

4-2015

# Effect of Olfaction on the Perception of Movie Clips

Nikita A. Wong

Western University, [nwong227@uwo.ca](mailto:nwong227@uwo.ca)

Follow this and additional works at: [https://ir.lib.uwo.ca/psychd\\_uht](https://ir.lib.uwo.ca/psychd_uht)



Part of the [Psychology Commons](#)

---

## Recommended Citation

Wong, Nikita A., "Effect of Olfaction on the Perception of Movie Clips" (2015). *Undergraduate Honors Theses*. 30.  
[https://ir.lib.uwo.ca/psychd\\_uht/30](https://ir.lib.uwo.ca/psychd_uht/30)

This Dissertation/Thesis is brought to you for free and open access by the Psychology Department at Scholarship@Western. It has been accepted for inclusion in Undergraduate Honors Theses by an authorized administrator of Scholarship@Western. For more information, please contact [tadam@uwo.ca](mailto:tadam@uwo.ca), [wlsadmin@uwo.ca](mailto:wlsadmin@uwo.ca).

Effect of Olfaction on the Perception of Movie Clips

Nikita Ann Wong

Honours Psychology Thesis  
Department of Psychology  
University of Western Ontario  
London, Ontario, CANADA  
April, 2015

Thesis Advisor: Rhodri Cusack, Ph.D.

### **Abstract**

Odours are important to many species but their effect on human perception in the context of concurrent auditory and visual stimulation has received little investigation. Here we examined how the experience of viewing audio-visual movie clips changes when accompanied by congruent or incongruent odours. Using an olfactometer to control odourant delivery, thirty-five undergraduate students from Western University were randomly presented 36 different odour-video pairs twice. Following each presentation, participants completed three Likert scales to assess multisensory interaction in terms of engagement, pleasantness, and emotional arousal. Comparison of congruent and incongruent odours to the no odour control condition revealed that incongruent odours had a greater effect than congruent odours on participant ratings, and that this effect acted to negatively influence experience, reducing engagement, pleasantness, and emotional arousal. There was little difference between congruent odours and no odour on ratings of engagement and emotional arousal; however, even congruent odours reduced pleasantness ratings, suggesting all odours used were, to an extent, unpleasant. An interaction suggested that certain movies were more strongly modulated by odour than others. We interpret our results as evidence of crossmodal competition, in which the presence of an odour leads to suppression of the auditory and visual modalities. This was confirmed using functional magnetic resonance imaging in a single participant. Future research should continue to investigate the surprising role odour plays in multisensory interaction.

### **Effect of Olfaction on the Perception of Movie Clips**

Odours are of utmost importance to many species, communicating pertinent information about food sources, predators, and mating opportunities. As humans, however, we are primarily visual animals; and in comparison, our sense of smell is commonly regarded as being quite poor. The direct result of this is that the study of human olfaction has been overlooked (Keller & Vosshall, 2004), with many details of olfactory perceptual processing inadequately understood, or remaining to be investigated. Yet humans frequently engage in activities to infuse, mask, and eradicate odours from themselves and the surrounding environment. Besides being consciously enjoyed, odours also play an important role in shaping everyday experiences through their powerful ability to modulate cognition (e.g., how pain is experienced) and resulting behaviour (e.g., Villemure, Slotnick & Bushnell, 2003).

### **Overview of Crossmodal Correspondences and Olfaction**

Crossmodal correspondences or associations have been defined as the integration of sensory information from two or more modalities. A review of the relevant literature reveals that crossmodal sensory correspondences have long been a subject of psychological investigation and that, over the years, numerous interactions have been found between different pairs of senses (Spence, 2011). Historically, however, aside from its well-known influence on taste perception, research on olfaction in these crossmodal associations has largely been limited to the ways odour perception is modulated by the other senses (e.g., Demattè, Sanabria & Spence, 2009; Deroy, Crisinel & Spence, 2013).

Recently, the crossmodal research focus has expanded, and the understanding of how smell affects the perception of vision, audition, and touch, has become a growing area of interest (Deroy et al., 2013). New research has conducted mixture discrimination testing in an attempt to

establish the lowest limit of the number of olfactory mixtures humans can discriminate. Using these findings and complex mathematics, it was calculated that humans can identify at least one trillion different olfactory stimuli. Challenging the traditional belief that humans have a poor sense of smell (Bushdid, Magnasco, Vosshall & Keller, 2014), this finding emphasizes the importance of understanding how smell can influence day-to-day experiences has likely been underestimated.

Thus, the understanding of how smell modulates the perception of other senses remains in its infancy. The few past studies that have examined how olfaction can drive crossmodal associations have been limited by their highly controlled and artificial settings, focusing their investigations on very specific interactions of smell and one other sense (e.g., Belkin et al., 1997). As a better comprehension of how smell influences the other senses would add to the understanding of human experience on a whole, clearly further research is warranted. In this study we aim to add to this literature base by investigating how olfactory stimulation affects the perception of naturalistic audio-visual stimuli, in the form of short video clips.

### **Vision Affecting Olfaction**

Aside from smell's close relationship with gustation, it has been shown through numerous studies that smell interacts intimately with vision (e.g., Demattè et al., 2009). Indeed, substantial research has focussed on how the presence of a visual object can enhance olfactory perceptions. For example, speed and accuracy of odour identification and discrimination have been found to be facilitated by the presence of a congruent visual object. That is, when an image that semantically matches the odour is presented, odours are more easily identified and discriminated, and it has also been suggested that their perceived pleasantness increases (e.g., Demattè et al., 2009; Dolan & Gottfried, 2003; Zellner, Bartoli & Eckard, 1991).

**Olfaction Affecting Vision**

Early visual processing can be modulated by the presence of an odour cue (e.g., Robinson, Mattingely, & Reinhard, 2013). It has been proposed that odour acts as an object feature, and much like shape or colour, facilitates object identification when the odour and visual object are semantically congruent. Odour also has been shown to reflexively direct visual attention to congruent objects, which is likely a result of the finding that congruent odours increase object saliency (Chen, Zhou, Chen, He & Zhou, 2013). How this facilitation of visual attention influences object perception remains controversial. A direct example of this conflict can be seen across independent studies, which suggest that the presence of a congruent odour can act to either increase or decrease the number and length of visual fixations on the congruent object (Seigneuric, Durand, Jiang, Baudouin & Schaal, 2010; Seo, Roidl, Müller & Negoias, 2010). Nonetheless, findings assessing visual attention using various experimental paradigms (e.g., rapid serial visual presentation and attentional blink) continue to confirm the role of odour in enhancing object saliency and facilitating the direction of visual attention (Robinson et al., 2013).

Olfactory-visual crossmodal association has also been supported by electroencephalographic (EEG) evidence. The finding that the N100 component, which has been associated with preattentive perceptual processing, was enhanced in females when visual stimuli were accompanied by congruent, versus incongruent or absent, odours has been taken as evidence to support olfactory modulation of early visual processes (Robinson, Reinhard & Mattingely, 2014). EEG findings from the investigation of incongruent odour-object pairings using a similar paradigm provide converging evidence for these results (Sarfarazi, Richardson, Behan & Sedgwick, 1999). Further evidence of the intimate connection between the olfactory

and visual systems has been demonstrated using repetitive transcranial magnetic stimulation (rTMS). When rTMS is applied to the visual cortex (200 bursts of three pulses at 50 Hz with a burst frequency of 5 Hz) improved olfactory discrimination has been demonstrated, suggesting that some higher-level olfactory processes can be facilitated by enhancement of visual cortex activity (Jadauji, Dordjevic, Lundström & Pack, 2012).

### **Olfaction Affecting Audition**

To our knowledge, the relationship between olfaction and auditory perception has yet to be investigated in humans. However, some evidence of such a crossmodal association may be obtained from animal studies. For example, an investigation of the behavioural influence of smell in male moths demonstrated that in the presence of competing olfactory and auditory stimuli the normal response to an auditory cue was reduced (Skals, Anderson Kannevorff, Löfstedt & Surlykke, 2004). Additionally, exposure to pups' body odours can increase neuronal sensitivity in the primary auditory cortex of female rats (Cohen, Rothschild & Mizrahi, 2011). Wesson and Wilson (2010) revealed that 20-30% of neurons in the olfactory tubercle of mice responded to auditory cues; thus opening to speculation the idea that the olfactory tubercle could be a location of auditory-olfactory integration (Wesson & Wilson, 2010). Together, these findings lend support to the idea that an olfactory-auditory crossmodal correspondence may similarly be found in humans.

### **Audition Affecting Olfaction**

There is considerably more evidence to support an auditory-olfactory interaction in humans. In a series of experiments testing the 1857 proposition that sounds could be used to describe scents (Piesse, 1857), Belkin and colleagues (1997) empirically demonstrated that odours are indeed readily and consistently matched to auditory cues of varying pitch and

loudness. Additionally, similar to the findings from studies on olfactory-visual pairings, prior research has emphasized the importance of congruency in auditory-olfactory crossmodal correspondences. When accompanied by a congruent sound, evaluations of odour pleasantness are significantly higher (Seo & Hummel, 2011; Seo, Lohse, Lockett & Hummel, 2014). These congruent sound-smell pairings have also been shown to influence ratings of environmental pleasantness. For example, the experience of shopping has been rated as significantly more enjoyable when Christmas scents (e.g., cinnamon) are paired with Christmas music, compared to other music genres (Spangenberg, Grohmann & Sprott, 2004). It has been suggested that because the auditory cues themselves are rated as pleasant, that this effect could be explained by the transfer of hedonic ratings from the auditory to olfactory modality (Velasco, Balboa, Marmolejo-Ramos & Spence, 2014). However, this effect may also be modulated by the ability to identify the odours, which has been shown to increase perceptions of odour pleasantness, and has been found to improve when odours are accompanied by semantically congruent sounds (Seo & Hummel, 2011; Seo et al., 2014). Therefore, there is significant evidence to support the argument that olfactory perception can be moderated by available sounds.

### **Olfaction-Vision-Audition Crossmodal Associations**

To our knowledge, there are only two studies that have researched the relationship between smell and more than one other sensory modality. Both examined the interaction of the olfactory, auditory, and visual systems. Through a series of intricate comparisons, it has been demonstrated that specific scents are consistently matched with the same pitch and shape descriptors across participants. In forming these associations, odours were preferentially matched with sounds and decisions appear to have been made along emotional dimensions (e.g., arousing scents were matched to arousing sounds). Thus, it was proposed that an olfactory-



visual-auditory crossmodal association might be emotion dependent (Crisinel, Jacquier, Deroy & Spence, 2013). The interaction of odourants congruent and incongruent with audio-visual stimuli has also been studied in relation to fear responses. Regardless of the congruency of audio-visual and olfactory stimuli a fear response was elicited. However, when all three sensory systems communicated fear (i.e. were congruent) the fear response was marginally stronger, indicating that the odours increased the experience of fear elicited by the audio-visual stimuli (de Groot, Semin & Smeets, 2014).

In summary, prior research has suggested that olfaction can influence visual processing (Chen et al., 2013; Jadauji et al., 2013; Robinson et al., 2013; Robinson et al., 2014; Sarfarazi et al., 1999; Seigneureic et al., 2010; Seo et al., 2010) and may also potentially modulate auditory perception (Cohen et al., 2011; Skals et al., 2004; Wesson & Wilson, 2010). The effect of sensory congruency has been shown to play a role in multisensory interactions, notably by directing visual attention (Chen et al., 2013; Robinson et al., 2013; Robinson et al., 2014; Seigneureic et al., 2010; Seo et al., 2010) and modulating perceived odour pleasantness (Seo & Hummel, 2011; Seo et al., 2014; Spangenberg et al., 2004). Few studies have investigated more complex olfactory crossmodal associations (Crisinel et al., 2013; de Groot et al., 2014) and the existing findings are limited by their artificiality. For example, although comparing scents to musical tones and geometric shapes (Crisinel et al., 2013) are important ways to isolate certain properties that may be used to describe olfactory dimensions, these situations do not represent how odours are naturally encountered. Therefore, the question remains as to how odours influence day-to-day experiences.

