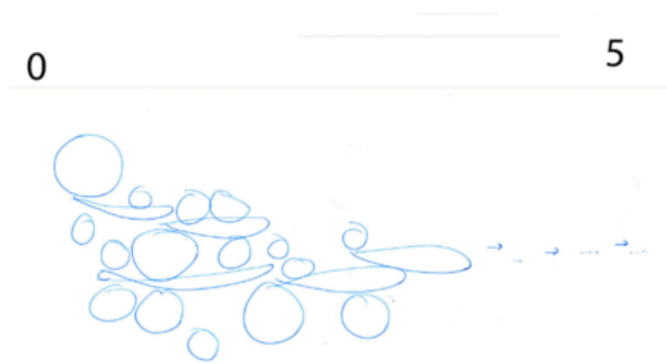
Wine 11:

White pepper, spicy, red fruit, racey, open

Appendix G: Training 2 Tasting Notes

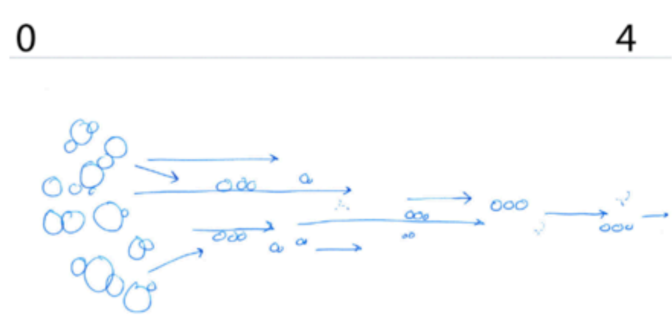
Shape Tasting Notes

Wine 15:



Wine 16:

Wine 17:



Linguistic Tasting Notes

Wine 15:

Black raspberry, floral, cocoa, tart, exposed

Wine 16:

Umami, saline, soy, balsam, rustic, chewy

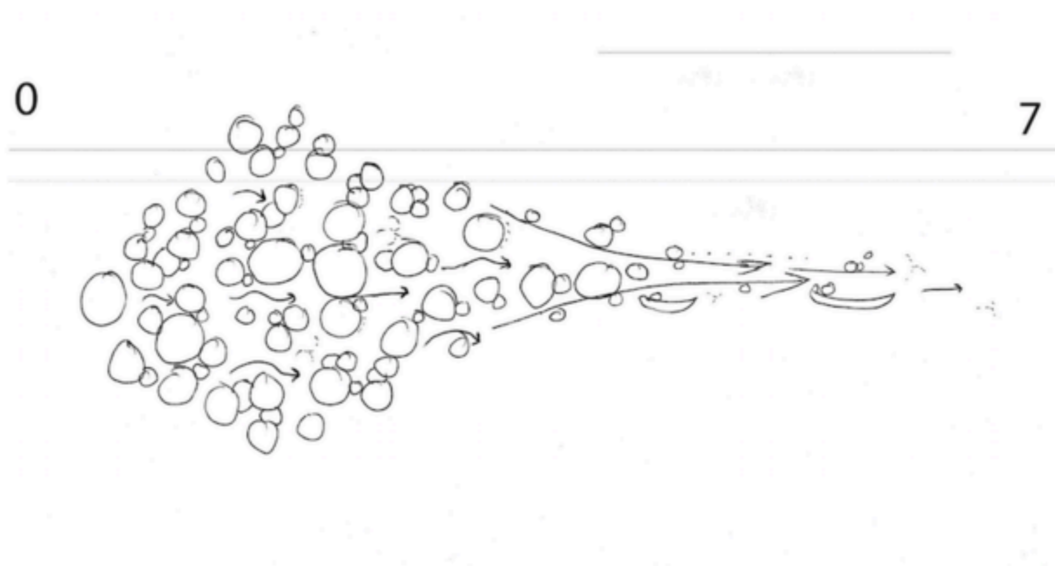
Wine 17:

