

The Effect of Language on Perceived Odour Intensity

Clare Cassidy

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Business School, School of Art, Dublin.

Supervisor: Dr Rosie Reid

Programme Leader: Dr Rosie Reid

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Department of Psychology

Dublin Business School

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Abstract

This study explored the effect of language priming on perceived odour intensity. This was investigated by measuring changes in EEG alpha wave amplitude, and through a perceived odour intensity self-report scale among 32 participants. The experiment used a 2x2 between-subjects factorial design with a within-subjects component. Four conditions investigated differences between 2 odour stimuli containing drops of rosemary essential oil that were of the same intensity in the presence and absence of a language prime, and odours of varying intensities in the presence and absence of a language prime. A mixed factorial ANOVA found no significant effects for differences across conditions for varying intensities or language prime on perceived odour intensity or EEG amplitude.

The Effect of Language on Perceived Odour Intensity

General introduction

The purpose of this research is to investigate the effect that language priming has on perceived odour intensity. It has been established in research that olfactory processing is a sensory system that is particularly vulnerable to the effects of priming. There are a number of reasons contributing to how and why this occurs which will be discussed further throughout this study, particularly in relation to the role of language and olfaction. Firstly, this study will provide a brief overview of the role that top down processing has on olfactory perception. From this, how top down processing in turn affects odour discrimination and identification will be evaluated. How humans classify dimensions of odour will then be investigated in relation to intensity as well as hedonic and sourced-based classification. This will be examined in relation to how olfactory pathways with which odours are encoded contribute to both an unrefined feature analysis of the odour itself, as well as a weak language-olfactory connection. Finally the role of electroencephalographic (EEG) studies as well as other contributing research investigating odour priming will be discussed, as well as how this relates to language and odour.

Top down processing in odour perception

Research indicates that odour perception is influenced by both bottom up and top down processing. Bottom up processing interprets physical stimuli in relation to sensory receptors. Top down processing on the other hand relies on the integration of multiple inputs including memory, concepts and expectations to influence perception (Matlin, 2009). Signal Detection Theory provides a framework with which to explain how perception occurs during perceptual tasks. A signal in this context refers to sensory information (Swets, Tanner &

Birdsall, 1961). In this theory, perception depends on deciding between two hypotheses in which either a signal is present, or is not present. In deciding this, a set of subjective values is assigned to the signal criterion. The decision on what is perceived depends on whether or not the observation of the signal exceeds this criterion value (Green & Swets, 1966; Swets et al., 1961). The criterion value can be affected by both the environment in which the signal occurs, as well as the observer's detection goal (Swets et al., 1961; Engen, 1972). In the event of priming, expectations of what will be perceived can shift, therefore the observer's detection goal will be affected by lowering the value assigned to the criterion. Therefore the likelihood of the signal being detected will increase, as the criterion threshold is lowered. If the criterion value assigned to perceiving the sensory information is met or exceeded, then the signal will be detected (Swets Tanner & Birdsall, 1961; Engen, 1972) Therefore, it can be argued that olfactory perception in humans can be affected by priming. While odour detection requires only sensory processes, odour discrimination and identification relies on both sensory and cognitive processes (De Wijk, & Cain, 1994). It can be argued that this reliance on top down information is one of the reasons why odour object naming in humans is found to be considerably more difficult when compared to other sensory modalities such as vision. Top down processing likewise makes humans more vulnerable to the effects of priming.

Language: The Disconnect Between Odour Discrimination and Identification

It has been well established in olfactory research that odour discrimination and identification in humans is weak, and that the connection between odour and language is problematic. Accuracy in common odour naming occurs on average less than fifty per cent of the time (Engen & Ross, 1973; Jonsson & Olsson, 2003). In a study by Cain (1979) it was posited that there are three elements which affect odour identification. Those are familiarity

with an odour, a highly established connection between odour and name, and the presence of an aid in recalling the name of an odour. It has been found that odour recognition drops significantly if one or more of these elements are missing. Likewise, research suggests that errors in odour naming often go unrecognised by the participant, and that self-evaluation on olfactory identification performance is often higher than the actual results (Cain & Potts, 1996) indicating a lack of awareness in relation to the limited capabilities of olfactory performance. Another phenomenon which presents itself is the “tip-of-the-nose” state. This describes the state of recognising the odour but being unable to retrieve its name. This phenomenon is often characterised by partial retrieval of information such as the first letter of the odour (Lawless, & Engen, 1977).