In the present study we investigated the interaction of smell with vision and audition, by examining how the perception of short movie clips changed when accompanied by congruent, or

incongruent odours. We focused on the role smell plays in modulating other senses, and in doing so we applied congruency findings from prior work demonstrating the influence of other sensory modalities on olfactory perception (e.g., Seo et al., 2014), to the current research on how smell can drive multisensory interactions. Our study also expanded on past findings by using evidence that highlighted the importance of congruency in pairs of multisensory interactions (e.g., Chen et al., 2013; Seo & Hummel, 2011) in the examination of a three-way olfactory mediated crossmodal correspondence. In this investigation, we specifically aimed to confirm the existence of an olfactory-visual-auditory interaction suggested by previous research (Crisinel et al., 2013; de Groot et al., 2014), and to clarify the exact nature in which smell influences audio-visual perception. Furthermore, the current study also confronted the issue of artificiality that is prevalent in previous research (e.g., Belkin et al., 1997). By using naturalistic audio-visual stimuli we hoped to obtain a better understanding of how these senses truly interact under everyday circumstances.

Given previous evidence that congruency of crossmodal information can increase hedonic ratings and direct visual attention, we hypothesized that the presence of odours congruent with the audio-visual stimuli should enhance the experience of watching movie clips, compared to the no odour condition. If odours were found to interact with audio-visual stimuli in this manner, we also expected that exposure to incongruent odours would provide less experiential enhancement relative to the congruent odour condition.

### **Experiment 1**

Experiment 1 investigated the effect of olfactory stimulation on participant audio-visual experience using behavioural measures. We tested how smell influences the perception of audio-visual stimuli by presenting short video clips accompanied by odourants administered via an

olfactometer, which allowed for the precise control over odourant delivery. Following each odour-movie pairing participants completed three Likert scales, which were used as measures of audio-visual experience, assessing engagement (i.e., attention), emotional arousal, and pleasantness (i.e., emotional valence). It was hypothesized that the ratings for each of these dependent measures would increase when the videos were accompanied by a congruent odour, compared to no odour, and that relative to the effect of congruent odours, incongruent odours would have a smaller effect.

## Methods

Prior to conducting this study approval for all procedures was obtained through the University Research Ethics Board for Health Sciences Research at Western University.

**Participants.** A total of 35 students (18 females, 17 males) aged 18 to 19 ( $M = 18.43$ ,  $SD = 0.50$ ) participated in this study. All recruitment was conducted through Western's Psychology Research Participation Pool and students were granted 1.0 credits towards their course requirement for participating. Pilot testing of the program was conducted on two individuals, whose data were excluded from final analyses. The data for a participant who did not complete the full task was also excluded, as well as the data for two more students due to technical malfunctions. Eligible participants must have reported normal hearing and smell as well as normal or corrected to normal vision. Individuals with perfume allergies or sensitivities were excluded from participation.

**Stimuli and presentation.** Six odourants were used as olfactory stimuli: pine (Bioforce Canada Inc., Dollard-des-Ormeaux, Québec), rose (NOW Foods, Bloomingdale, Illinois), ginger (NOW Foods, Bloomingdale, Illinois), baby oil (Johnson & Johnson Inc., Markham, Ontario), cherry (Green Earth Stores Ltd., London, Ontario), and patchouli (NOW Foods, Guelph,

Ontario). All of the odourants selected for this experiment were previously used as olfactory stimuli in other perceptual research (e.g., Chrea, Valentin, Sulmont-Ross, Ly Mai, Hoang Nguyen & Abdi, 2004). These six odours were chosen to have diverse qualities with the underlying aim that they would elicit stronger congruency effects.

A computer-controlled air-dilution olfactometer (OLFACT-fMRI, Osmic Enterprises Inc., Cincinnati, Ohio) delivered all odours by passing clean air through vials containing cotton pads saturated with 5-7 ml of the undiluted odourants. This constant stream (2.0 L/min) of non-heated, non-humidified air diluted the odourants before participants received them through a nasal cannula. Odours were presented for 4 s, beginning 2 s before the onset of the video, to allow for the more pungent stimuli to reach participants and dissipate before the start of the next trial. Clean air was presented as a control for the one third of trials as “no odour” pairings.

Each of the six odours was paired with two congruent videos of the same subject (e.g., two different babies; Table 1), totalling 12 audio-visual stimuli. Rather than have only one video for each odour condition, we opted to have two, simultaneously providing more variety for participants and a greater number of trials. All videos were presented in a randomized order on a 15.6-inch laptop screen 6 times across two blocks, paired twice each with its congruent odour, its designated incongruent odour, and clean air.

Videos were sourced online from YouTube ([www.youtube.com](http://www.youtube.com)) and converted to .AVI format using an online file converting system (<http://www.clipconverter.cc>). A video-editing program (VideoPad Video Editor Free, v. 3.83 Intel, NCH Software, Co.) was used to shorten each of the videos to 15 s. The same program was used to overlay new soundtracks for those video clips that had a disrupted audio component as a result of editing. Custom Microsoft Visual

Table 1

*Congruent and Incongruent Pairings of Odour and Audio-Visual Stimuli*

Olfactory stimuli	Audio-visual stimuli	
	Congruent	Incongruent
Pine	Walking through forest	Cherry pie being served
Rose	Woman dancing	Soup being served
Ginger	Soup being served	Woman bathing baby
Baby oil	Woman bathing baby	Walking through forest
Cherry	Cherry pie being served	Panorama of cave
Patchouli	Panorama of cave	Woman dancing

*Note.* There were two each of the audio-visual stimuli shown here, varying slightly, but communicating similar information, totalling 12 videos overall.

Studio Express 12.0 code was used to run this experiment. Headphones delivered auditory information at a comfortable listening level.

**Measures.** Three Likert scales were used to probe participants' subjective experience of the audio-visual stimuli. These items required participants to provide a rating on a scale of 0 to 100. To measure how much attention the videos commanded the first scale had participants rate their level of engagement from boring to engaging. To assess emotion, we used the two-dimensional model of arousal and valence (Russell, 1980), and had participants rate their experience of the movie clips from unpleasant to pleasant, and not emotionally arousing to emotionally arousing.

**Procedure.** Upon arrival participants were taken to an individual testing room in the Brain and Mind Institute at Western University where they were seated and provided informed consent. Participants were told that they were going to see a series of videos while being presented a variety of smells, and that following each video they were to answer the three scales, which would be presented on-screen. They were to answer these three questions in terms of their response to the videos, and not the odour stimuli. Individuals were then fitted with headphones,

and a nasal cannula, which provided odours from the olfactometer. The computer program was loaded and the experimenter left the participant alone in the room.

On each trial participants were presented with an odour-video pairing that may be congruent, incongruent, or have no odour. The 24 odour-video pairings (12 congruent, 12 incongruent) and the 12 videos presented without an odour (i.e., no odour pairings) were presented once in each of the two blocks for a total of 72 presentations. The odour-video pairs were the same across all participants, but presented in a random order within the blocks. Directly following each of the 72 trials, participants answered the scales on-screen while clean air flowed through the nasal cannula to minimize olfactory desensitization. After the final trial, participants were debriefed and had the opportunity to ask the experimenter questions. It was anticipated that participants would take approximately 45 minutes to complete the experiment.

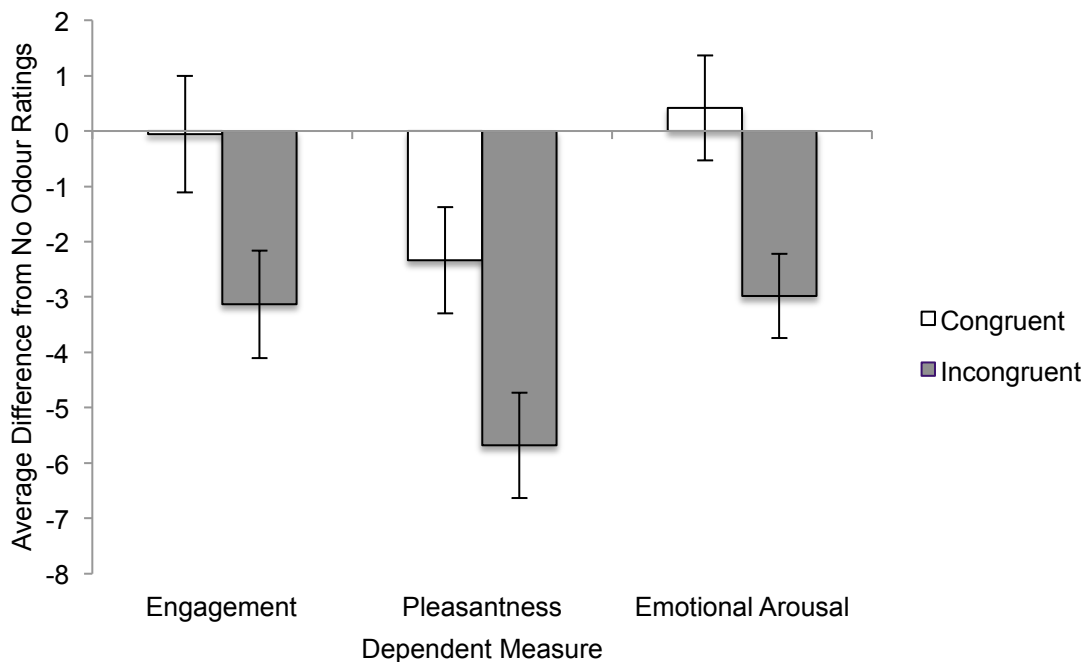
## Results

SPSS 22.0 (SPSS, Inc.) was used to analyze all behavioural data and POSTHOC was used to obtain the  $q$  values for Tukey's Honestly Significant Difference (HSD) post hoc test. Three separate 3 (Odour Condition)  $\times$  12 (Video) repeated measures analysis of variances (ANOVA) were conducted to investigate the influence of odour condition and video on ratings of engagement, pleasantness, and emotional arousal. Despite fulfillment of the sphericity assumption in all three cases (engagement:  $W = 0.845$ ,  $\chi^2(2) = 4.726$ ,  $ns$ ; pleasantness:  $W = 0.999$ ,  $\chi^2(2) = 0.020$ ,  $ns$ ; emotional arousal:  $W = 0.918$ ,  $\chi^2(2) = 2.408$ ,  $ns$ ), the Huynh-Feldt epsilon values were used to obtain a more conservative estimate.

**Effect of odour condition.** Odour condition had a significant effect on ratings of engagement,  $F(2, 54) = 7.068$ ,  $p = .002$ ,  $\eta^2 = .196$ , pleasantness,  $F(2, 58) = 17.740$ ,  $p < .001$ ,  $\eta^2 = .380$ , and emotional arousal,  $F(2, 58) = 8.183$ ,  $p = .001$ ,  $\eta^2 = .220$ . Thus, consistent with our

hypotheses, participants' perception of the audio-visual stimuli was significantly changed depending on the odour condition of the trial. However, as shown in Figure 1, for both engagement and emotional arousal, average ratings of congruent odours (engagement:  $M = 50.506$ ,  $SE = 2.176$ ; emotional arousal:  $M = 48.554$ ,  $SE = 2.019$ ) were virtually the same as trials without an odour (engagement:  $M = 50.544$ ,  $SE = 2.452$ ; emotional arousal:  $M = 48.106$ ,  $SE = 2.149$ ), and a priori paired  $t$ -tests revealed these slight differences as non-significant in both cases (engagement:  $t(29) = -0.053$ ,  $ns$ ; emotional arousal:  $t(29) = 0.441$ ,  $ns$ ). On the other hand, incongruent odours (engagement:  $M = 47.478$ ,  $SE = 2.021$ ; emotional arousal:  $M = 45.203$ ;  $SE = 2.195$ ) were significantly less engaging,  $t(29) = -3.160$ ,  $p = .002$ , and less emotionally arousing,  $t(29) = -3.924$ ,  $p < .001$ , compared to no odour. Therefore, the effect of odour operated opposite to our expectations, with incongruent odours having a greater effect than congruent odours and acting to negatively influence experience.

