Bidirectional lexical-gustatory synesthesia

Francois Richer, Guillaume-Alexandre Beaufils, Sophie Poirier

Université du Québec à Montréal

Correspondence to: F. Richer, Dept of Psychology, UQAM, Box 8888, Montreal, QC, H3C 3P8, Canada. Francois.Richer@uqam.ca. Tel: 1 514-987-3000, FPS: 1 514-987-7953

Abstract

In developmental lexical-gustatory synesthesia, specific words (inducers) can trigger taste perceptions (concurrents) and these synesthetic associations are generally stable. We describe a case of multilingual lexical-gustatory synesthesia for whom some synesthesias were bidirectional as some tastes also triggered auditory word associations. Evoked concurrents could be gustatory but also tactile sensations. In addition to words and pseudowords, many voices were effective inducers, suggesting increased connections between cortical taste areas and both voice-selective and language-selective areas. Lasting changes in some evoked tastes occurred during childhood suggesting that some plasticity can be present after the initial learning of associations. Inducers were often linked to taste concurrents phonologically or semantically, but also through identifiable childhood episodes (persons or events). Several inducers were phonologically linked to episodic inducers suggesting a process of secondary acquisition for many inducers. Implications of these observations are discussed.

Keywords: insula, oral sensations, voice processing, timbre, autobiographical events, brain development, plasticity, consciousness

1. *Introduction*

Synesthesia is a neurological condition in which stimulation of specific sensory or cognitive modalities evokes unusual supplementary perceptions in another modality. In lexical-gustatory synesthesia, several heard or imagined words (inducers) automatically and involuntarily trigger specific tastes (concurrents). There is evidence for a certain degree of familial aggregation in synesthesia, suggesting a genetic component in some cases (Asher et al., 2009; Barnett et al., 2008).

Reports of lexical-gustatory synesthesia have suggested that these atypical sensations are not linked to exceptional associative learning capacity, that they are unidirectional (tastes do not evoke words), generally stable over time and that inducer words are often phonologically or semantically related to the names of foods serving as concurrents (Ferrari, 1907, 1910; Gendle, 2007; Pierce, 1907; Simner & Haywood, 2009; Simner & Logie, 2007; Ward & Simner, 2003; Ward, Simner, & Auyeung, 2005).

Learning experiences appear to be involved in the formation of specific synesthetic associations. There is evidence that some synesthetic associations are acquired during early exposure to the inducers, such as early schooling for graphemes (Simner, Harrold, Creed, Monro, & Foulkes, 2009). In grapheme-color synesthesia, specific synesthetic associations have been linked to autobiographical events in some cases, through colored letter magnets or jigsaw puzzles (Hancock, 2006; Witthoft & Winawer, 2006). In lexical-gustatory synesthesia however, few reports have explored the episodic links between inducers and their concurrents. Inducer words are often familiar names which may have semantic or episodic links to the concurrent taste (e.g. *Quaker* (brand) → “oatmeal”). Also, for any given word, the probability of being an effective inducer is positively correlated to its frequency (Gendle, 2007; Ward & Simner, 2003). However, it is unclear to what extent specific episodic events can induce specific word-taste associations.

We report a case of bidirectional lexical-gustatory synesthesia in whom many word-taste associations appear to be linked to childhood persons or events. The main goal of the study was to explore the autobiographical links between inducers and concurrents and thus interviews were used to try to identify most inducer words evoking each taste concurrent. The identified clusters of inducer words were further explored by testing words and pseudowords phonetically related to inducers and words semantically-related to inducers. Finally, inducers were analyzed in relation to the autobiography of the subject.

2. Case description

PS is a 24-year-old (born 1986) right-handed French-Canadian woman with a university education. PS is a fluent speaker in French and English, both learned in her preschool years. She can have a simple conversation in Spanish, learned after age 9 during trips to Mexico. PS's performance was in the normal range for verbal fluency, verbal memory (Wechsler Memory Scale III Logical stories), figural memory (Taylor's complex figure) and olfaction (University of Pennsylvania Smell Identification Test). She had good grades in school except for some difficulty in mathematics. She showed no evidence of left-right confusion in contrast to previously reported cases of lexical-gustatory synesthesia (Ward & Simner, 2003). She has shown interest in artistic expression in both theater and drawing. Her mother is also a lexical-gustatory synesthete. The family history includes vocal tics in her father and an anxiety disorder in her brother.