There are a number of theories as to why the link between odour naming and language is weak. Firstly, research has found that olfaction is the only sensory modality that is not integrated through the thalamus prior to processing in the cortex (Shepherd, 2005). This could have implications as research suggests that the thalamus is associated with language processing (Klostermann, Krugel, & Ehlen, 2013). Likewise, one early theory put forward by Lorig (1999) posits that odour naming is difficult because some cortical resources involved in language processing are also involved in olfactory processing. Although specific cortical areas remain unidentified in this early study, supporting research is highlighted that when language and odour is processed simultaneously, this causes interference. The theory posits that the construct of what makes an odour, or a word are both temporal compounds in that they have multiple individual features which make up the whole unit. Words have phonemes, and syllables which when perceived as a whole become attached to the appropriate representation. Likewise for odour to be perceived, meaning is attributed to the individual features by means of unifying them through spatial encoding. Support for this theory has been found in a study by Walla and colleagues (2003), in which words were encoded by

participants in conjunction with the presence of an odour stimulus. It was found that word recognition performance significantly decreased as a result of the presence of the odour. These aspects serve to highlight that the link between language and odour is tentative. This difficulty in odour discrimination and identification is further supported by how humans categorise odours. These classifications can be described as coarse, unrefined and characterised by vague descriptors, particularly in contrast to how other sensory modalities such as vision operate, and can help underline the vulnerability in olfactory processing in relation to language priming.

Odour Classification: A Symptom of Early, Unrefined Processing

When looking at the perceptual features of olfactory processing in comparison to other sensory modalities such as vision, it can be argued that odour classification in humans is unrefined, coarse and has poor feature analysis. This can be seen in both the olfactory pathways through which odours are encoded, and also how humans categorise odour. Olofsson and Gottfried (2015) contend that how the olfactory language pathway in the brain is configured ultimately limits the feature analysis of odours. For example, the piriform cortex is particularly associated with the preliminary stages olfactory processing (Gottfried, 2010; Olofsson, Rogalski, Harrison, Mesulam, & Gottfried, 2013), and more specifically, odour categorisation (Olofsson & Gottfried, 2015). However, in contrast to the visual system, the piriform cortex is poorly connected with the language network, while being richly connected with regions associated with emotion and memory, such as the basolateral amygdala (Olofsson & Gottfried, 2015). Research suggests that odour processing relies on top down mechanisms shown in a study which found that just reading smell related words such as “cinnamon”, “jasmine”, and “garlic”, activated the region as well as others associated

with olfaction (González et al., 2006). However, Olofsson and Gottfried (2015) argue that the piriform cortex has little opportunity to embellish odour representations with lexical-semantic detail in contrast to the visual system which has a number of opportunities for a refined feature analysis, and arguably this helps contribute to susceptibility towards the effects of priming.

Odour Classification: Intensity and Other Dimensions of Odour Heavily Interlinked

Odour classification is arguably characterised by its poor connection to the language network as well as its strong association with emotion and memory. Odour is invisible and difficult to localise unlike visual stimuli (Engen, 1982), and this is reflected in not only how humans tend to classify odours, but also how these classifications are particularly susceptible to language priming. Firstly, research has been unable to establish a universal consensus on how odour is classified (Wise, Olsson & Cain, 2000), however the most common ways in which humans categorise odours are by being described in terms of their source, through the dimension of hedonic evaluation (Herz, 2005), and through intensity. Other dimensions include edibility and familiarity (Stevenson, 2010).

Source based odour naming relates to how an odour is often associated with an event or place, or is referred to in relation to broader semantic categories such as similar smelling objects (Jonsson & Olsson, 2003), once again highlighting the rich connection to memory and experience. Hedonic evaluation refers to the determined attractiveness or likeability of an odour, and is often evaluated through ratings of pleasantness or unpleasantness (Distel et al., 1999; Herz, Beland & Hellerstein, 2004), highlighting the connection to emotion. Odour intensity can be described as the perceived strength of an odour, which can be likened to density and volume as opposed to brightness or loudness (Berglund & Hoglund, 2012).