There was also a significant effect of odour condition on pleasantness ratings,  $F(2, 58) = 17.740$ ,  $p < .001$ ,  $\eta^2 = .380$ , indicating that participants' perception of video pleasantness varied significantly with the type of accompanying odour. Contrary to the pattern of results for engagement and emotional arousal ratings, on average, participants rated both congruent ( $M = 52.611$ ,  $SE = 1.628$ ) and incongruent ( $M = 49.315$ ,  $SE = 1.731$ ) trials as less pleasant than no odour ( $M = 54.943$ ,  $SE = 1.642$ ) trials. When analyzed with a priori paired  $t$ -tests, these comparisons of average pleasantness ratings for congruent,  $t(29) = -2.229$ ,  $p = .017$ , and incongruent,  $t(29) = -5.689$ ,  $p < .001$ , trials to no odour trials were both found to be significant. Overall, the presence of any odour was significantly less pleasant than not having an odour, with the incongruent odours having the larger effect, demonstrating again the opposite effect to what was hypothesized.



*Figure 1.* Average difference in the ratings of engagement, pleasantness, and emotional arousal for the congruent and incongruent odour trials compared to the average dependent measure ratings for the no odour trials. Error bars represent the standard errors of the means.

**Effect of video.** When collapsed across odour condition, considerable variability between the mean ratings of videos was seen for the three dependent measures (Figure 2). Indeed, the repeated measures ANOVA revealed this variability to be significant for ratings of engagement,  $F(5, 124) = 3.669, p = .006, \eta^2 = .112$ , pleasantness,  $F(6, 171) = 5.918, p < .001, \eta^2 = .169$ , and emotional arousal,  $F(4, 123) = 6.306, p < .001, \eta^2 = .179$ . Comparisons of the mean video ratings were assessed using Tukey's HSD post hoc test (Table 2).

**Odour  $\times$  video interaction effect.** These main effects of odour condition and video also interacted significantly for all three dependent measures (engagement:  $F(14, 401) = 1.915, p = .024, \eta^2 = .062$ ; pleasantness:  $F(9, 256) = 6.311, p < .001, \eta^2 = .179$ ; emotional arousal:  $F(4, 123) = 6.306, p < .001, \eta^2 = .179$ ). That is, the influence of odour congruency on participants'



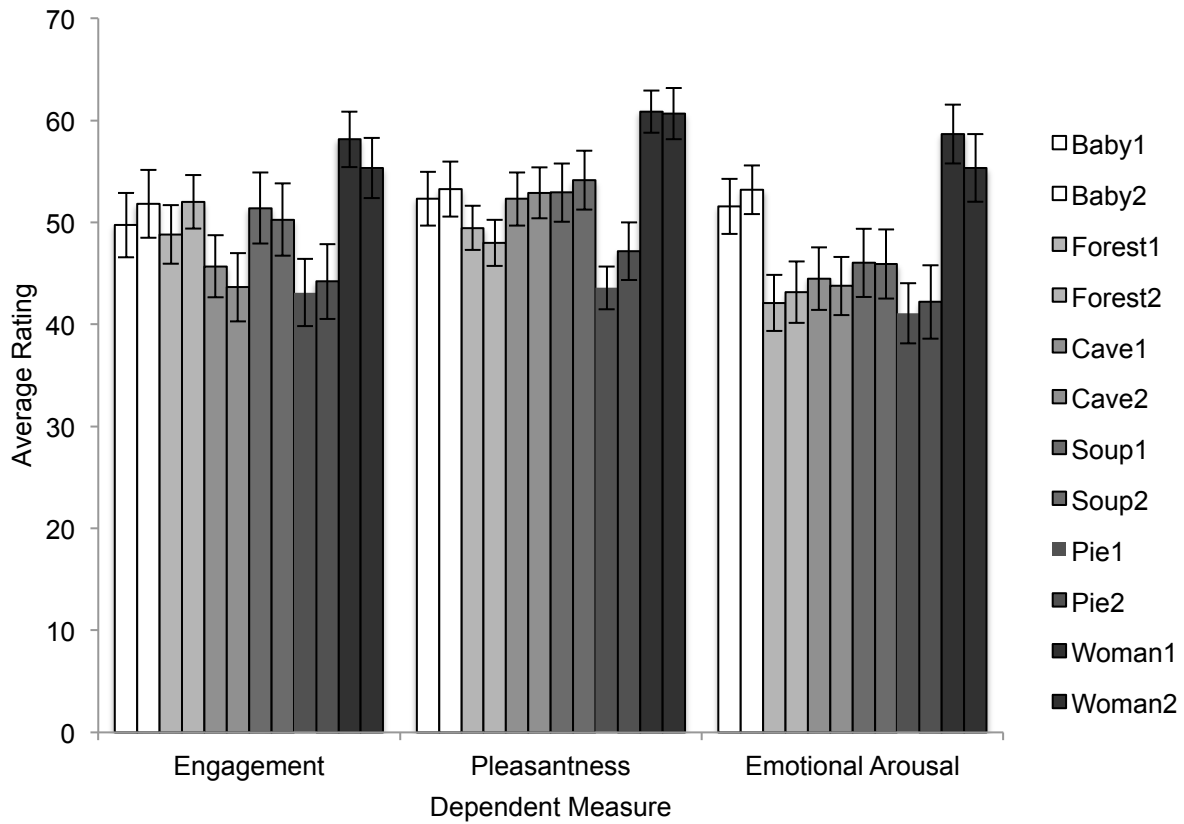


Figure 2. Average ratings for engagement, pleasantness, and emotional arousal (on a scale of 0-100) between videos when collapsed across odour conditions. Error bars represent the standard errors of the means.

Table 2.

*Significant Post Hoc Comparisons for Dependent Measures Between Videos*

Video Comparison	Engagement	<i>Q</i> Value	
		Pleasantness	Emotional Arousal
Baby1-Forest1		2.331	
Baby1-Pie1		3.532	
Soup1-Pie1	1.217		
Woman1-Forest1			2.533*
Woman1-Pie1	2.205		2.688
Woman1-Forest2		2.632*	2.369
Woman1-Cave2	2.127		2.277
Woman1-Soup2			1.950
Woman1-Pie2	2.044	2.795	2.515
Soup2-Pie1		2.156	
Woman2-Forest1		2.288	2.022
Woman2-Pie1	2.205	3.489*	
Woman2-Forest2		2.589	1.859
Woman2-Pie2		2.752	

*Note.* \* $p < .001$ . All other values significant at  $p < .05$ .

ratings of audio-visual experience varied with the video presented. As the odour-video pairings were not completely counterbalanced, we do not have all of the information required to unambiguously interpret this interaction effect. However, it appears that either some odours were more effective than others at modulating video perception, or that particular videos were more susceptible to the influence of the odours.

**Degree of congruency.** In light of the subjectivity of forming congruent odour-video pairs, additional analyses were conducted to investigate if the strength (or degree) of the congruency of the pairs considerably influenced results. That is, were some pairs better matched (i.e., more congruent) than others, and if so, could this account for some of the variation in the results. As making accurate congruent pairings of movies and odours is arguably more difficult than making incongruent matches, any variability in the effect of congruency should be greater for ratings of congruent trials than incongruent trials, if the degree of congruency did significantly contribute to our findings.

To investigate this, paired *t*-tests were conducted comparing the standard deviations of the difference between congruent-no odour and incongruent-no odour trials for each dependent measure. There was no significant difference in the effect of the congruency of the matches for any of the dependent measures (engagement:  $t(29) = 1.611$ , *ns*; pleasantness:  $t(29) = 0.024$ , *ns*; emotional arousal:  $t(29) = 0.537$ , *ns*). Therefore, any difference in the effect of the suitability of the matches on ratings was not statistically different for congruent and incongruent pairs.

## **Discussion**

The results of Experiment 1 provide evidence for the existence of an olfactory-visual-auditory crossmodal interaction. Specifically, our results revealed a significant decrease in audio-visual experience when videos were accompanied by an incongruent odour, and that this

influence was considerably greater than the effect of the congruent odours. These findings run counter to our hypothesis that congruent odours would have a greater, positive influence on experiential ratings. Instead, congruent odours were shown to have virtually the same effect as no odour on ratings of engagement and emotional arousal, although ratings of pleasantness significantly decreased, suggesting that all odours were, to an extent, unpleasant in comparison to clean air. Interpretation of the significant interaction effect is somewhat complicated by the fact that the odour-video pairs were not completely counterbalanced. It appears that either certain odours were more effective at modulating video perceptions, or that some videos were more susceptible to the influence of an odour. To our knowledge, these findings are the first to reveal a significant influence of olfaction on the perception of concurrently presented audio-visual stimuli.

The current results, however, challenge past crossmodal olfactory research that highlights the importance of congruency (e.g., Seo et al., 2014) and its role in enhancing perception in the measured modality. Some of this difference may be accounted for based on the different tasks performed, or the odourants used; however, in forming our hypotheses, we extrapolated the findings of bimodal comparisons driven by other senses, to our investigation of a three-way olfactory driven crossmodal correspondence. Thus, our results could simply reflect that these interactions operate differently in the opposite direction, or, as is quite likely, that the addition of a third sensory modality changes how they interact.

We speculate that the divergence of our results from previous research can be interpreted as crossmodal competition between the olfactory and audio-visual stimuli for the incongruent pairs. It is logical to postulate that the presence of a non-matching, and unexpected, odour could have drawn participants' attention away from the videos, and thus decreased their ratings of

engagement and emotional arousal, as results indicated. Although not supported by other olfactory crossmodal research, there is evidence to support this hypothesis in audio-visual research where neuroimaging evidence has shown a significant suppression of activity in the sensory regions for the modality that was not attended to by participants (Johnson & Zatorre, 2005).

Furthermore, the subjectivity, and malleability, of odour perception makes olfaction a unique sense that is particularly susceptible to the influence of accompanying sensory information (e.g., Cupchik, Phillips & Truong, 2005). It is quite possible that this effect of odour on the perception of the audio-visual stimuli was itself altered by the different accompanying videos, which is logical in light of our significant interaction effect. This is exacerbated by our use of subjective rating scales, which do not allow us to know for certain that participants were actually responding to the videos, as they were instructed, and cannot take into consideration differences in individuals' personal experience of the odour stimuli. The use of a more objective measure of audio-visual experience would begin to help reconcile this limitation, and confirm that the effects on our behavioural measures truly reflect the influence of the olfactory stimuli on audio-visual experience.

## **Experiment 2**

The results of Experiment 1 supported our general expectation that the odour condition would significantly influence perception of the movie clips, however the direction of the results was surprising and novel, inconsistent with the existing literature on olfactory crossmodal correspondence. The purpose of Experiment 2 was to investigate our hypothesis that these findings represent crossmodal competition. Employing a modified version of our behavioural design in an magnetic resonance imaging (MRI) environment, we assessed the brain activity of a

single participant who was presented the same odour-video stimuli in the scanner without the ratings scales.

The use of functional MRI (fMRI) provided us with an objective measure of the effect of odour, and allowed us to investigate the brain mechanisms mediating the interaction. It also made it possible for us to address some of the subjectivity of Experiment 1 by helping to clarify whether participants were responding to the audio-visual stimuli or the odours. Based on past research on non-matching sensory information and selective attention (e.g., Johnson & Zatorre, 2005), as well as our behavioural findings, we anticipated that a significant suppression of activity in the visual and auditory cortices would be seen with the presentation of an odour, and that this suppression would be greatest when the odour was incongruent.

## **Methods**

The University Research Ethics Board for Health Sciences Research at Western University approved all procedures for Experiment 2.

**Participant.** A single male undergraduate student aged 19 was recruited from Western University and participated in Experiment 2. The participant self-reported normal hearing, smell, and vision, completed the appropriate MRI screening forms, and provided informed consent. He was compensated \$15 per hour for his participation.