ripe, syrup, sweet, fat, short

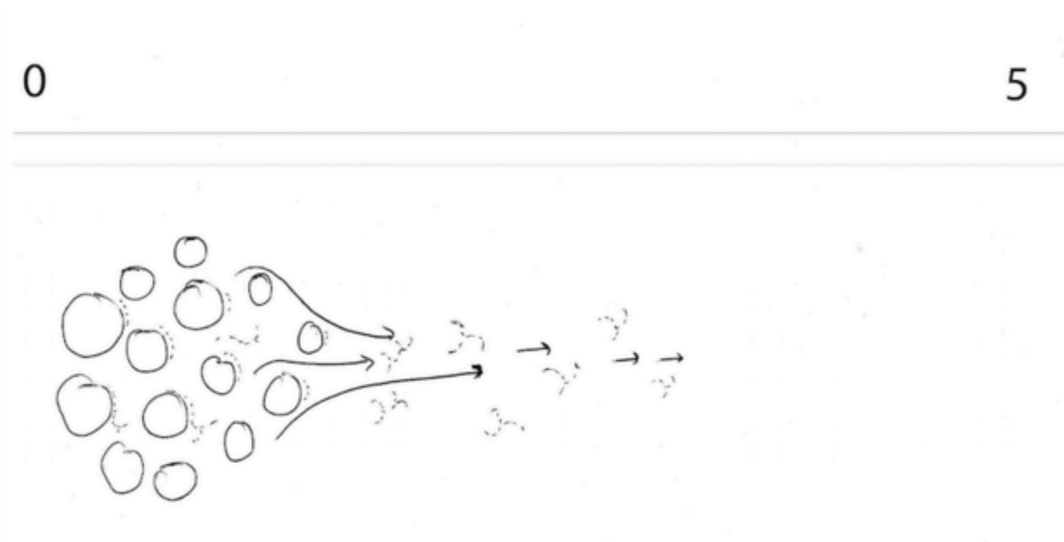
Appendix H: Training 3 Tasting Notes

Shape Tasting Notes

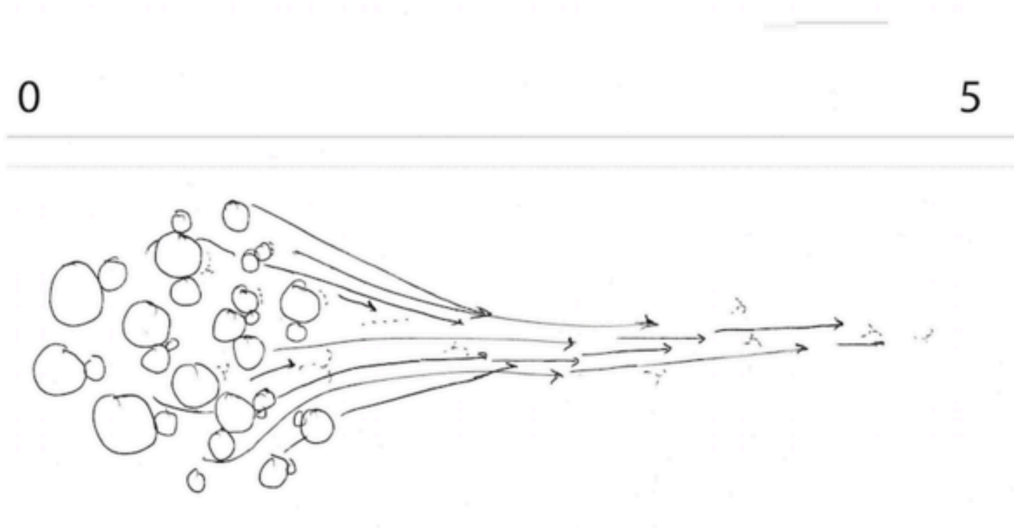
Wine 18



Wine 19



Wine 20



Linguistic Tasting Notes

Wine 18

Raspberry, ripe, floral, plush, medium-grained tannin

Wine 19

Lavender, blue fruit, structured, firm tannins, short

Wine 20:

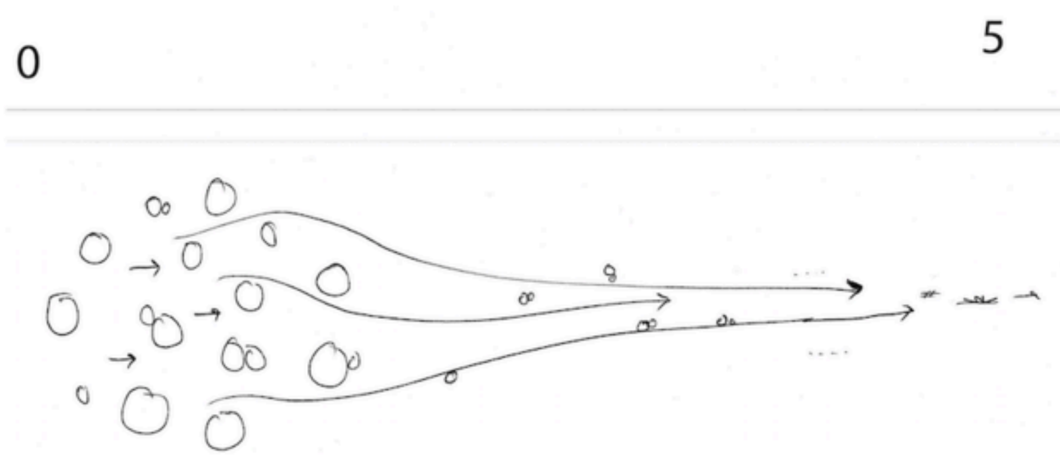
Violet, blueberry, convection sugar, fruit forward, rustic, pungent