Hedonic evaluation as well as odour as a source are particularly dominating themes in olfactory priming research, however, by comparison there has been considerably less research done in relation to odour intensity. Research indicates that the perceptual dimensions of odour are highly interlinked and difficult to separate. For example, the exposure effect attributes an increase in subjective preference to a stimulus when there has been repeated exposure to that stimulus (Harmon-Jones & Allen, 2001). This has been reflected in a number of studies which show a positive correlation between pleasantness ratings and familiarity in odour. For example, a study which tested forty odours which were familiar and unfamiliar to the participants found that there was a strong correlation between familiarity and odours which were liked and conversely, odours which were rated higher in unpleasant ratings corresponding with increased unfamiliarity (Sulmont, Issanchou & Koster, 2002). Similar findings were evident in another study which investigated ratings of intensity, familiarity and pleasantness between Japanese and German participants. It was found that pleasantness ratings increased significantly for both groups in relation to odours considered more culturally familiar to each. Japanese participants rated Japanese tea, soy sauce and dried fish significantly higher than German participants. Conversely, German participants rated anise, church incense and almonds higher than Japanese participants. Likewise, less familiar odours were rated more intensely like church incense for the Japanese, while dried fish, Japanese tea and soy beans were significantly more intense for German participants (Ayabe-Kanamura, et al., 1998). These studies demonstrate that dimensions of odour are highly interlinked, and can be affected by previous experience and exposure.

Priming in Olfactory Studies

The effects of priming have been well established in a large body of research. Priming refers to exposure of a stimulus which can then influence higher-order behavioural and cognitive outcomes in response to a later stimulus without the individual's awareness of this influence (Smeets & Dijksterhuis, 2014). Language priming has been used extensively in olfactory research, particularly semantic and construal priming (Smeets & Dijksterhuis, 2014). Semantic priming relates to category identification and is associated strongly with memory, while construal refers to priming based on judgement. A judgement made following construal priming for example would rely largely on the interpretation of that prime (Smeets & Dijksterhuis, 2014).

Many studies have looked at how odour dimensions are affected by manipulating the perception of the stimuli. For example, in an fMRI study, hedonic perception was changed when the same odour was given different labels. Reference odours labelled as "flowers" to establish positive hedonic ratings and "burned plastic" for unpleasant ratings were used to identify the activated regions before the test odours were administered. Then the same odour was labelled as either "cheddar cheese", or "body odour", resulting in two distinctly separate activations of regions associated with pleasant or unpleasant ratings. There was an increased activation in regions for pleasant ratings in the anterior cingulate cortex and medio-orbital frontal cortex for cheddar cheese in comparison to body odour. Likewise, there was more activation for the cheddar cheese label in the medio-frontal cortex in comparison to the body odour label. Areas of the brain that were not exclusive to priming were the primary olfactory cortical areas close to the piriform cortex, and smaller activations in the right lateral orbito-frontal cortex. (de Araujo, Rolls, Velazco, Margot, & Cayeux, 2005). These findings are supported by a similar study, with which the same set of odours were presented with positive labels such as "fresh cucumber", "breath mint", or "parmesan cheese" respectively and found

that depending on the label, the odours were correlated with either positive or negative hedonic ratings in a self-report rating scale (Herz, & von Clef, 2001).

These studies likewise can be compared to odour intensity studies, highlighting the interconnectedness between the dimensions of intensity and hedonic evaluation. For example, in a study which compared odours between German, Mexican and Japanese participants, in relation to intensity, familiarity and hedonic ratings it was found that for most odorants, all three were significantly correlated with each other (Distel et al., 1999) This study suggests that perceived intensity was correlated with higher hedonic ratings when it was more familiar to the participant. For example, for the Japanese group, there were significant correlations between Japanese related odours in comparison to European ones such as Japanese tea, soy sauce and fermented soy beans (Distel et al., 1999). This research suggests that priming can be heavily influenced by context.

Further supporting research for the effect of priming is evident in a study which compared hedonic odour ratings when paired with images of thin individuals and overweight individuals. The odours stimuli presented were odourless, however, it was found that the odours were rated as significantly more unpleasant when paired with images of overweight people than thin people (Incollingo, Rodrigues, Tomiyama & Ward, 2015).