**Task.** The task was identical to that completed in the laboratory, except that the three rating scales were removed and replaced with a black screen for 10 s. MRI compatible, the olfactometer was used to deliver the same odourants through a nasal cannula to the participant inside the scanner, and odour presentation lasted for the full length of the video. Videos were back projected and viewed in a mirror while MRI compatible headphones (Sensimetrics Corp.) delivered the sound. The fMRI run took approximately 30 minutes. The participant also

completed a short recognition memory task following the scanning session. This required him to identify the image he had previously seen in a series of 12 pairs of screenshots (50% novel).

**MRI acquisition.** MRI data were acquired on a Siemens Prisma 3T at the Centre for Functional and Metabolic Mapping at the Robarts Research Institute, Western University. For functional MRI, two runs of 1330 volumes (15.2 mins) were acquired using T2\*-weighted echo-planar imaging (TR = 686 ms, TE = 30 ms, FA = 54 degrees, 36 slices, matrix size =  $64 \times 64$ , voxel size  $3 \times 3 \times 3.3$  mm). Multiband acceleration to acquire 4 slices simultaneously, using a sequence from the Center for Magnetic Resonance Research at the University of Minnesota. Brain anatomy was captured using a T1-weighted 3D MPRAGE sequence (TR = 2300 ms, TE = 2.98 ms, TI = 900 ms, matrix size  $240 \times 256 \times 192$ , 1 mm isotropic).

**Preprocessing.** Analysis was performed using the *automatic analysis* pipeline software (Cusack et al., 2015) with SPM8. The fMRI data were motion corrected, and co-registered to the anatomical image. The warping to transform the individual subject's space to the standard MNI-152 template space was derived from the anatomical image using SPM's normalisation and then applied to the fMRI volumes. The fMRI data were smoothed with a Gaussian kernel (10 mm full-width half-maximum).

**Statistical analyses.** A general linear model, as implemented in SPM8 was used to separate the responses to the three conditions. Specifically, for each of the two runs, a boxcar regressor was formed for the no-odour, incongruent, and congruent conditions. To correct for multiple comparisons across the brain, we used the conservative family-wise error (FWE) threshold, with an alpha of 0.05. These regressors were then compared, collapsing across sessions, by a set of contrasts. These included contrasts of no odour-incongruent, no odour-congruent, and congruent-incongruent.

## Results

Analysis of the general brain activity when the participant was watching the videos versus baseline revealed strong activation in the visual cortex, and to a lesser extent the auditory, parietal, and frontal regions, all of which were significant at  $p < 0.05$ , corrected for multiple comparisons (Figure 3A; Table 3; see Appendix A for additional regions of activation). As expected, additional contrasts revealed results that mirrored our behavioural findings. The presence of congruent (Figure 3B) and incongruent (Figure 3C) odours produced widespread suppression in the movie response compared to the no odour trials (both  $p < 0.05$  FWE). This reduction was significantly less for the congruent trials compared to the incongruent trials ( $p < .001$  uncorrected; Figure 3D), supporting the direction of the behavioural results.

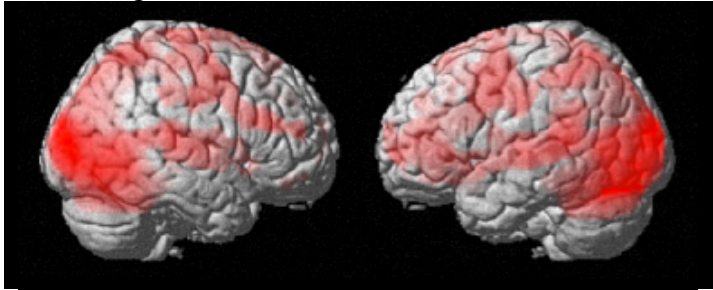
**Recognition memory task.** The participant successfully identified ten of the 12 recognition memory pairs. However, with only a single participant, and presentation of the videos in all three odours conditions, interpretation of this data is limited.

## Discussion

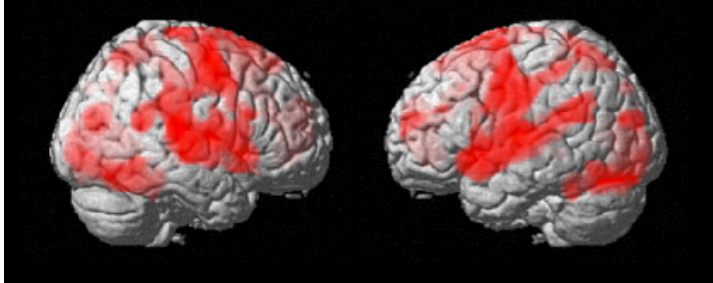
The presence of any odour significantly reduced activity in the visual and auditory cortices of the participant compared to the no odour trials, and this suppression was greatest when an incongruent odour was presented. These results reflect our findings from Experiment 1 and support our hypothesis that the behavioural results for the incongruent condition could represent crossmodal competition. Therefore, it seems even more likely with this neuroimaging data, that the decrease in engagement and emotional arousal ratings seen in



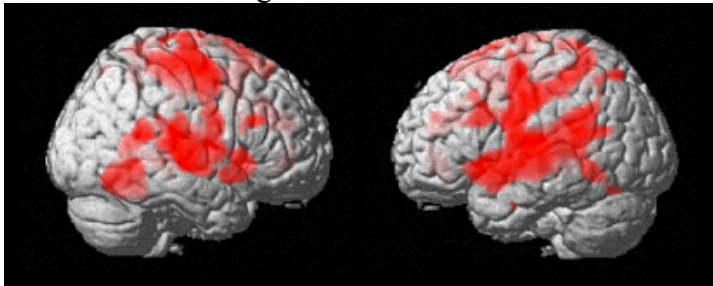
A. Collapsed across all three conditions



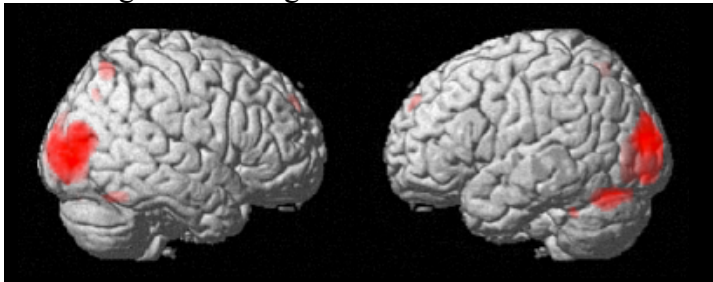
B. No Odour-Incongruent Contrast



C. No Odour-Congruent Contrast



D. Congruent-Incongruent Contrast



*Figure 3.* Plots of the contrasts between odour conditions. Figures 3A-C  $p < .05$  (FWE-corr). Figure 3D  $p < .001$  (uncorr).

Table 3.

*Regions Activated by Video and Olfactory Stimulation*

Brain Region	MNI Coordinates (mm)			Peak $T$	$p$ value
	x	y	z		
All-baseline					
Right occipital region	24	-94	10	42.94	0.000
Right hippocampal region	24	-26	-2	7.83	0.000
Right orbitofrontal region	20	42	-18	5.32	0.001
Left hippocampal region	-22	-32	-2	4.41	0.031
No odour-incongruent					
Right precentral region	50	-2	54	7.62	0.000
Left frontal region	-30	60	16	5.82	0.000
Left occipital region	-30	-88	20	5.28	0.001
Left hippocampal region	-16	-34	-2	5.12	0.001
No odour-congruent					
Left temporal region	-54	0	-4	6.83	0.000
Right precentral region	50	-6	54	6.76	0.000
Left hippocampal region	-24	-32	-8	4.50	0.022
Right inferior frontal region	64	18	22	4.85	0.005
Congruent-incongruent					
Left occipital region	-30	-92	16	5.07	0.002
Left cerebellar region	-34	-66	-24	4.66	0.011

*Note.* Corrected for multiple comparisons across the brain.

Experiment 1, can be attributed to participant distraction by, and attention to, the non-matching odour, and causing a shift in their attention away from the video.

This finding is consistent with past research of selective attention and crossmodal competition in other pairs of modalities, particularly vision and sound (Johnson & Zatorre, 2005). There is considerable neuroimaging evidence that has demonstrated a suppression of neural activity according to attentional processes both within, and across, modalities (e.g., Smith, Singh & Greenlee, 2000). There has not been, to our knowledge, any previous research involving the olfactory modality investigating these unimodal or crossmodal competition paradigms. Additionally, the behavioural research on olfactory crossmodal correspondences does not support this idea of competition between olfaction and the other senses. The literature has primarily focussed on the finding that congruent odours are important in facilitating the ability for olfactory information to influence the perception of other sensory stimuli (Chen et al., 2013; Robinson et al., 2013; Robinson et al., 2014; Seigneuric et al., 2010; Seo et al., 2010; Seo & Hummel, 2011; Seo et al., 2014; Spangenberg et al., 2004). Interestingly, there is evidence that olfactory processing changes depending on how the odour is attended to (Rolls, Grabenhorst, Margot, de Silva & Velazco, 2008), and competition has been shown to occur binarily (i.e., between the nostrils; Gottfried, 2009). Thus, there are findings to support the idea of olfactory stimuli engaging in sensory competition.

Furthermore, these neuroimaging results help to reconcile some of the subjectivity of Experiment 1 by supporting our assumption that participants were responding to the rating scales for their experience of the audio-visual stimuli. There was a clear change in the activity of the auditory and visual brain regions upon the presentation of the odours, suggesting the ability for odour to simultaneously modify early level sensory processing in the visual and auditory

cortices. This suppression of brain activity mirrors our behavioural results, thereby supporting that our scales accurately measured the general change in audio-visual experience according to the different odour conditions.

Of course, these findings are limited by the fact that only one individual participated in Experiment 2; however, activation was very significant for our relevant contrasts, indicating the strength of this effect. The fact that the changes in brain activity reflected the findings of our behavioural experiment also helps to confirm their validity. Further research involving more participants would be useful to further investigate the specific brain regions involved in this interaction, and how they change with the presentation of different stimuli. Additional participants could help to clarify the role of memory, and how it relates to the crossmodal competition seen in the interaction of the olfactory, visual, and auditory modalities.

### **General Discussion**

The purpose of the present study was to investigate how an odour stimulus affects the perception of concurrent audio-visual stimulation. Despite the importance of odours to many species, the understanding of how smell can influence the perception of information in other sensory modalities remains poor (Keller & Vosshall, 2004). In Experiment 1, we presented a series of short movie clips paired with semantically congruent or incongruent odours, and assessed participants' audio-visual experience. We hypothesized that a congruent odour should enhance ratings of engagement, pleasantness, and emotional arousal, compared to no odour, and that relative to congruent pairs, incongruent trials would provide less experiential enhancement. Using the same experimental design in Experiment 2, but excluding the three rating scales, we acquired fMRI data to provide an objective measure of the effect of odour, and to investigate the brain mechanisms mediating the interaction.

Overall, the findings of this study support our general hypothesis that the odour condition would significantly influence how participants perceived the audio-visual stimuli. However, the odours operated in the opposite manner to what was expected. Rather than the congruent odours, incongruent odours had a greater effect on video perception, and this effect acted to negatively influence experience. The effect of the congruent odours had little effect on the behavioural ratings of engagement and emotional arousal, although pleasantness ratings were significantly lower compared to the no odour trials. The neuroimaging results reflected these behavioural findings with a significant reduction in the movie response during odour trials compared to no odour trials, and this effect was greatest for the incongruent odour trials.

### **Comparison to Past Research**

Indeed, these results are not in line with a number of studies. Our hypotheses were based on three general findings: (1) congruent odours can facilitate visual attention (Chen et al., 2013; Robinson et al., 2013); (2) the pleasantness of an odour is increased when accompanied by a congruent visual or auditory stimulus (Seo & Hummel, 2011; Seo et al., 2014; Spangenberg et al., 2004); and (3) preliminary evidence suggesting an interaction of olfaction, vision and audition (Crisinel et al., 2013; de Groot et al., 2014). All of these findings highlight the importance of congruency and its role in enhancing perception in the measured modality, which the present findings certainly did not demonstrate.