Appendix I: Training 4 Tasting Notes

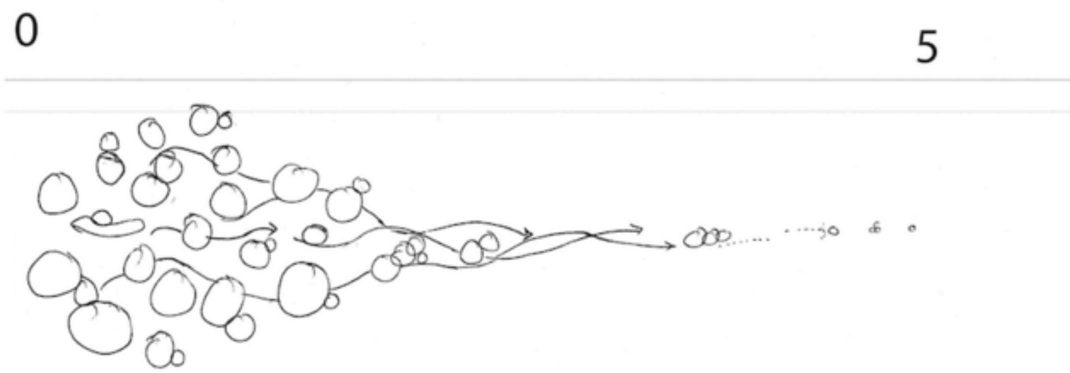
Shape Tasting Notes

Wine 12

Wine 13



Wine 14



Linguistic Tasting Notes

Wine 12

bluefruit, suave, ripe, structured

Wine 13

red cherry, black cherry, moss, racey, light bodied, tart

Wine 14

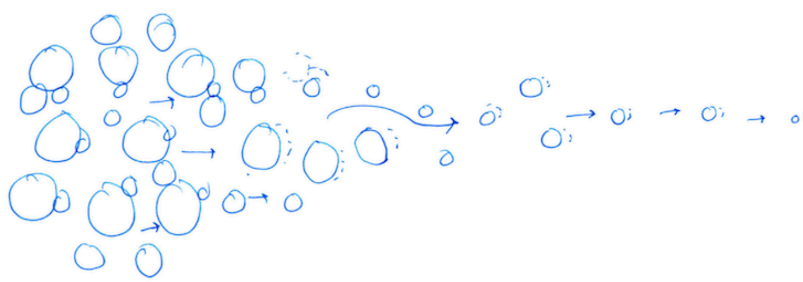
peppercorns, blackberry, red spice, supple, balanced, juicy, fine-texture