Other priming studies have found results that suggest that perception of the intensity of an odour can be affected by whether the odour is labelled as hazardous or healthy. When looking at Signal Detection Theory, it can be argued that this can be attributed to two reasons. Firstly, labelling an odour as a potential hazard can bring about a shift in attentional resources to have a higher focus on the odour itself, and secondly, a change in odour threshold may occur. A change in odour intensity threshold may occur as both the detection goal of the participant has changed, as well as the initial reception of how the odour is evaluated (Dalton, 1996). For

example, one study which labelled three separate odours as either hazardous, healthy or neutral found that participants reported a higher level of perceived irritation and intensity with the odour labelled as hazardous in comparison to the other two odours. Sensory adaptation is thought to have occurred within the first part of the 20 minute exposure, with perceived intensity and irritation ratings declining. Sensory adaptation is the process in which the response to a stimulus is weakened with repeated stimulus presentations (Kolb & Whishaw, 2014). However, toward the latter stages of the exposure, there was an increase in these ratings, suggesting that the negative cognitive bias had an effect on the perceived intensity and irritation. Likewise, this study found that reporting of various health symptoms were recorded at the lowest in the healthy odour bias condition, and highest in the harmful odour bias condition (Dalton, 1999). Similarly in another study which also looked at perceived odour intensity in relation to hazardous and healthy labels, it was found that odour detection thresholds were significantly different depending on the characterisation of the odour (Dalton, 1996). These studies however, use three different odours for each label, and therefore have not compared intensity ratings for the same odour at different concentrations within the same condition, therefore this research seeks to investigate whether changes in odour intensity perception can occur within the same odour and same condition.

EEG and Odour

The physiological effects of odour on brainwave amplitude in EEG output has been widely researched. While early studies such as Moncrieff (1962) found that the presence of odours can effect EEG activity, these studies were not replicable, as they did not specify electrode placement and occurred within uncontrolled experimental conditions. Since then studies have shown inconsistent results depending on differing experimental conditions and

techniques in odour delivery affecting the reliability of EEG (Martin, 1998). For example research has shown that EEG output can be affected by odours that are undetectable to the participant. This was found in a study by Lorig and colleagues (1990), in which both EEG activity, and subjective mood tests were affected by the presence of an odour in low concentration that remained unconsciously detected by participants. Likewise, research has shown that the odour stimulus itself can be subject to demand characteristics, in that if the participant is not made aware of the identity of the odour, this may alter EEG output while cognitive activity occurs as the participant attempts to identify the odour (Lorig, 2000). Therefore controlling for these variables increases the reliability of the EEG output.

Current olfactory priming studies are conducted by analysing components in event-related potentials (ERPs). An ERP is a measured brain response that has been averaged out over a number of trials. It is a response to the onset of a particular event or introduction of a stimulus (Grigor, Van Toller, Behan, & Richardson, 1999). Types of components in ERPs vary, for example, the N400 was observed when images were presented alongside incongruent odours, and is associated with odour and visual processing (Grigor et al., 1999). In another study, the P200 and N100, P300 were found to represent the process of identifying odour labels without reference to other modalities such as visual stimuli (Lorig, Turner, Matia, & Warrenburg, 1995). In one odour priming study, the same odour was presented to three groups a labelled as either healthy, hazardous or neutral. It was found in an analysis of the ERPs that in the healthy condition the P200 and N100 components were shortened, while in the hazardous condition they were longer (Laudien et al., 2008). This indicates that top down processing has an effect on olfactory perception, and is reflected by the modulation of EEG frequencies. For this current study, facilities to use an ERP paradigm were unavailable, therefore measuring average EEG amplitude will be used instead.

Olfactory studies have shown that odours can have an effect on EEG output with several studies showing changes in alpha waves. Alpha waves have been shown to be affected by sensory stimulation (Schurmann & Basar, 2001), and an increase in alpha frequency is associated with relaxed states (Kolb, & Wishaw, 2009). For example, essential oils such as lavender and chamomile have shown a significant increase in alpha waves (Masago, et al., 2000). Studies investigating the effect of rosemary essential oils using EEG have shown an overall decrease in alpha waves (Masago, et al., 2000; Sayorwan et al., 2013). This study therefore will investigate EEG amplitude while using varying intensities of Rosemary Essential Oils. Electrode placement will be focused on the F3, and F4 sites (Sayorwan et al., 2013; Diego et al., 2008; Masago et al., 2000).