It may be that the difference between tasks of the studies probing the effect of odour on visual attention and ours can account for the divergent findings. The current task did not require individuals to find, identify, or scan for a particular object within the context of distractor stimuli, as did the research probing visual attention (Chen et al., 2013; Robinson et al., 2013; Seigneure et al., 2010; Seo et al., 2010). Rather, the subject of the videos was always obvious

and was the only visual stimulus participants were attending to during experimentation. Thus, it could be that our study simply did not require the congruent odour to facilitate visual attention, and so the expected increase in engagement ratings for videos accompanied by a congruent odour was not seen.

Additionally, it is likely that our choice of odours can account for the decrease in pleasantness ratings for the congruent odour trials as these results diverged considerably from the pattern of findings seen for the other dependent measures. However, our hypothesis was based on past findings that auditory and visual stimuli can modulate the hedonics of odour stimuli (Seo & Hummel, 2011; Seo et al., 2014; Spangenberg et al., 2004). As the ability for an odour to modulate the hedonics of an auditory or visual stimulus has not been investigated, it could be that this relationship operates differently in the opposite direction.

It is also possible, that our pleasantness results for the congruent pairs mimic the effects seen in the uncanny valley. The uncanny valley is a hypothesis that a robot that looks and acts almost, but not quite, humanlike causes repulsion, compared to a robot that clearly looks like a machine (Jentsch, 1997). As our odours were essential oils, they smelled closely to the real object, but when matched with a very naturalistic scene (i.e., the videos) may have been perceived as “not quite right.” A repulsion response to this slight mismatch may be what was reflected in the decrease in pleasantness ratings for the congruent pairs.

Lastly, our results do not support the findings of de Groot and colleagues (2014), who conducted the only other study that assessed participant response to simultaneously presented olfactory and audio-visual stimuli. In contrast, they found that a fear odour, compared to neutral odour, only very slightly increased the experience of fear when presented with fearful video clips. It is likely that their use of fear-communicating stimuli can account for the non-significant

difference between congruent and incongruent trials, where we found a strongly significant difference. Fear is often lifesaving and therefore would naturally take precedence over the neutral sensory information in the incongruent trials, closing the gap between the congruent and incongruent trials (de Groot et al., 2014).

As for why past research has continually found an enhancing effect of congruent multisensory information (e.g., Seo et al., 2010), and we did not, requires further research to fully understand. However, our current findings may be explained by the redundancy of the multisensory information in the congruent trials. There are two potential outcomes when redundant multisensory information is integrated: enhancement and equivalence (Partan & Marler, 1999). As the olfactory multisensory literature has thus far favoured the enhancement outcome, we made our hypotheses in line with this, assuming that the addition of a third sensory modality would increase the richness and realism of the audio-visual stimuli, consequently enhancing its overall experience. However, our behavioural findings appear to reflect the equivalency outcome, that is, that the result is equivalent to the effect of either stimulus individually. This is evident when comparing the similarity of the ratings of the no odour trials, which communicated only the audio-visual information, and the congruent odours trials. It may instead be argued that these results do not reflect a crossmodal integration of information between the odours and movies; however, the significant difference in the effect of congruent odours versus incongruent odours on the movie ratings, clearly demonstrates that this is not the case.

Since there is indeed a crossmodal interaction of the olfactory and audio-visual stimuli, an explanation for the inconsistency of the incongruent results with past findings must also be provided. In light of our novel findings of Experiment 1, we suggested that our findings might

reflect crossmodal competition. That is, in the face of an incongruent odour-video pairing, we speculated that participants chose to attend to the olfactory stimulus over the video because it was unexpected. Therefore, as participants were specifically instructed to complete the rating scales based on their response to the movie clips, if the incongruent odour captured their attention, their ratings of engagement and emotional arousal should decrease.

We investigated this hypothesis in Experiment 2, using neuroimaging to acquire a more objective measure. When accompanied by a congruent or incongruent odour, a significant reduction was seen in the movie response, supporting the idea that participants' attention has been shifted away from the auditory and visual modalities. Mirroring the behavioural results, this effect was stronger for incongruent than congruent odours. These results are consistent with previous research, which has shown a suppression of activity accompanying a shift in attention between information in different sensory modalities (Johnson & Zatorre, 2005; Smith et al., 2000). Thus, it appears quite logical that we can account for the strong, negative effect seen during incongruent trials by a shift in attention away from the audio-visual modalities to the information communicated by the olfactory modality.

### **Significance of Results**

Our study is the first to empirically demonstrate that olfactory stimulation can significantly influence how concurrently presented audio-visual stimuli are perceived. Our results highlight the role of incongruent olfactory information and crossmodal competition, as well as the effect of the redundant information of congruent odours in supporting sensory equivalency rather than enhancement. This research also adds to the overall understanding of olfaction and how multisensory information is combined to influence human experience.



Ideally, this work will motivate further research in this field, which is certainly needed in order to better understand how smell interacts with the other senses.

### **Implications and Applications**

The findings of this research may find applications in industry, which is eager to incorporate the use of scents into marketing and entertainment (e.g., Krishna, 2012). At this time, results appear to discourage the use of odours in marketing and entertainment as they have little effect on engagement and emotional arousal. However, as research in this area evolves, it will be beneficial to apply findings to inform the business, hospitality and entertainment industries.

Furthermore, additional research of this olfactory-visual-auditory interaction in an MRI environment would be useful to clarify the suggested interpretation of our results. Neuroimaging might also be used to locate the locus of multisensory interactions. Specifically, it would allow us to measure whether representations within auditory and visual sensory systems are changed by a concurrent odour, or whether the interactions are more cognitive, and only affect fronto-parietal systems.

Future findings may also have relevant clinical applications, as olfactory deficits are a precursor for several neurodegenerative disorders (e.g., Alzheimer's) and may reflect a disruption of the immune system (Atanasova et al., 2008). Thus, how perception of other sensory modalities changes with the disruption of smell could be important in understanding some of the symptoms of these disorders. Finally, as crossmodal associations have been thought to engage higher-level brain functioning to integrate and perceive sensory combinations, a deeper understanding of how olfactory, visual, and auditory stimuli interact may yield new paradigms that are aimed at detecting high-level brain functions in non-communicative patients.

### **Limitations and Future Directions**

Participants were not screened for normal odour detection and discrimination; however, they were required to report normal smell before taking part in this study. Additionally, it is unclear what the effect of the exact choice of odours, and their concentrations, will have had on our results. Supplementary statistical analyses did not find a significant influence on dependent measure ratings of the degree of congruency, supporting the idea that our specific odour-video matches were not a significant influencing factor. However, it remains unknown whether other odours (or other videos) might yield different interactions. Future studies might expand the selection of videos and odours.

Although significant, interpretation of the odour  $\times$  video interaction was limited by our incomplete counterbalancing. A better understanding of this interaction could clarify why the effect of congruency was inverted in this study compared to previous research. The knowledge of what smells are most effective at modulating audio-visual information, and which audio-visual contexts are more susceptible to the influence of an odour could also be important information for future olfactory crossmodal studies.

Furthermore, the use of subjective rating scales leaves some ambiguity surrounding how exactly participants responded to the stimuli. Objective psychophysics measures might confirm the behavioural effects of this study. An objective attentional monitoring task, for which change in performance as a result of odour might be assessed, would also be useful to further investigate the idea that selective attention is involved in the incongruent condition.

Overall, additional research is required in order to confirm, and better understand, the nature of this olfactory-visual-auditory crossmodal interaction. Future studies should investigate

more closely how these three sensory modalities interact by assessing the effect of each modality separately, as well as together, in order to understand how they change when combined.

### **Conclusions**

In summary, our findings are the first to demonstrate that odours can significantly modulate the perception of concurrent audio-visual stimulation. Specifically, we found that incongruent odours had a greater effect on video perception than congruent odours, and this effect acted to negatively influence experience. We suggest that this reflects crossmodal suppression, which is supported by our neuroimaging results as well as past research on selective attention in other pairs of modalities (e.g., Johnson & Zatorre, 2005). Overall, our study adds to the limited research investigating the role olfaction plays in modulating the other senses, although it does not support past findings. Further study is needed to better understand the nature of this olfactory-visual-auditory interaction.

### References

- AlumoMusic. (2012, December 29). *Happy background music – sunny side up by Alumo* [Video file]. Retrieved from <https://www.youtube.com/watch?v=nRy0W3jpk7Q>
- AlumoMusic. (2014, October 27). *Happy music for youtubers - 'make it shine' by Sophonic* [Video file]. Retrieved from <https://www.youtube.com/watch?v=JUaXos3ugDo>
- AnimalX. (2014, July 17). *Animals living in caves in Thailand* [Video file]. Retrieved from <https://www.youtube.com/watch?v=gXENLlyT2cM>
- Atanasova, B., Graux, J., El Hage, W., Hommet, C., Camus, V., & Belzung, C. (2008). Olfaction: a potential cognitive marker of psychiatric disorders. *Neuroscience & Biobehavioral Reviews*, 32(7), 1315-1325. doi:10.1016/j.neubiorev.2008.05.003
- Belkin, K., Martin, R., Kemp, S. E., & Gilbert, A. N. (1997). Auditory pitch as a perceptual analogue to odor quality. *Psychological Science*, 8(4), 340-342. doi:10.1111/j.1467-9280.1997.tb00450.x
- Bilgunko. (2009, August 6). *Girls in Paris - Aldo Giovanni & Melody Prochet*. [Video file]. Retrieved from <https://www.youtube.com/watch?v=r9JVJDEqbSg>
- Boomer963z (2009, April 27). *A Cinderella Story – best day of my life* [Video file]. Retrieved from [https://www.youtube.com/watch?v=z\\_KLOWdB8mY](https://www.youtube.com/watch?v=z_KLOWdB8mY)
- Brand, G., & Millot, J. (2001). Sex differences in human olfaction: Between evidence and enigma. *The Quarterly Journal of Experimental Psychology Section B*, 54(3), 259-270. doi:10.1080/713932757
- Bushdid, C., Magnasco, M. O., Vosshall, L. B., & Keller, A. (2014). Humans can discriminate more than 1 trillion olfactory stimuli. *Science*, 343(6177), 1370-1372. doi:10.1126/science.1249168

- Chen, K., Zhou, B., Chen, S., He, S., & Zhou, W. (2013). Olfaction spontaneously highlights visual saliency map. *Proceedings of the Royal Society B: Biological Sciences*, 280(1768), 20131729. doi:10.1098/rspb.2013.1729
- Chrea, C., Valentin, D., Sulmont-Rossé, C., Ly Mai, H., Hoang Nguyen, D., & Abdi, H. (2004). Culture and odor categorization: agreement between cultures depends upon the odors. *Food Quality and Preference*, 15(7), 669-679. doi:10.1016/j.foodqual.2003.10.005
- Cohen, L., Rothschild, G., & Mizrahi, A. (2011). Multisensory integration of natural odors and sounds in the auditory cortex. *Neuron*, 72(2), 357-369. doi:10.1016/j.neuron.2011.08.019
- Crisinel, A. S., Jacquier, C., Deroy, O., & Spence, C. (2013). Composing with cross-modal correspondences: music and odors in concert. *Chemosensory Perception*, 6(1), 45-52. doi:10.1007/s12078-012-9138-4
- Cupchik, G., Phillips, K., & Truong, H. (2005). Sensitivity to the cognitive and affective qualities of odours. *Cognition & Emotion*, 19(1), 121-131. doi:10.1080/0269993044100011
- Cusack, R., Vicente-Grabovetsky, A., Mitchell, D.J., Wild, C.J., Auer, T., Linke, A.C. Peelle, J.E. (2015). Automatic analysis: efficient neuroimaging workflows and parallel processing using Matlab and XML. *Frontiers in Neuroinformatics*, 8(90), 1-13. doi:10.3389/fninf.2014.00090
- de Groot, J. H., Semin, G. R., & Smeets, M. A. (2014). I can see, hear, and smell your fear: Comparing olfactory and audiovisual media in fear communication. *Journal of Experimental Psychology: General*, 143(2), 825-834. doi:10.1037/a0033731
- Demattè, M. L., Sanabria, D., & Spence, C. (2009). Olfactory discrimination: when vision