Appendix J: Post-Test Novel Wines Tasting Notes

Shape Tasting notes

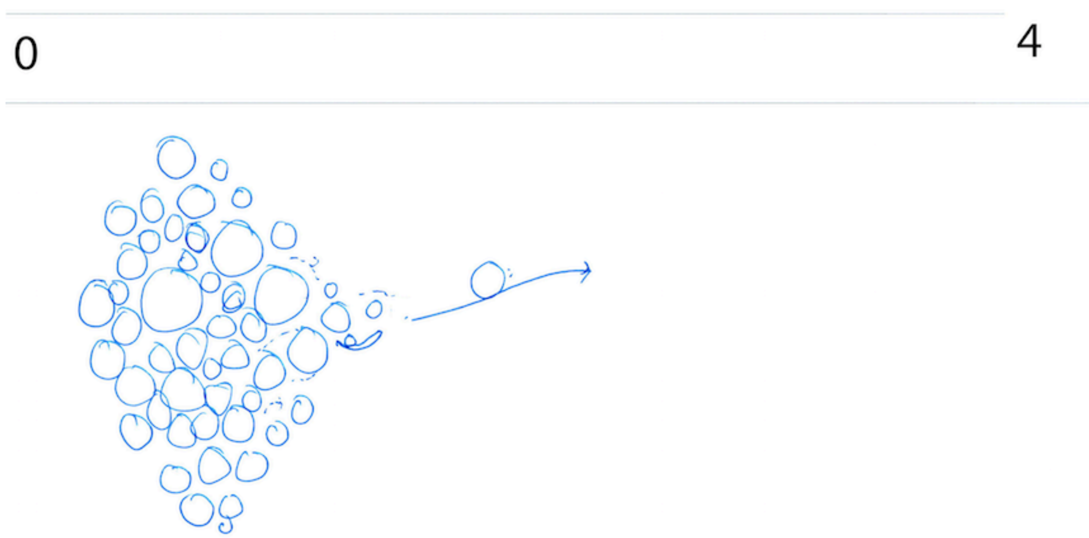
Wine 5

0 7



Distracter 1

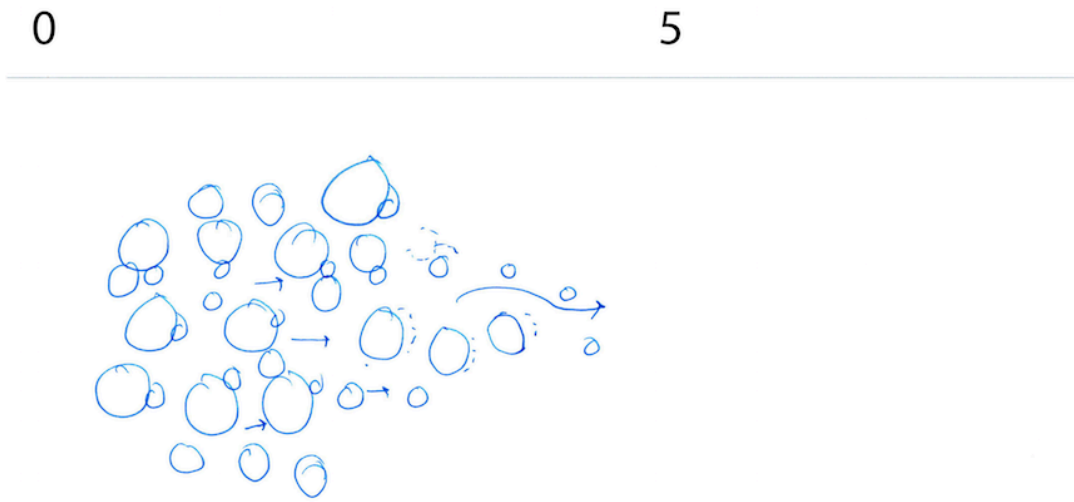
Distracter 2



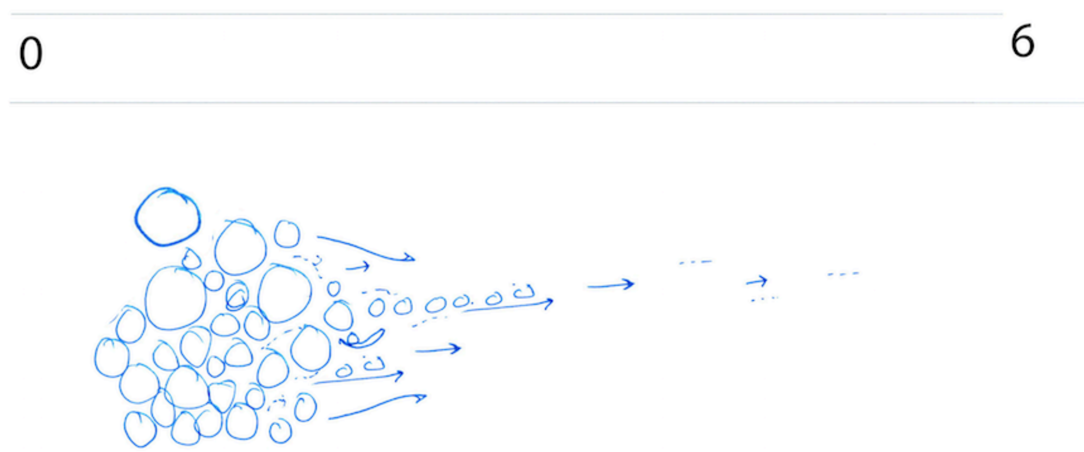
Distracter 3

Wine 6

Distracter 1



Distracter 2

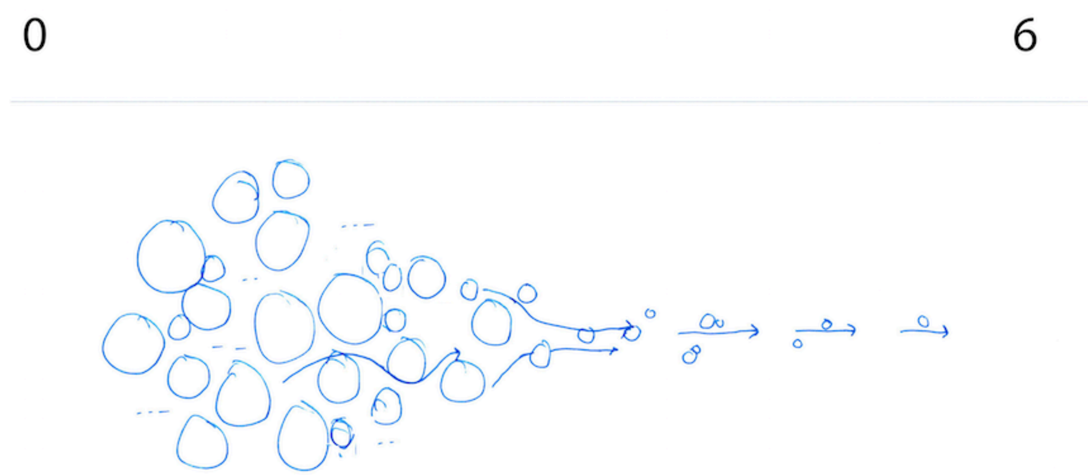


Distracter 3

Wine 7

Distracter 1

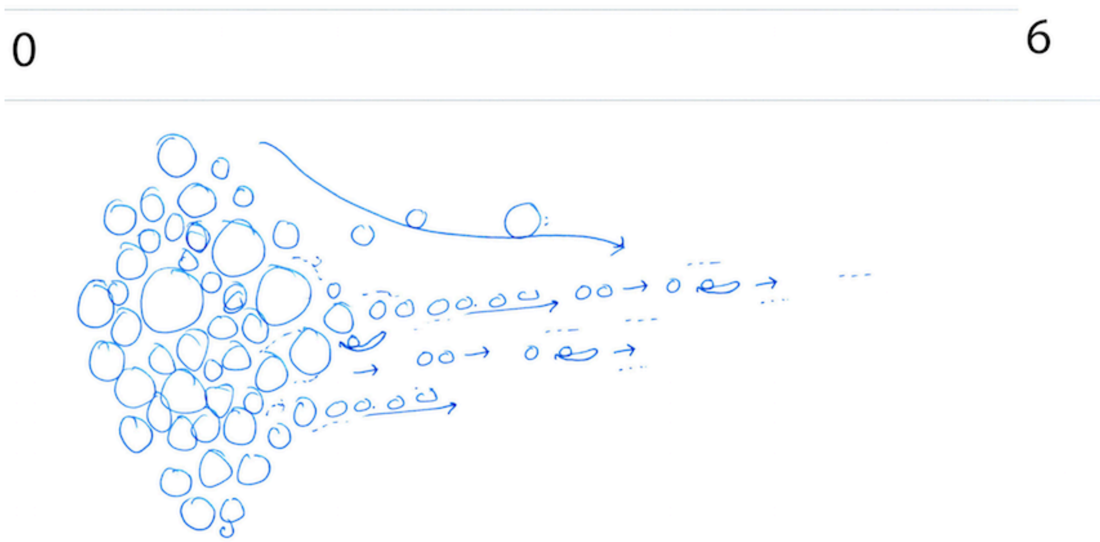
Distracter 2



Distracter 3

Wine 8

Distracter 1



Distracter 2

Distracter 3

Linguistic Tasting Notes

Wine 5

Forest fruit, earth, molasses, grainy, lively

Distracter 1

Nervy, floral, saline, structured, supple

Distracter 2

Bramble, tart, sleek, balanced, fruity

Distracter 3

Violet, saline, lavender, dark, forward

Wine 5

Bramble, cola, sleek, voluptuous, juicy

Distracter 1

Red fruit, ripe, sugar, grainy, dark

Distracter 2

Blackberry, saline, pepper, dark, racey

Distracter 3

Bright, floral, fruity, structured, big

Wine 7

Violet, candy, lavender, chewy, forward

Distracter 1

Bright, moss, fruity, silky, big

Distracter 2

Cherry, cola, grippy, voluptuous, fruity

Distracter 3

Red fruit, earth, sugar, grainy, lively

Wine8

Nervy, moss, saline, silky, supple

Distracter 1

Blackberry, candy, pepper, chewy, racey

Distracter 2

Cherry, tart, grippy, balanced, juicy

Distracter 3

Forest Fruit, ripe, molasses, silky, dark

Appendix K: Post-Test Counterbalancing

Post-Test 1: Matching Task

Permutation #	Type of Tasting Note Presented First	Order of Samples for Task
1	Shape	1256
2	Linguistic	1265
3	Shape	1526
4	Linguistic	1562