PS reported having experienced lexical-gustatory synesthesias as long as she could remember. Consistency of responses was assessed after 3 weeks on 250 words half orally, half in written format, and after 1.5 years on 300 words presented orally. The overall consistency of concurrents was above 99%. Strong perceptions always elicited the same concurrent described with the same degree of detail.

2.1. Concurrents

PS reported that her synesthetic sensations were automatic and not under voluntary control, and that for most concurrents, the experience was happening in her head and not in her mouth. As in previously reported cases, concurrents were described with a wealth of details often including many of their physical properties. Besides tastes, sensations could involve tactile sensations located in the mouth, throat, or esophagus, as well as texture, temperature, headaches, or stomach aches. Concurrents appeared quickly (< 1 s), but it often took time for PS to find the appropriate words to describe her sensation. The sensation remained as long as it was a focus of attention, otherwise it disappeared. In agreement with previous reports (Simner & Haywood, 2009; Ward & Simner, 2003), the vast majority of taste concurrents were linked to food eaten or items encountered during childhood. For instance coffee or alcoholic beverages are not present among the concurrents reported. Concurrents could be inedible (e.g. “soap bar”, put in the mouth during childhood), they could also be imaginary (never experienced) (*Barbie* → “sweet jelly with sour granules”). Some rare inducers could trigger two different concurrents, appearing simultaneously (e.g. *cauchemar* (nightmare) → “fish sticks” and “stomach ache”) or sequentially (e.g. *squirrel* → sequence of “sweet fruit juice” followed by a “salty taste”).

2.2. Language inducers

Language inducers could either be common words (42% of common words tested (284/677)), names of persons or places (93% of proper nouns tested (300/323)) or pseudowords (15% of pseudowords tested (20/134)). Proper nouns, mostly first names represented 44% of all inducers. Written words or pseudowords were effective inducers only when mentally voiced. Words in rapid succession (reading, listening to speeches or rapid conversation) and words heard during a concurrent task such as reading did not evoke concurrents because « attention had to be paid to individual words » and because any concurrent taste would disappear when other words were heard. Many word inducers were contextual: *cours* (course or class) → “beets”, whereas *cours de musique* (music class) → “sunflower seeds”; *Michelle* (female name)

→ “cantaloup”, whereas *Michel* (male name) → Ø; *amande* (almond) →Ø, whereas *amende* (fine) → “almond-filled candy”)

2.3. Voices and sounds

We found more than 30 voices that were effective inducers including those of friends, teachers, singers or other celebrities first encountered during either childhood (e.g. *voice of Madonna* → “munchkins”), adolescence (*voice of Beyonce* → “celery water”) or adulthood (*voice of Rihanna* → “uncooked ramen noodles”). Sometimes, the name of the person was also an inducer but in 80% of effective voice inducers it was not. Voices induced their corresponding concurrent regardless of the words pronounced but could lose their inducing power if the voice changed significantly (e.g. person singing vs being interviewed) or the voice could only be effective for some intonations. Some American accents evoked the taste of pizza crust whereas some British accents evoked the taste of cheese and Spanish accents evoked the taste of bacon.

Non-verbal sounds could also be effective inducers, (*sound of keys on a keyboard* → “tomatoes”). Sounds could sometimes be as effective as the corresponding word (*sound of galloping horse* → “surface of a charbroiled hamburger”, as well as the words *galop* (gallop) and *chevalier* (knight)).

2.4. Food vocabulary

Several household food names triggered the congruent taste. Of the 166 food names tested, 39% evoked a concurrent, a proportion similar to common words in general. We found no incongruent word-taste associations (e.g. *banana* → “orange”). Some food names triggered perceptions that were very different from the appropriate taste. For example, the word for fish (*poisson*) did not trigger the taste of fish but the sensation of “fish skin in the mouth”. PS did not report tasting or eating fish skin but remembered touching fish skin with her hands at an early age.