- matters?. *Chemical Senses*, 34(2), 103-109. doi:10.1093/chemse/bjn055
- Deroy, O., Crisinel, A. S., & Spence, C. (2013). Crossmodal correspondences between odors and contingent features: odors, musical notes, and geometrical shapes. *Psychonomic Bulletin & Review*, 20(5), 878-896. doi:10.3758/s13423-013-0397-0
- Entertaining with Beth. (2013, January 12). *Beth's easy potato and leek soup with garlic croutons* [Video file]. Retrieved from <https://www.youtube.com/watch?v=5dHAo23nmLU>
- EvilMonkey552. (2011, May 11). *Cinderella story dance scene* [Video file]. Retrieved from <https://www.youtube.com/watch?v=C1e1oyKd-iQ>
- Gottfried, J. A. (2009). Olfaction: when nostrils compete. *Current Biology*, 19(18), R862-R864. doi:10.1016/j.cub.2009.08.030
- Gottfried, J. A., & Dolan, R. J. (2003). The nose smells what the eye sees: crossmodal visual facilitation of human olfactory perception. *Neuron*, 39(2), 375-386. doi:10.1016/S0896-6273(03)00392-1
- Inspired Taste. (2013, June 27). *How to make homemade strawberry pie – strawberry pie recipe* [Video file]. Retrieved from <https://www.youtube.com/watch?v=FD1B6FOjySA>
- Jadauji, J. B., Djordjevic, J., Lundström, J. N., & Pack, C. C. (2012). Modulation of olfactory perception by visual cortex stimulation. *The Journal of Neuroscience*, 32(9), 3095-3100. doi:10.1523/JNEUROSCI.6022-11.2012
- Jentsch, E. (1997). On the psychology of the uncanny (1906) 1. *Angelaki: Journal of the Theoretical Humanities*, 2(1), 7-16. doi:10.1080/09697259708571910
- Johnson's Baby. (2012, February 23). *Nice work | Johnson's® baby commercial – head-to-*

- toe® wash* [Video file]. Retrieved from <https://www.youtube.com/watch?v=qvE1-U6C4fE>
- Johnson's Baby. (2012, February 23). *Mom thing | Johnson's® baby commercial – baby lotion* [Video file]. Retrieved from <https://www.youtube.com/watch?v=7axKvxkSIsQ>
- Johnson's Baby. (2012, February 23). *You're doing OK, Mom! | Johnson's® baby commercial* [Video file]. Retrieved from <https://www.youtube.com/watch?v=yotq4zr0dRc>
- Johnson, J. A., & Zatorre, R. J. (2005). Attention to simultaneous unrelated auditory and visual events: behavioral and neural correlates. *Cerebral Cortex, 15*(10), 1609-1620.  
doi:10.1093/cercor/bhi039
- Joy of Baking. (2014, November 6). *Cherry pie recipe demonstration – Joyofbaking.com* [Video file]. Retrieved from <https://www.youtube.com/watch?v=pN6SxZ7FdoA>
- Keller, A., & Vosshall, L. B. (2004). Human olfactory psychophysics. *Current Biology, 14*(20), R875-R878.
- Kin Community. (2012, September 15). *Beth's grilled cheese and soup recipes: full menu (sandwiches mozzarella cheddar brie) || kin eats* [Video file]. Retrieved from <https://www.youtube.com/watch?v=iwOsit-OxNM>
- Krishna, A. (2012). An integrative review of sensory marketing: Engaging the senses to affect perception, judgment and behavior. *Journal of Consumer Psychology, 22*(3), 332-351.  
doi:10.1016/j.jcps.2011.08.003
- Nature 3D Taeuber. (2013, February 3). *Winter forest ride* [Video file]. Retrieved from <https://www.youtube.com/watch?v=ODEIiSAXlgc>
- Nature 3D Taeuber. (2014, February 5). *4K video, UHD: January forest walk (in the snow)* [Video file]. Retrieved from <https://www.youtube.com/watch?v=DU5UyBQcng4>

Partan, S., & Marler, P. (1999). Communication goes multimodal. *Science*, 283(5406), 1272-1273. doi:10.2307/2896573

Piessé, G. S. (1857). *The art of perfumery and methods of obtaining the odors of plants*. Philadelphia, PA: Lindsay and Blakiston.

Robinson, A. K., Mattingley, J. B., & Reinhard, J. (2013). Odors enhance the salience of matching images during the attentional blink. *Frontiers in Integrative Neuroscience*, 7(77). doi:10.3389/fnint.2013.00077

Robinson, A. K., Reinhard, J., & Mattingley, J. B. (2014). Olfaction Modulates Early Neural Responses to Matching Visual Objects. *Journal of Cognitive Neuroscience*. Advance online publication. doi:10.1162/jocn\_a\_00732

Rolls, E. T., Grabenhorst, F., Margot, C., da Silva, M. A., & Velazco, M. I. (2008). Selective attention to affective value alters how the brain processes olfactory stimuli. *Journal of Cognitive Neuroscience*, 20(10), 1815-1826. doi:10.1162/jocn.2008.20128

Russell, J. A. (1980). A circumplex model of affect. *Journal of personality and social psychology*, 39(6), 1161. doi:10.1037/h0077714

Sarfarazi, M., Cave, B., Richardson, A., Behan, J., & Sedgwick, E. M. (1999). Visual event related potentials modulated by contextually relevant and irrelevant olfactory primes. *Chemical Senses*, 24(2), 145-154. doi:10.1093/chemse/24.2.145

Seigneuric, A., Durand, K., Jiang, T., Baudouin, J. Y., & Schaal, B. (2010). The nose tells it to the eyes: crossmodal associations between olfaction and vision. *Perception*, 39(11), 1541. doi:10.1068/p6740

Seo, H. S., & Hummel, T. (2011). Auditory–olfactory integration: congruent or pleasant sounds



- amplify odor pleasantness. *Chemical senses*, 36(3), 301-309. doi:10.1093/chemse/bjq129
- Seo, H. S., Roidl, E., Müller, F., & Negoias, S. (2010). Odors enhance visual attention to congruent objects. *Appetite*, 54(3), 544-549. doi:10.1016/j.appet.2010.02.011
- Seo, H. S., Lohse, F., Luckett, C. R., & Hummel, T. (2014). Congruent sound can modulate odor pleasantness. *Chemical senses*, 39(3), 215-228. doi:10.1093/chemse/bjt070
- Skals, N., Anderson, P., Kannevorff, M., Löfstedt, C., & Surlykke, A. (2005). Her odours make him deaf: crossmodal modulation of olfaction and hearing in a male moth. *Journal of Experimental Biology*, 208(4), 595-601. doi:10.1242/jeb.01400
- Smith, A. T., Singh, K. D., & Greenlee, M. W. (2000). Attentional suppression of activity in the human visual cortex. *Neuroreport*, 11(2), 271-278. doi: 10.1097/00001756-200002070-00010
- Spangenberg, E. R., Grohmann, B., & Sprott, D. E. (2005). It's beginning to smell (and sound) a lot like Christmas: the interactive effects of ambient scent and music in a retail setting. *Journal of Business Research*, 58(11), 1583-1589. doi:10.1016/j.jbusres.2004.09.005
- Spence, C. (2011). Crossmodal correspondences: A tutorial review. *Attention, Perception, & Psychophysics*, 73(4), 971-995. doi:10.3758/s13414-010-0073-7
- Stevens, J. C., & Marks, L. E. (1965). Cross-modality matching of brightness and loudness. *Proceedings of the National Academy of Sciences*, 54(2), 407-411. doi:10.1073/pnas.54.2.407
- The Gray Boxwood. (2014, July 7). *Simple cherry pie* [Video file]. Retrieved from [https://www.youtube.com/watch?v=5l0mDJ\\_6-Wk](https://www.youtube.com/watch?v=5l0mDJ_6-Wk)
- [Untitled photograph of a cave]. Retrieved March 22, 2015, from:

<http://images.fineartamerica.com/images-medium-large/-cave-entrance-in-ohio-sven-brogren.jpg>

[Untitled photograph of a cherry pie]. Retrieved March 22, 2015, from:

<http://www.myadventuresinthecountry.com/wp-content/uploads/2011/11/CherryPie4.jpg>

[Untitled photograph of a slice of cherry pie]. Retrieved March 22, 2015, from:

<http://www.asweetpeachef.com/wp-content/uploads/2010/07/Sweet-Cherry-Pie.png>

[Untitled photograph of a Tasmanian cave]. Retrieved March 22, 2015, from:

[http://witchesdiary.com/lilyth/wp-content/uploads/2014/11/Newdegate\\_cave-Tasmania-Australia13-300x200.jpg](http://witchesdiary.com/lilyth/wp-content/uploads/2014/11/Newdegate_cave-Tasmania-Australia13-300x200.jpg)

[Untitled photograph of creamy corn soup]. Retrieved March 22, 2015, from:

<https://www.cuisinesolutions.com/media/products/creamycornandpoblanosoup/original.jpg>

[Untitled photograph of tomato soup]. Retrieved March 22, 2015, from:

<http://letschatfitness.co.uk/wp-content/uploads/2013/04/Tomato-Soup.png>

Velasco, C., Balboa, D., Marmolejo-Ramos, F., & Spence, C. (2014). Crossmodal effect of music and odor pleasantness on olfactory quality perception. *Name: Frontiers in Psychology*, 5(1352). doi:10.3389/fpsyg.2014.01352

Villemure, C., Slotnick, B. M., & Bushnell, M. C. (2003). Effects of odors on pain perception: deciphering the roles of emotion and attention. *Pain*, 106(1), 101-108. doi:10.1016/S0304-3959(03)00297-5

Wesson, D. W., & Wilson, D. A. (2010). Smelling sounds: olfactory–auditory sensory convergence in the olfactory tubercle. *The Journal of Neuroscience*, 30(8), 3013-3021. doi:10.1523/JNEUROSCI.6003-09.2010

Zellner, D. A., Bartoli, A. M., & Eckard, R. (1991). Influence of color on odor identification and liking ratings. *The American Journal of Psychology*, 547-561. doi:10.2307/1422940

Zellner, D. A., & Whitten, L. A. (1999). The effect of color intensity and appropriateness on color-induced odor enhancement. *The American Journal of Psychology*.  
doi:10.2307/1423652

## Appendix A

**Contrast: all-baseline**

STATISTICS: volume summary (labels and percentages for the entire volume)

=====

x,y,z {mm}	nom du label	% Cluster	Nb Vx	Cluster	% Label	Nb Vx Label
24 -94 10	Occipital_Mid_R	31.46	515	7.72	2098	
24 -94 10	Occipital_Sup_R	17.86	515	6.51	1413	
24 -94 10	Cuneus_R	9.32	515	3.37	1424	
24 -94 10	Calcarine_R	6.02	515	1.67	1861	
24 -94 10	OUTSIDE	0.19	515	0.00	0	
-8 -96 20	Occipital_Sup_L	48.93	515	18.45	1366	
-8 -96 20	Occipital_Mid_L	30.10	515	4.74	3270	
-8 -96 20	Calcarine_L	18.06	515	4.12	2258	
-8 -96 20	Cuneus_L	2.72	515	0.92	1526	
-8 -96 20	OUTSIDE	0.19	515	0.00	0	
4 -86 4	Calcarine_R	47.77	515	13.22	1861	
4 -86 4	Lingual_L	38.45	515	9.45	2095	
4 -86 4	Lingual_R	6.41	515	1.43	2300	
4 -86 4	Calcarine_L	0.58	515	0.13	2258	
4 -86 4	OUTSIDE	0.19	515	0.00	0	
24 -26 -2	Hippocampus_R	55.92	515	30.44	946	
24 -26 -2	ParaHippocampal_R		23.11	515	10.51	1132
24 -26 -2	Thalamus_R	0.58	515	0.28	1057	
24 -26 -2	Lingual_R	0.39	515	0.09	2300	
24 -26 -2	OUTSIDE	0.19	515	0.00	0	
20 42 -18	Frontal_Mid_Orb_R	42.33	515	21.48	1015	
20 42 -18	Frontal_Inf_Orb_R	25.83	515	7.79	1707	
20 42 -18	Frontal_Sup_Orb_R	23.88	515	12.34	997	
20 42 -18	Rectus_R	1.94	515	1.34	745	
20 42 -18	Frontal_Med_Orb_R		0.39	515	0.23	856
20 42 -18	OUTSIDE	0.19	515	0.00	0	
28 52 -12	Frontal_Sup_Orb_R	17.86	515	9.23	997	
28 52 -12	Frontal_Mid_R	15.53	515	1.57	5104	
28 52 -12	Frontal_Mid_Orb_R	0.19	515	0.10	1015	
28 52 -12	OUTSIDE	0.19	515	0.00	0	
-22 -32 -2	ParaHippocampal_L		36.31	515	19.12	978
-22 -32 -2	Hippocampus_L	35.34	515	19.53	932	
-22 -32 -2	Lingual_L	10.68	515	2.63	2095	
-22 -32 -2	Thalamus_L	3.11	515	1.45	1100	
-22 -32 -2	OUTSIDE	0.19	515	0.00	0	

table shows at most 3 local maxima > 8.0mm apart per cluster.