5	Linguistic	2156
6	Shape	2165
7	Linguistic	2516
8	Shape	2561
9	Shape	5126
10	Linguistic	5162
11	Shape	5214
12	Linguistic	3261
13	Linguistic	6125
14	Shape	6152
15	Linguistic	6215
16	Shape	6251

Post-Test 1: Triangle Test

Permutation #	First Set Presented	Set1: Order of Wines	Set 3: Order of Wines
1	1	112	556
2	3	112	565
3	1	112	665

4	3	112	656
5	3	121	556
6	1	121	565
7	3	121	665
8	1	121	656
9	1	221	556
10	3	221	565
11	1	221	665
12	3	221	656
13	3	212	556
14	1	212	565
15	3	212	665
16	1	212	656

Post-Test 2: Matching Task

Permutation #	Type of Tasting Note Presented First	Order of Samples for Task
1	Shape	7834
2	Linguistic	7843
3	Shape	7384
4	Linguistic	7382
5	Linguistic	8734
6	Shape	8743
7	Linguistic	8374
8	Shape	8347
9	Shape	3784
10	Linguistic	3748
11	Shape	3874
12	Linguistic	3847
13	Linguistic	4783

14	Shape	4738
15	Linguistic	4873
16	Shape	4837

Post-Test 2: Triangle Test

Permutation #	First Set Presented	Set4: Order of Wines	Set 2: Order of Wines
1	4	778	334
2	2	778	343
3	4	778	443
4	2	778	434
5	2	787	334
6	4	787	343
7	2	787	443
8	4	787	434
9	4	887	334
10	2	887	343
11	4	887	443
12	2	887	434
13	2	878	334
14	4	878	343
15	2	878	443
16	4	878	434

Appendix L: Chi-Square Test of Independence Categorical Variables

Table 1. Improvement from pre-test to post-test on the easy triangle test. No significant differences across the three groups, chi2(4, 38) = 3.9748, p = 0.409. There was a slight trending difference between the shape group and control group, chi2(2, 25) = 3.2240, p = 0.199.

	Control	Linguistic	Shape
Improved	2	2	3
Same	8	10	9