2.5. Bidirectional associations

PS reported that some tastes made her think of specific words. Word concurrents were common words or names of familiar people. Some tastes triggered the only inducer word linked to them (e.g. “inside of french fries” → *personne* (person)), while some tastes could evoke one of several inducer words (e.g. “Ruffles potato chips” → *achat* (purchase), *magasin* (store), *magazine, jeans,* or *Ginette*) depending on the context or on recent thoughts. In some cases, even though many inducer words elicited a specific taste, the reverse synesthesia was always to a single concurrent word (e.g. always thinking of the name *Valery* while eating “celery”, while the taste and texture of “celery” was induced by the words *celery*, *city* and *grave* (low pitched)).

PS reported that while feeling an inducer taste, she could pay close attention to the word concurrent evoked in her head and this could trigger the taste again and so on for a few cycles. She also reported that as a child she often played games during meals when tastes would make her think of words or names (e.g. while eating “celery” she would say « please call me Valery from now on » and now the name *Valery* triggers the taste of celery systematically and vice-versa, resulting in a pleasant word-taste loop that could be sustained for several seconds). Associations to odors were extremely rare, however, PS reported that the “smell of soap” spontaneously evoked the word *Billy* (a brand of soap) and vice versa.

2.6. Transformations of synesthetic associations

PS reported that her synesthetic associations had generally remained stable over time. However, she noted transformations in some associations. At age 7, she developed a bidirectional association between “ladyfingers” (biscuits) and the *voice and name of singer Madonna*. A few years later, “munchkin donuts” began to trigger the same name and voice and soon thereafter the *name and voice of Madonna* only triggered the taste of “munchkin donuts” and no longer “ladyfingers”, even if the taste of “ladyfingers” was still an effective inducer of *Madonna’s name and voice*. Other inducers phonologically related to *Madonna* such as *Donna* and *Saint-Donat* (town name) also triggered the taste of “munchkin donuts”. Also, the name

Simard (neighbors since age 1) first evoked the taste of “parsley on the tip of the tongue” and later (around age 10) was replaced by the taste of “boiled spinach”. In the two examples studied, the original and secondary taste concurrents were similar to PS (“ladyfingers”/”munchkin donuts”, “parsley”/”boiled spinach”), suggesting that lexical-gustatory synesthesia can show an associative drift based on taste similarity. Also, one of these synesthesias was bilateral (munchkins) but not the other.

2.7. English and Spanish words

English was a second language for PS but she started acquiring it before age 5 and was bilingual by age 12. We tested 94 high-frequency English words and 45% triggered synesthetic perceptions in PS. Some French inducers and their English translation elicited the same taste (e.g. *bird* or *oiseau* →“sunflower seeds”). However, a word could trigger a taste in only one of the two languages (e.g. *butter* → Ø, but *beurre* (French for butter) → “butter”; *salty* → “taste of grain of salt” but *salé* (salty) or *sel* (salt) → Ø). The diversity of the inducer-concurrent links for English words was similar to what was observed with French words. In some cases, the taste could be elicited by a corresponding English food name (e.g. *hazel* → “hazelnut chocolate”). The inducer could also be linked phonologically to the food name (e.g. *beagle* → “toasted bagel with butter”). Semantic clusters of inducers could trigger the same taste (e.g. *job*, *work*, *shop* → “pork chops”).

In contrast to her fluency in English, PS learned only limited Spanish and only after age 9. We tested 90 high-frequency Spanish words and 25% induced a concurrent taste (e.g. *gracias*, *por favor* → “western omelette”). The majority of Spanish inducers were phonologically linked to a French inducer (e.g. *topez* → “pork rinds” like the French name *Thérèse*). Some Spanish inducers were phonologically linked to the French name of the food corresponding to the concurrent taste, (e.g. *gato* (Spanish for cat, French homophone means cake) → “cake”; *ola* → “olives”; porque → “porc”). Unlike what was observed for English words, we could not find

Spanish word inducers with phonological or semantic links to Spanish food names, nor any clusters of Spanish inducers independent of French word clusters.