Rationale

Research indicates that perceived odour intensity can be affected by cognitive bias. A key contributing reason for this relates to how olfactory processing is particularly vulnerable to top down influences. Despite familiarity with an odour it is common for odour discrimination and identification to be poor in humans (Engen & Ross, 1973; Jonsson & Olsson, 2003). There are a number of theories as to why this is. One theory provides research which suggests that language processing and olfactory processing compete for the same cortical resources, making odour identification more difficult (Lorig, 1999; Walla et al., 2003). Likewise, other theories suggests that because olfaction is not integrated through the thalamus prior to processing in the cortex, this may have implications for how it is processed in relation to language (Klostermann, Krugel, & Ehlen, 2013; Sheperd, 2005). Following from this, other theories argue that areas involved in olfactory processing are more

strongly connected with areas associated to emotion and memory, and less connected with the language network (Olofsson & Gottfried, 2015). All of these theories help to contribute to the susceptibility of priming in olfactory processing.

Perceived odour intensity while being interlinked with other dimensions of odour is under-researched in contrast to classifications such as hedonic rating and source based evaluation. Likewise, olfaction studies have shown a wealth of evidence as to the role of priming in odour processing, through both self-evaluative means and fMRI studies. However, results remain to be limited when looking at EEG studies, particularly in relation to perceived odour intensity. Therefore the purpose of this study is to investigate the effect that language bias has on perceived odour intensity by observing differences in brainwave amplitude on EEG output, as well as through a self-report odour intensity scale.

H1. It is hypothesised that perceived odour intensity will be significantly higher in the group where the intensity of an odour has been manipulated compared to the group where the intensity of an odour has not been manipulated.

H2. It is hypothesised that perceived odour intensity will be significantly higher in the group where there is a language bias stating that the odour intensity has been manipulated when it has not, compared to the group where there is no language bias or odour intensity manipulation present.

H3. It is hypothesised that there will be a significant difference in the brainwave amplitude between a group where the intensity of an odour is manipulated, and a group where the intensity of an odour is not manipulated.

H4: It is hypothesised that there will be a significant difference in the brainwave amplitude between a group where there is a language bias stating that the odour intensity has

been manipulated when it has not, and a group where there is no language bias or odour intensity manipulation present.

Method

Participants

Thirty-two participants (22 female, 10 male) were sourced for this experiment using a convenient sampling in both Dublin Business School, and through Facebook group advertising on DBS Facebook pages as well as external pages. Information sheets were provided to students within Dublin Business School during class, stating the relevant information, and inviting them to participate. The majority of participants sourced were undergraduate students, and all were recruited on a volunteer basis. For the control condition, and condition 2 there were 4 participants each, for condition 1, condition 3 and condition 4 there were 8 participants each. Participants were selected on the basis that they were over 18 years of age, were right-handed, were not suffering from a cold or flu at the time of the experiment, and did not have a neurological brain-disorder, long-term psychiatric illness or have suffered from a traumatic brain injury.

Design

This study is true experimental 2x2 between-subjects factorial design with a within-subjects component. Quantitative methods were used, and the study had a control condition and four experimental conditions. The dependent variables (DVs) remained the same across the five conditions. These were perceived odour intensity, as measured through an odour

intensity scale, and alpha brainwave amplitude as measured by EEG output. The DVs were measured by the odour intensity scale using within-subjects independent variables (IVs) with two levels labelled as odour stimulus 1 and odour stimulus 2. The IVs for the control condition and for condition 2 had two varying intensities of odours in the absence of a language primer (varying intensity, no prime group). Condition 1 had two odours of the same intensity, in the absence of a language primer (same intensity, no prime group), condition 3 had two odours of the same intensity in the presence of a language primer (same intensity, prime group). Finally, condition 4 had two odours of varying intensities in the presence of a language primer (varying intensity, prime group). Participants were given a number which was put into <https://randomizer.org/>, an online computer generator which then randomly assigned them to groups.