Worse	3	1	0

Table 2. Improvement from pre-test to post-test on the easy triangle test (pre-test) and novel triangle tests (post-test). There was a significant difference across the three groups, chi2(4, 38) = 9.5128, p = 0.049. There was a significant difference between linguistic and shape group, chi2(2, 25) = 7.3718, p = 0.025. No significant difference between control and shape group (chi2(2, 25) = 2.2493, p = 0.325) nor control and linguistic group (chi2(2, 26) = 3.8526, p = 0.146).

	Control	Linguistic	Shape
Improved	2	0	5
Same	1	4	1
Worse	10	9	6

Table 3. Improvement from pre-test to post-test on the difficult triangle test. Trend toward a significant difference across the three groups, chi2(4, 38) = 8.5385, p = 0.074. Significant difference between control and linguistic group, chi2(2, 26) = 7.833, p < 0.02. Trend toward significant difference between shape and control group, chi2(2, 25) =

4.3193 p < 0.115. No significant difference between shape and linguistic group, chi2(2, 25) = 1.9814, p = 0.371.

	Control	Linguistic	Shape
Improve	5	3	2
Same	8	4	7
Worse	0	6	3

Table 4. Improvement from pre-test to post-test on the linguistic matching tasks. No significant difference across groups, chi2(4, 38) = 1.60, p = 0.81.

	Control	Linguistic	Shape
Improve	4	5	4
Same	7	4	5
Worse	2	4	3

Table 5. Improvement from pre-test to post-test on the shape matching tasks. No significant difference across groups, chi2(4, 38) = 3.90, p = 0.42.

	Control	Linguistic	Shape
Improve	4	6	5
Same	5	1	2
Worse	4	6	5

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