2.8. Pseudowords

A list of 134 pseudowords was created using 94 pseudowords from two standard test batteries (Wechsler Individual Achievement Test (WIAT-II, french canadian version) and Batterie d'Evaluation du Langage Ecrit (BELEC)) and of a list of 40 grammatically correct (pronounceable) pseudowords created using parts of inducer words. For instance, *chuile* was created from chu- from *chute* and -uile from *tuile* and *apparloup* was created from *appartement* and *cantaloup*. Of the pseudowords derived from inducers, 30% induced a concurrent, whereas only 9% of the pseudowords from test batteries evoked a concurrent. All effective pseudoword inducers from test batteries contained phonemes linked to an effective inducer word. The higher proportion of effective pseudowords in the set constructed from inducers confirms previous reports on the relative effectiveness of phonemes included in inducer words (Gendle, 2007; Simner & Haywood, 2009). More surprising was the observation that some pseudowords were more effective than the words they were related to (e.g. *crevette* (shrimp) → Ø but *crevillon* → "canned shrimp"). PS reported that some pseudowords sounded like a « play on words » for known words which would generate interest in the sound long enough to trigger a taste.

2.9. Unpleasant or « ugly » words

Not all concurrents were pleasant (e.g. *Marie-Eve or Virginie* → "tactile sensation of excrements"; *Johanne* or *Manon* → "tactile sensation of urine"). We found only 15 words and no pseudowords which evoked sensations associated with negative emotions. In some cases, the inducer and the unpleasant concurrent could be linked phonologically (*Varennes* → "tactile sensation of veins in mouth" (*veines* in French, rhymes with inducer); the name *Bégin* → "tactile sensation of vagina" (vagin in French, rhymes with inducer)).

In some cases, the inducer and the unpleasant concurrent could be linked through autobiographical episodes. The word *cauchemar* (French for nightmare) evoked a stomach

ache. The word *chérie* (French for Honey) evoked “granulous vomit in the esophagus”, and PS reported that the association was linked to a movie viewed in 1990 (PS was 4 at the time) entitled « Honey I shrunk the kids! » (French translation) which featured a scene involving granulous apple particles, followed by several repetitions of the word *chérie* and by a scene involving swallowing and regurgitating mud. The expression *Bla-bla-bla* evoked a “tactile sensation of dried nasal mucus (booger) on the lip”, and PS reported that the inducer referred to the title of a TV show she watched regularly between ages 7 and 10. She also reported having a shameful social episode involving nasal mucus on the lip at age 5.

2.10. Word clusters

We identified 54 word clusters in which several words were associated with the same taste. These clusters varied in size between 4 and 25 words. Fifty percent of the clusters contained at least one inducer showing a phonetic link to the name of the concurrent (e.g. *Mindy*, *Samantha*, *Amanda*, *Miranda*, *Esmeralda* and *Emma* → “mint candy” (*menthe* in French)). In 15% of clusters, at least one inducer showed a semantic link to the concurrent. For example, the taste of “peanut butter” was evoked by the words *Kraft* (popular brand), *California*, *kid*, *child*, *girl*, *Terry*, *Jerry*, *Victoria*, *Linda*, and *umbrella* as well as some words containing the sound /ʃ/, including the French words *parchemin* and *schéma*.