Materials

Odour Intensity Scale

An Odour Intensity Scale (Knaapila et al., 2008) was used to determine the perceived odour intensity for odour stimulus 1 and odour stimulus 2. This scale was categorised into 9 possible ratings, with rating 1 labelled as ‘Weakest Possible Intensity’, and rating 9 as ‘Strongest Possible Intensity’. Participants were provided a sheet with two scales on it labelled ‘Odour 1’ and ‘Odour 2’, there were asked to circle one rating per scale for each odour presented. Reliability ratings were unavailable for Rosemary Essential oils, however, test-retest reliability for four other odours tested 6 days apart were available with intraclass correlations ranging at 0.76, 0.72, 0.47 and 0.37 for each (Knaapila et al., 2008).

Other materials included Innavir Rosemary Essential Oil 100ml, pipette, two 8oz clear plastic squeeze bottle condiment dispensers to contain the odour mixed with 30ml

water, sticky labels to identify the bottles as 'Odour 1' and 'Odour 2', a measuring container to dispense the water. Also included was a pen, an information sheet, a consent form and debrief sheet, a biofeedback unit, computer, a blunted syringe, cables, EEG cap, electrodes, and electrode gel. Wet wipes were also used to clean the electrode gel for both the participants, and from the EEG cap.

Apparatus

EEG was recorded using the Powerlab ML856 26T biofeedback unit, the data acquisition software was Labchart v7.3.7. Data was analysed using SPSS v22.

Procedure

The experiment was conducted in the biofeedback room at Balfe Street, DBS. Prior to the experiment, bottles containing 30ml of water labelled 'Odour 1', and 'Odour 2' were placed on the table, with the appropriate amount of Rosemary Essential oil depending on the condition, alongside the information sheet, and consent form. Across each condition participants were brought into the room, requested to read the information sheet and consent form, and once signed had the experimental procedure explained to them. The experiment required deception, therefore participants were informed that the study was to investigate whether odour intensity perception declined with age. They were requested to provide their age, and to evaluate the intensities of two odours. They were informed that there was deception and that a full debriefing would be provided at the end of the experiment. Participants were informed that there was minimal risk in taking part in the study, and that they could withdraw from the study at any time. Participants were informed that names would be kept confidential, and data would be matched with a private identification code to help ensure confidentiality. Once any questions were answered and the consent form was

signed, participants were brought to the EEG machine, where they sat facing away from the computer monitor. The electrode cap was placed on their head, along with the earth wire which was connected to either the right or left ear. Electrode gel was applied to the electrodes using a blunted syringe to increase conductivity. EEG readings were taken from the F4 and F3 sites using the 10/20 international system. To reduce artefacts on EEG feedback, all participants were requested to close their eyes gently while the recordings took place, they were requested to move as minimally as possible, and that the odour bottles would be handed to them, that they breathe normally and were permitted to squeeze the odour bottle to increase the opportunity to smell. They were informed that the recordings would take place during 10 second intervals, with 3-5 second breaks in between, and that this would occur 10 times each for both odour 1 and odour 2. Intermittent presentation of an odour stimulus in comparison to continuous presentation has been found to help minimise the effects of sensory adaptation therefore there would be a 30 second break in between recordings for odour stimulus 1 and 2 to help minimise sensory adaptation (Kobayashi et al., 2008).

Across each condition, odour stimulus 1 had 1 drop of Rosemary Essential oil. For condition 1 and condition 3, odour stimulus 2 had 1 drop of Rosemary Essential oil. For condition 2 and condition 4, odour stimulus 2 had 10 drops of Rosemary Oil. Across each condition participants were requested to smell from two bottles, and afterwards rate their intensities on the odour scale between 1 and 9. For condition 1, and 2 participants were told that the odours may be varied or may be the same to help prevent response bias and demand characteristics. For condition 4 and 3 which was the language prime condition, participants were informed that the second odour was more intense than the first odour.

Once the EEG readings had taken place, the participants were then requested to fill out the odour intensity scales, and having completed this, the electrode cap was removed. They were then given a full debriefing as well as a debrief sheet. The average length of time

the entire procedure took was about 25 minutes. The debrief sheet informed the participant that the true nature of the study was to investigate the effect of language priming on perceived odour intensity. The participants were informed that their age would not be included in the data. Any questions were answered and the subject was thanked for their participation.