-----  
 Height threshold: T = 4.29, p = 0.000 (0.050)  
 Extent threshold: k = 0 voxels, p = 1.000 (0.050)  
 Expected voxels per cluster, <k> = 38.595  
 Expected number of clusters, <c> = 0.05  
 Expected false discovery rate, <= NaN  
 Degrees of freedom = [1.0, 2592.0]  
 Smoothness FWHM = 20.1 20.4 17.3 {mm} = 10.0 10.2 8.6 {voxels}  
 Search vol: 1379696 cmm; 172462 voxels; 179.5 resels  
 Voxel size: [2.0, 2.0, 2.0] mm (1 resel = 883.62 voxels)

=====  
 =====  
**noodour-cong**

STATISTICS: volume summary (labels and percentages for the entire volume)

=====  
 =====

x,y,z {mm}	nom du label	% Cluster	Nb Vx Cluster	% Label	Nb Vx Label
-54 0 -4	Temporal_Pole_Sup_L	68.74	515	27.55	1285
-54 0 -4	Insula_L	13.01	515	3.61	1858
-54 0 -4	Temporal_Mid_L	12.43	515	1.30	4942
-54 0 -4	Rolandic_Oper_L	2.14	515	1.11	990
-54 0 -4	Temporal_Sup_L	1.94	515	0.44	2296
-54 0 -4	OUTSIDE	0.19	515	0.00	0
-44 -40 22	Rolandic_Oper_L	36.70	515	19.09	990
-44 -40 22	Temporal_Mid_L	33.98	515	3.54	4942
-44 -40 22	Angular_L	22.72	515	9.97	1173
-44 -40 22	SupraMarginal_L	4.66	515	1.91	1256
-44 -40 22	Temporal_Sup_L	0.58	515	0.13	2296
-44 -40 22	OUTSIDE	0.19	515	0.00	0
-60 -4 24	Postcentral_L	26.21	515	3.47	3892
-60 -4 24	Precentral_L	15.53	515	2.27	3526
-60 -4 24	OUTSIDE	0.19	515	0.00	0
50 -6 54	Frontal_Mid_R	50.10	515	5.05	5104
50 -6 54	Postcentral_R	28.35	515	3.82	3823
50 -6 54	Precentral_R	20.19	515	3.08	3381
50 -6 54	OUTSIDE	0.19	515	0.00	0
68 -20 4	Temporal_Mid_R	78.25	515	9.14	4409

68 -20 4	Rolandic_Oper_R	17.86	515	6.91	1331	
68 -20 4	Temporal_Sup_R	0.19	515	0.03	3141	
68 -20 4	OUTSIDE	0.19	515	0.00	0	
40 -32 60	Parietal_Inf_R	82.14	515	31.45	1345	
40 -32 60	Postcentral_R	14.56	515	1.96	3823	
40 -32 60	Precentral_R	0.19	515	0.03	3381	
-24 -70 54	Parietal_Inf_L	80.58	515	16.96	2447	
-24 -70 54	Parietal_Sup_L	15.15	515	3.78	2065	
-24 -70 54	Precuneus_L	3.88	515	0.57	3528	
-24 -70 54	OUTSIDE	0.19	515	0.00	0	
-38 -66 54	Parietal_Sup_L	33.59	515	8.38	2065	
-38 -66 54	Parietal_Inf_L	28.74	515	6.05	2447	
-38 -66 54	Angular_L	21.75	515	9.55	1173	
-38 -66 54	OUTSIDE	0.19	515	0.00	0	
-14 -72 56	Precuneus_L	38.64	515	5.64	3528	
-14 -72 56	Parietal_Sup_L	18.25	515	4.55	2065	
-14 -72 56	OUTSIDE	0.19	515	0.00	0	
60 -52 -8	Temporal_Inf_R	38.25	515	5.54	3557	
60 -52 -8	Temporal_Mid_R	5.05	515	0.59	4409	
60 -52 -8	OUTSIDE	0.19	515	0.00	0	
42 -64 -16	Temporal_Inf_R	39.22	515	5.68	3557	
42 -64 -16	Cerebelum_Crus1_R	22.91	515	4.46	2648	
42 -64 -16	Fusiform_R	21.75	515	4.45	2518	
42 -64 -16	Cerebelum_6_R	7.77	515	2.23	1795	
42 -64 -16	Occipital_Inf_R	0.97	515	0.51	989	
42 -64 -16	OUTSIDE	0.19	515	0.00	0	
50 -62 -16	Cerebelum_Crus1_R	62.14	515	12.08	2648	
50 -62 -16	Fusiform_R	12.23	515	2.50	2518	
50 -62 -16	Temporal_Inf_R	11.46	515	1.66	3557	
50 -62 -16	Cerebelum_6_R	7.18	515	2.06	1795	
50 -62 -16	Occipital_Inf_R	6.80	515	3.54	989	
50 -62 -16	OUTSIDE	0.19	515	0.00	0	
-16 -34 -2	Hippocampus_L	25.05	515	13.84	932	
-16 -34 -2	ParaHippocampal_L	22.72	515	11.96	978	
-16 -34 -2	Precuneus_L	19.22	515	2.81	3528	
-16 -34 -2	Cerebelum_4_5_L	18.25	515	8.36	1125	
-16 -34 -2	Lingual_L	11.07	515	2.72	2095	
-16 -34 -2	Thalamus_L	2.72	515	1.27	1100	
-16 -34 -2	OUTSIDE	0.19	515	0.00	0	
-10 -48 2	Precuneus_L	31.65	515	4.62	3528	
-10 -48 2	Cerebelum_4_5_L	19.81	515	9.07	1125	
-10 -48 2	Lingual_L	17.28	515	4.25	2095	
-10 -48 2	Vermis_4_5	14.56	515	11.28	665	
-10 -48 2	Cingulum_Post_L	5.44	515	6.05	463	

-10 -48 2	Hippocampus_L	4.66	515	2.58	932	
-10 -48 2	Calcarine_L	0.39	515	0.09	2258	
-10 -48 2	OUTSIDE	0.19	515	0.00	0	
-24 -32 -8	ParaHippocampal_L		40.00	515	21.06	978
-24 -32 -8	Fusiform_L	32.82	515	7.32	2310	
-24 -32 -8	Hippocampus_L	21.94	515	12.12	932	
-24 -32 -8	Thalamus_L	4.08	515	1.91	1100	
-24 -32 -8	OUTSIDE	0.19	515	0.00	0	
16 -34 0	Cingulum_Post_R	26.80	515	41.19	335	
16 -34 0	Precuneus_R	21.36	515	3.37	3265	
16 -34 0	ParaHippocampal_R		15.53	515	7.07	1132
16 -34 0	Thalamus_R	7.96	515	3.88	1057	
16 -34 0	Lingual_R	5.24	515	1.17	2300	
16 -34 0	Hippocampus_R	0.19	515	0.11	946	
16 -34 0	OUTSIDE	0.19	515	0.00	0	
16 -48 4	Precuneus_R	43.50	515	6.86	3265	
16 -48 4	Cerebelum_4_5_R	30.29	515	18.12	861	
16 -48 4	Lingual_R	18.64	515	4.17	2300	
16 -48 4	Cingulum_Post_R	3.88	515	5.97	335	
16 -48 4	Vermis_4_5	1.55	515	1.20	665	
16 -48 4	ParaHippocampal_R		1.36	515	0.62	1132
16 -48 4	Calcarine_R	0.19	515	0.05	1861	
16 -48 4	OUTSIDE	0.19	515	0.00	0	
14 -58 -4	Fusiform_R	77.86	515	15.93	2518	
14 -58 -4	Cerebelum_6_R	15.34	515	4.40	1795	
14 -58 -4	Lingual_R	1.55	515	0.35	2300	
14 -58 -4	Vermis_4_5	0.39	515	0.30	665	
14 -58 -4	Cerebelum_4_5_R	0.19	515	0.12	861	
14 -58 -4	Calcarine_R	0.19	515	0.05	1861	
50 24 24	Frontal_Inf_Tri_R	12.23	515	2.93	2151	
50 24 24	Frontal_Inf_Oper_R	5.83	515	2.14	1399	
50 24 24	Frontal_Mid_R	2.33	515	0.24	5104	
50 24 24	OUTSIDE	0.19	515	0.00	0	
64 18 22	Precentral_R	39.81	515	6.06	3381	
64 18 22	Frontal_Inf_Tri_R	32.23	515	7.72	2151	
64 18 22	Frontal_Inf_Oper_R	8.35	515	3.07	1399	
64 18 22	OUTSIDE	0.19	515	0.00	0	
-46 -66 -20	Cerebelum_6_L	34.56	515	10.51	1694	
-46 -66 -20	Fusiform_L	23.69	515	5.28	2310	
-46 -66 -20	Temporal_Inf_L	21.75	515	3.50	3200	
-46 -66 -20	Occipital_Inf_L	11.84	515	6.48	941	
-46 -66 -20	Cerebelum_Crus1_L		5.44	515	1.08	2603
-46 -66 -20	OUTSIDE	0.19	515	0.00	0	
-2 42 0	Cingulum_Ant_R	59.61	515	23.38	1313	