Several clusters (24%) contained inducers linked to the concurrent through autobiographical episodes, many through persons PS met during childhood from age 3 to 7. For example, the taste of raisins was triggered by the name *Atis*,. In kindergarten at age 5, PS regularly drank her morning milk with a girl whose last name was Atis who was the only child in the class to eat raisins with her milk. PS copied her friend’s habit a few month later. The same taste was also triggered by the word *metis* (‘s’ is voiced in French) (Ms Atis was metis) and by the phonologically related *améthyste* (amethyst). The same taste was evoked by the names *Elise* and *Marquis* and by words related phonologically to *Elise* (*Lise*, *Lili*, *Louise*, *Lisette*). At age 7, PS often ate raisins while watching a TV show that was hosted by a woman called Elise

Marquis. The taste of “sponge candy” was triggered by the names *André* and *Caron* (André Caron was a friend in daycare at age 3) and by words phonologically related to *Caron* (*carreau, carré*, *Charron*, *Charest*, *Gagnon*, *Gagné*) or to *André* (*Andrea*, *Andreanne*). These examples indicate that the inducer value of episodic inducers can generalize to words that are phonologically-related to the episodic inducers.

3. Discussion

The present case points to previously unrecognized features of lexical-gustatory synesthesia, including that 1) word-taste associations can be bidirectional, 2) established inducer-concurrent links can undergo lasting changes, 3) voices can be effective inducers independent of lexical inducers, and 4) childhood episodes can play a major part in the development of clusters of inducers.

To our knowledge, PS is the first reported case of bidirectionality in lexical-gustatory synesthesia. Several tastes in her mouth systematically triggered an explicit representation of one of the inducer words associated with this specific taste. In grapheme-color synesthesia, colors can facilitate or interfere with grapheme perception (Cohen Kadosh et al., 2005; Ward & Sagiv, 2007; Weiss, Kalckert, & Fink, 2009), but except in rare cases (Cohen Kadosh & Henik, 2006), subjects do not report perceiving a grapheme when a color is presented. Explicit bidirectionality in PS helps maintain synesthetic experiences in consciousness for a few seconds. It may also facilitate other features of synesthesias such as the development of clusters of inducers but this could not be addressed here.

PS also showed transformations in synesthesias: similar tastes could replace original concurrents. The phenomenon of concurrent replacement suggests that the stability of synesthesia has limits and that some plasticity can be present after the initial learning of associations.

In lexical-gustatory synesthesia, taste concurrents are often triggered by multiple inducer words linked phonologically or semantically to each other and/or to the name of the concurrent. In the present case, several clusters of inducers (e.g. taste of raisins) did not contain inducers linked to the concurrent either phonologically or semantically, but contained inducers linked to the concurrent through childhood episodes (friends' names, TV shows, movies) that occurred between ages 3 and 9. The clusters involving autobiographical episodes often contained inducers that were phonologically linked to the episodic inducer (e.g. *Atis* and *amethyst* linked to the taste of raisins), suggesting that clusters can develop from one or a few primary inducers to secondary phonologically-related inducers. In one cluster (raisins), the episodic influence appeared to be linked to at least two distinct phases (two names (Atis, Elyse) respectively heard at ages 5 and 7) and secondary phonologically-related inducers were found for both names. The importance of childhood for these synesthesias may be linked to the rapid increase in vocabulary, semantic associations and person-name associations in that period, or to the emotional significance of specific events at this age such as the first school years and vacations.

In PS, Spanish word inducers were most often phonetically linked to French inducers or French concurrent names. This suggests that most Spanish inducer words acquired their synesthetic associations mainly secondarily through previously acquired associations as is the case for pseudowords, either because of PS's low exposure to Spanish or to the late age at which this exposure occurred. This will have to be tested further in more cases.

In PS, the majority of inducers appeared to be lexical in that a given phoneme could only trigger a taste concurrent when embedded in specific words or pseudowords and not independently. However, numerous human voices (friends, celebrities) were also effective inducers. Voice-selective cortical areas have been documented in superior temporal cortex (Belin, Lafaille, Ahad, & Pike, 2000; Petkov et al., 2008) and insular cortex (Remedios, Logothetis, & Kayser, 2009). These areas may show an increased connectivity to gustatory

cortex in PS independently of the hyperconnectivity between language cortex and gustatory cortex.