-2	42	0	Frontal_Med_Orb_R	7.77	515	4.67	856
-2	42	0	Cingulum_Ant_L	7.57	515	2.79	1400
-2	42	0	Frontal_Sup_Medial_L	5.05	515	0.87	2992
-2	42	0	Frontal_Med_Orb_L	3.11	515	2.23	719
-2	42	0	Frontal_Sup_Medial_R	0.39	515	0.09	2134
-2	42	0	OUTSIDE	0.19	515	0.00	0
-22	44	26	Frontal_Sup_Medial_L	59.42	515	10.23	2992
-22	44	26	Frontal_Mid_L	29.51	515	3.13	4863
-22	44	26	Frontal_Sup_L	9.90	515	1.42	3599
-22	44	26	OUTSIDE	0.19	515	0.00	0
-24	0	-4	Pallidum_L	52.23	515	91.81	293
-24	0	-4	Amygdala_L	16.50	515	38.64	220
-24	0	-4	Putamen_L	2.91	515	1.49	1009
-24	0	-4	OUTSIDE	0.19	515	0.00	0
10	4	8	Caudate_R	66.60	515	34.51	994
10	4	8	Putamen_R	28.74	515	13.91	1064
10	4	8	Thalamus_R	4.27	515	2.08	1057
10	4	8	Pallidum_R	0.19	515	0.36	280
10	4	8	OUTSIDE	0.19	515	0.00	0
48	-36	-2	Temporal_Sup_R	40.78	515	6.69	3141
48	-36	-2	Temporal_Mid_R	17.86	515	2.09	4409
48	-36	-2	OUTSIDE	0.19	515	0.00	0
-58	-4	-30	Temporal_Pole_Mid_L	37.48	515	25.56	755
-58	-4	-30	Temporal_Mid_L	28.54	515	2.97	4942
-58	-4	-30	Temporal_Inf_L	0.19	515	0.03	3200
-58	-4	-30	OUTSIDE	0.19	515	0.00	0
36	14	28	Frontal_Inf_Tri_R	42.72	515	10.23	2151
36	14	28	Precentral_R	27.96	515	4.26	3381
36	14	28	Frontal_Inf_Oper_R	8.16	515	3.00	1399
36	14	28	Frontal_Mid_R	0.19	515	0.02	5104
36	14	28	OUTSIDE	0.19	515	0.00	0
12	-14	18	Caudate_R	45.24	515	23.44	994
12	-14	18	Thalamus_R	12.43	515	6.05	1057
12	-14	18	OUTSIDE	0.19	515	0.00	0
-28	-30	-12	ParaHippocampal_L	41.36	515	21.78	978
-28	-30	-12	Fusiform_L	27.38	515	6.10	2310
-28	-30	-12	Hippocampus_L	16.50	515	9.12	932
-28	-30	-12	Temporal_Inf_L	13.59	515	2.19	3200
-28	-30	-12	OUTSIDE	0.19	515	0.00	0
-22	10	-16	Frontal_Sup_Orb_L	21.36	515	11.42	963
-22	10	-16	Olfactory_L	16.70	515	30.71	280
-22	10	-16	Rectus_L	14.17	515	8.57	852
-22	10	-16	ParaHippocampal_L	13.59	515	7.16	978
-22	10	-16	Temporal_Pole_Sup_L	12.04	515	4.82	1285



-22	10	-16	Frontal_Inf_Orb_L	6.41	515	1.95	1690
-22	10	-16	Putamen_L	4.27	515	2.18	1009
-22	10	-16	Insula_L	2.72	515	0.75	1858
-22	10	-16	Amygdala_L	2.33	515	5.45	220
-22	10	-16	OUTSIDE	0.19	515	0.00	0

table shows at most 3 local maxima > 8.0mm apart per cluster.

-----  
 Height threshold: T = 4.29, p = 0.000 (0.050)  
 Extent threshold: k = 0 voxels, p = 1.000 (0.050)  
 Expected voxels per cluster, <k> = 38.595  
 Expected number of clusters, <c> = 0.05  
 Expected false discovery rate, <= NaN  
 Degrees of freedom = [1.0, 2592.0]  
 Smoothness FWHM = 20.1 20.4 17.3 {mm} = 10.0 10.2 8.6 {voxels}  
 Search vol: 1379696 cmm; 172462 voxels; 179.5 resels  
 Voxel size: [2.0, 2.0, 2.0] mm (1 resel = 883.62 voxels)

=====  
 =====  
**noodour-incong**

STATISTICS: volume summary (labels and percentages for the entire volume)

=====  
 =====

x,y,z {mm}	nom du label	% Cluster	Nb Vx Cluster	% Label	Nb Vx Label
36 -62 -18	Temporal_Inf_R	56.89	515 8.24	3557	
36 -62 -18	Fusiform_R	8.54	515 1.75	2518	
36 -62 -18	Cerebelum_6_R	2.33	515 0.67	1795	
36 -62 -18	Cerebelum_Crus1_R	2.33	515 0.45	2648	
36 -62 -18	Occipital_Inf_R	0.19	515 0.10	989	
36 -62 -18	OUTSIDE	0.19	515 0.00	0	
-34 -68 -20	Cerebelum_Crus1_L	42.33	515 8.37	2603	
-34 -68 -20	Cerebelum_6_L	23.50	515 7.14	1694	
-34 -68 -20	Fusiform_L	0.39	515 0.09	2310	
-34 -68 -20	Occipital_Inf_L	0.19	515 0.11	941	
-2 -84 -6	Calcarine_R	47.18	515 13.06	1861	
-2 -84 -6	Lingual_R	30.49	515 6.83	2300	
-2 -84 -6	Cerebelum_6_L	9.51	515 2.89	1694	
-2 -84 -6	Calcarine_L	9.51	515 2.17	2258	
-2 -84 -6	Vermis_6	1.17	515 1.62	371	

-2 -84 -6	Lingual_L	0.78	515	0.19	2095	
-2 -84 -6	OUTSIDE	0.19	515	0.00	0	
50 -2 54	Frontal_Mid_R	37.28	515	3.76	5104	
50 -2 54	Precentral_R	26.60	515	4.05	3381	
50 -2 54	OUTSIDE	0.19	515	0.00	0	
66 -10 10	Postcentral_R	24.08	515	3.24	3823	
66 -10 10	Heschl_R	18.64	515	38.55	249	
66 -10 10	Rolandic_Oper_R	13.01	515	5.03	1331	
66 -10 10	Temporal_Sup_R	2.91	515	0.48	3141	
66 -10 10	OUTSIDE	0.19	515	0.00	0	
-50 -4 44	Postcentral_L	60.39	515	7.99	3892	
-50 -4 44	Precentral_L	5.05	515	0.74	3526	
-50 -4 44	OUTSIDE	0.19	515	0.00	0	
-30 60 16	Frontal_Mid_L	28.54	515	3.02	4863	
-30 60 16	Frontal_Sup_L	27.96	515	4.00	3599	
-30 60 16	OUTSIDE	0.19	515	0.00	0	
-44 34 26	Frontal_Inf_Tri_L	47.96	515	9.77	2529	
-44 34 26	Frontal_Mid_L	7.18	515	0.76	4863	
-44 34 26	OUTSIDE	0.19	515	0.00	0	
-30 -88 20	Occipital_Sup_L	13.01	515	4.90	1366	
-30 -88 20	Occipital_Mid_L	8.93	515	1.41	3270	
-30 -88 20	OUTSIDE	0.19	515	0.00	0	
-44 -80 18	Angular_L	66.21	515	29.07	1173	
-44 -80 18	Occipital_Mid_L	28.35	515	4.46	3270	
-44 -80 18	Temporal_Mid_L	0.58	515	0.06	4942	
-44 -80 18	OUTSIDE	0.19	515	0.00	0	
-16 -34 -2	Hippocampus_L	25.05	515	13.84	932	
-16 -34 -2	ParaHippocampal_L		22.72	515	11.96	978
-16 -34 -2	Precuneus_L	19.22	515	2.81	3528	
-16 -34 -2	Cerebelum_4_5_L	18.25	515	8.36	1125	
-16 -34 -2	Lingual_L	11.07	515	2.72	2095	
-16 -34 -2	Thalamus_L	2.72	515	1.27	1100	
-16 -34 -2	OUTSIDE	0.19	515	0.00	0	
-10 -16 14	Caudate_L	24.66	515	13.20	962	
-10 -16 14	Thalamus_L	2.52	515	1.18	1100	
-10 -16 14	OUTSIDE	0.19	515	0.00	0	
-14 -84 40	Parietal_Sup_L	54.37	515	13.56	2065	
-14 -84 40	Occipital_Sup_L	27.96	515	10.54	1366	
-14 -84 40	Cuneus_L	7.96	515	2.69	1526	
-14 -84 40	Precuneus_L	6.21	515	0.91	3528	
-14 -84 40	OUTSIDE	0.19	515	0.00	0	
-40 24 38	Frontal_Inf_Oper_L	90.49	515	44.89	1038	
-40 24 38	Frontal_Inf_Tri_L	4.85	515	0.99	2529	
-40 24 38	Frontal_Mid_L	0.19	515	0.02	4863	

table shows at most 3 local maxima > 8.0mm apart per cluster.

```

-----
Height threshold: T = 4.29, p = 0.000 (0.050)
Extent threshold: k = 0 voxels, p = 1.000 (0.050)
Expected voxels per cluster, <k> = 38.595
Expected number of clusters, <c> = 0.05
Expected false discovery rate, <= NaN
Degrees of freedom = [1.0, 2592.0]
Smoothness FWHM = 20.1 20.4 17.3 {mm} = 10.0 10.2 8.6 {voxels}
Search vol: 1379696 cmm; 172462 voxels; 179.5 resels
Voxel size: [2.0, 2.0, 2.0] mm (1 resel = 883.62 voxels)
    
```

=====  
 =====  
 cong-incong

These are listed also at FWE p<0.05, the lower threshold was just for the rendering.

STATISTICS: volume summary (labels and percentages for the entire volume)

```

=====
=====
    
```

x,y,z {mm}	nom du label	% Cluster	Nb Vx Cluster	% Label	Nb Vx Label
-30 -92 16	Occipital_Sup_L	27.38	515 10.32	1366	
-30 -92 16	Occipital_Mid_L	3.69	515 0.58	3270	
-30 -92 16	OUTSIDE	0.19	515 0.00	0	
24 -90 -10	Occipital_Mid_R	53.20	515 13.06	2098	
24 -90 -10	Fusiform_R	30.87	515 6.31	2518	
24 -90 -10	Cerebelum_Crus1_R	7.57	515 1.47	2648	
24 -90 -10	Lingual_R	4.27	515 0.96	2300	
24 -90 -10	Calcarine_R	2.33	515 0.64	1861	
24 -90 -10	Cerebelum_6_R	1.17	515 0.33	1795	
24 -90 -10	Occipital_Inf_R	0.19	515 0.10	989	
24 -90 -10	OUTSIDE	0.19	515 0.00	0	
18 -98 6	Cuneus_R	37.28	515 13.48	1424	
18 -98 6	Occipital_Sup_R	24.47	515 8.92	1413	
18 -98 6	Calcarine_R	17.48	515 4.84	1861	
18 -98 6	Occipital_Mid_R	15.15	515 3.72	2098	
18 -98 6	Occipital_Inf_R	5.44	515 2.83	989	
18 -98 6	OUTSIDE	0.19	515 0.00	0	
4 -86 2	Calcarine_R	46.60	515 12.90	1861	
4 -86 2	Lingual_L	33.01	515 8.11	2095	

4	-86	2	Lingual_R	7.38	515	1.65	2300	
4	-86	2	Calcarine_L	0.97	515	0.22	2258	
4	-86	2	OUTSIDE	0.19	515	0.00	0	
38	-82	16	Occipital_Sup_R	6.02	515	2.19	1413	
38	-82	16	Occipital_Mid_R	0.58	515	0.14	2098	
38	-82	16	OUTSIDE	0.19	515	0.00	0	
-34	-66	-24	Cerebelum_6_L	39.42	515	11.98	1694	
-34	-66	-24	Cerebelum_Crus1_L		17.86	515	3.53	2603
-34	-66	-24	Fusiform_L	0.19	515	0.04	2310	
40	-86	4	Occipital_Inf_R	67.77	515	35.29	989	
40	-86	4	Occipital_Mid_R	17.67	515	4.34	2098	
40	-86	4	OUTSIDE	0.19	515	0.00	0	

table shows at most 3 local maxima > 8.0mm apart per cluster.

-----  
 Height threshold: T = 4.29, p = 0.000 (0.050)  
 Extent threshold: k = 0 voxels, p = 1.000 (0.050)  
 Expected voxels per cluster, <k> = 38.595  
 Expected number of clusters, <c> = 0.05  
 Expected false discovery rate, <= NaN  
 Degrees of freedom = [1.0, 2592.0]  
 Smoothness FWHM = 20.1 20.4 17.3 {mm} = 10.0 10.2 8.6 {voxels}  
 Search vol: 1379696 cmm; 172462 voxels; 179.5 resels  
 Voxel size: [2.0, 2.0, 2.0] mm (1 resel = 883.62 voxels)

=====

=====