The present observations also confirm the main properties of lexical-gustatory synesthesia described previously (e.g., Gendle, 2007; Simner & Haywood, 2009; Ward & Simner, 2003), including: 1) Childhood food experiences form most if not all taste concurrents. 2) Food names and words containing phonemes of the food names can trigger the associated taste but not systematically. 3) Synesthetic taste associations often add an affective dimension to auditory word representations and they can be pleasant or unpleasant. 4) Inducers can be cognitive representations as well as physical stimuli and attention to the inducer can affect the duration or probability of occurrence of concurrent tastes. Despite large differences in the cases and word samples examined, the proportion of effective inducers in PS (42% of all words tested) was similar to that observed in other reported cases of lexical-gustatory synesthesia (47% in Gendle (2007) and 56% in Ward and Simner (2003)).

One explanation for the neural basis of developmental synesthesia is a hyperconnectivity between distinct cortical sensory or cognitive systems, for example from a partial failure of normal synaptic pruning processes (Maurer, 1993). Diffusion-tensor imaging data in a case of auditory interval-gustatory synesthesia have suggested a hyperconnectivity between auditory cortex and gustatory cortex (Hänggi, Beeli, Oechslin, & Jäncke, 2008). However, the insula appears to be involved in auditory and phonological processing in addition to gustatory processing (Bamiou, Musiek, & Luxon, 2003; Remedios et al., 2009) and in cross-modal sensory interactions involving auditory input (Kimura, Imbe, & Donishi, 2010), and thus a local hyperconnectivity in the insula could also be involved. PS also reported pain and visceral sensations, modalities which are strongly represented in the insula. Alternative models of synesthesia that do not necessarily involve atypical connections include a dysinhibition of normal but inhibited connections (Grossenbacher & Lovelace, 2001), or limbic system mediation (Cytowic, 1993). The present observations cannot address the question of the specific

mechanisms of synesthetic induction, but they are compatible with the presence of hyperplasticity affecting selective cortical areas during childhood in PS. Limbic mediation can be inferred in some of PS's synesthesias such as pleasant or unpleasant concurrents triggered by episodic inducers such as names and TV shows. Also, changes in brain plasticity around puberty (Huttenlocher & Dabholkar, 1997) could explain the fact that concurrents exclude tastes first experienced after puberty, but also that episodic inducers are systematically from ages 10 and younger and that words (e.g. Spanish) acquired later are mainly secondary inducers.

In conclusion, the present case indicates that lexical-gustatory synesthesia can be bidirectional and can undergo lasting transformations during childhood. Moreover, it suggests that specific synesthetic associations are often acquired through autobiographical episodes and can evolve into clusters of inducers phonologically linked to the primary episodic inducers.

References

Asher, J. E., Lamb, J. A., Brocklebank, D., Cazier, J. B., Maestrini, E., Addis, L.,… Monaco, A. P. (2009). A whole-genome scan and fine-mapping linkage study of auditory-visual synesthesia reveals evidence of linkage to chromosomes 2q24, 5q33, 6p12, and 12p12. *Am J Hum Genet, 84* (2), 279-285.

Bamiou, D. E., Musiek, F., & Luxon, L. M. (2003). The insula (Island of Reil) and its role in auditory processing Literature review. *Brain Res Brain Res Rev*, *42* (2), 143-154.

Barnett, K. J., Finucane, C., Asher, J. E., Bargary, G., Corvin, A. P., Newell, F. N., & Mitchell, K. J. (2008). Familial patterns and the origins of individual differences in synesthesia. *Cognition, 106* (2)*,* 871-893.

Belin, P., Zatorre, R. J., Lafaille, P., Ahad, P., & Pike, B. (2000). Voice-selective areas in human auditory cortex. *Nature, 403* (6767), 309-312.

Cohen Kadosh, R., & Henik, A. (2006). When a line is a number: color yields magnitude information in a digit-color synesthete. *Neuroscience,137* (1), 3-5.

Cohen Kadosh, R., Sagiv, N., Linden, D. E., Robertson, L. C., Elinger, G., & Henik, A. (2005). When blue is larger than red: colors influence numerical cognition in synesthesia. *J Cogn Neurosci, 17* (11)*,* 1766-1773.

Cytowick, R. E. (1993). *The man who tasted shapes*. Cambridge, MA: MIT Press.

Ferrari, G. C. (1907). Una varieta nuova di sinestesia. *Riv Psicol, 3,* 297-317.

Ferrari, G. C. (1910). Un nuovo caso di sinestesia uditivo-gustativa. *Riv Psicol, 6,* 101-104.

Gendle, M. H. (2007). Word-gustatory synesthesia: a case study. *Perception, 36* (4), 495-507.

Grossenbacher, P. G., & Lovelace, C. T. (2001). Mechanisms of synesthesia: cognitive and physiological constraints. *Trends Cogn Sci, 5* (1), 36-41.

Hancock, P. (2006). Monozygotic twins' colour-number associations: a case study. *Cortex, 42* (2), 147-150.

Hänggi, J., Beeli, G., Oechslin, M., & Jäncke, L. (2008). The multiple synæsthete E.S.: neuroanatomical basis of interval-taste and tone-colour synæsthesia. *Neuroimage*, *43* (2), 192-203.

Huttenlocher, P. R., & Dabholkar, A. S. (1997). Regional differences in synaptogenesis in human cerebral cortex. *J Comp Neurol, 387* (2), 167-178.

Kimura, A., Imbe, H., & Donishi, T. (2010). Efferent connections of an auditory area in the caudal insular cortex of the rat: anatomical nodes for cortical streams of auditory processing and cross-modal sensory interactions. *Neuroscience, 166* (4), 1140-1157.

Maurer, D. (1993). Neonatal synesthesia: implications for the processing of speech and faces. In de Boysson-Bardies, B., de Schonen, S., Jusczyk, P., McNeilage, P., & Morton, J. (Eds), *Developmental Neurocognition: Speech and face processing in the first year of life* (pp. 109-124). Dordrecht, Netherlands: Kluwer Academic Publishers.

Petkov, C. I., Kayser, C., Steudel, T., Whittingstall, K., Augath, M., & Logothetis, N. K. (2008). A voice region in the monkey brain. *Nat Neurosci, 11* (3), 367-374.

Pierce, A. H. (1907). Gustatory audition: a hitherto undescribed variety of synæsthesia. *Am J Psychol, 18* (3), 341-352.

Remedios, R., Logothetis, N. K., & Kayser, C. (2009). An auditory region in the primate insular cortex responding preferentially to vocal communication sounds. *J Neurosci, 29* (4), 1034-1045.

Simner, J. (2007). Beyond perceptions: synæsthesia as a psycholinguistic phenomenon. *Trends Cogn Sci, 11* (1), 23-29.

Simner, J., Harrold, J., Creed, H., Monro, L., & Foulkes, L. (2009). Early detection of markers for synæsthesia in childhood populations. *Brain, 132* (1)*,* 57-64.

Simner, J., & Haywood, S. L. (2009). Tasty non-words and neighbours: The cognitive roots of lexical-gustatory synæsthesia. *Cognition, 110* (2)*,* 171-181.

Simner, J., & Logie, R. H. (2007). Synæsthetic consistency spans decades in a lexical-gustatory synæsthete. *Neurocase, 13* (5)*,* 358-365.

Ward, J., & Sagiv, N. (2007). Synæsthesia for finger counting and dice patterns: a case of higher synæsthesia? *Neurocase, 13* (2)*,* 86-93.

Ward, J., & Simner, J. (2003). Lexical-gustatory synæsthesia: linguistic and conceptual factors. *Cognition, 89* (3)*,* 237-261.

Ward, J., Simner, J., & Auyeung, V. (2005). A comparison of lexical-gustatory and grapheme-colour synæsthesia*. Cogn Neuropsychol, 22* (1)*,* 28-41.

Weiss, P. H., Kalckert, A., & Fink, G. R. (2009). Priming letters by colors: evidence for the bidirectionality of grapheme-color synesthesia. *J Cogn Neurosci, 21* (10)*,* 2019-2026.

Witthoft, N., & Winawer, J. (2006). Synesthetic colors determined by having colored refrigerator magnets in childhood. *Cortex, 42* (2)*,* 175-183.