Results

Statistical Analysis

A mixed factorial ANOVA was conducted to measure differences across conditions in relation to average EEG amplitude. Average EEG per interval for all participants was calculated for both odour stimulus 1 and odour stimulus 2 for this purpose, giving two EEG amplitude averages per odour. This was investigated to measure if there was an effect on amplitude in the presence or absence of a language prime, and whether there was an effect when both odour stimuli were of the same intensity, or of varied intensities.

A mixed factorial ANOVA was also conducted to measure differences across conditions in relation to perceived odour intensity. This was investigated as to whether there was an effect when both odour stimuli were of the same intensity, or varying intensities, as well as in the presence or absence of a language prime.

Descriptive Statistics

All data was checked for normality distribution, in most cases the assumptions were met. However, for EEG amplitude, a Shapiro-Wilks' test indicated that distribution was not normal, likewise while skewness was normal in both EEG amplitude averages, kurtosis was not at 5.59 for EEG amplitude 1, and 4.1 for EEG amplitude 2. However, it was determined

that parametric tests are robust enough to withstand violations to assumptions of normality (Pagano, 2012). The skewness and kurtosis for the perceived odour intensity scales were both normal and between -2 and 2. Table 1.1 below illustrates the mean, standard deviation, skewness and kurtosis of perceived odour intensity for odour stimulus 1 and odour stimulus 2.

Table 1.1 *Descriptive statistics for Perceived Odour Intensity between Odour Stimulus 1 and Odour Stimulus 2*

Variable	Mean	SD	Skewness	Kurtosis
Odour Stimulus 1	5.84	1.82	-.201	-.612
Odour Stimulus 2	6.4	1.34	.128	-.667

Perceived Odour Intensity

For condition 3 there was an increase in perceived odour intensity between odour stimulus 1 and odour stimulus 2 although both stimuli were identical in odour intensity. This could be attributed to a language prime being present in this condition. In contrast, in condition 1 where both odour stimuli were of equal intensity but there was no language prime, there was a decrease between odour stimulus 1 and odour stimulus 2 for perceived

odour intensity. For condition 2 where the odours were of varying intensities, there was no difference in perceived odour intensity between odour stimulus 1 and 2. This could be attributed to the absence of a language prime. Table 1.2 below illustrates the mean and standard deviation across each condition for perceived odour intensity for both odour stimulus 1 and 2.

Table 1.2 *Descriptive statistics for Perceived Odour Intensity between Odour Stimulus 1 and Odour Stimulus 2 across all conditions*

Group	Variable	Mean	SD
Condition 1 (same intensity, no prime)	Odour Stimulus 1	6.5	.756
	Odour Stimulus 2	5.75	1.16
Condition 2 (varying intensity, no prime)	Odour Stimulus 1	6.63	2.26
	Odour Stimulus 2	6.63	1.19
Condition 3 (same intensity, prime)	Odour Stimulus 1	5.13	1.96
	Odour Stimulus 2	6.38	1.19

Condition 4 (varying intensity, prime)	Odour Stimulus 1	5.12	1.64
	Odour Stimulus 2	6.88	1.72

EEG Amplitude

The descriptive statistics for average EEG amplitude illustrate that in conditions 2 and 4 where the participants received varying odour intensities, the brainwave amplitude increased for condition 2 while it decreased for condition 4. An overview of descriptive statistics between condition 2 and condition 4 is illustrated in Table 1.3. While in condition 1 and 3 where the intensity of an odour was not varied, condition 1 decreased in amplitude from odour stimulus 1 ($m=.09$, $SD=1.61$) to odour stimulus 2 ($m=-.66$, $SD=1.14$), while condition 3 increased from odour stimulus 1 ($m=-.61$, $SD=1.74$) to odour stimulus 2 ($m=-.43$, $SD=1.2$).

Table 1.3 *Descriptive statistics for average EEG amplitude between odour stimulus 1 and odour stimulus 2 in conditions where there were varying intensities.*

Group	Variable	Mean	SD
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Condition 2	Odour Stimulus 1	.28	1.08
Condition 2	Odour Stimulus 2	.42	1.84
Condition 4	Odour Stimulus 1	.88	3.54
Condition 4	Odour Stimulus 2	-.97	2.13

Inferential Statistics

Perceived Odour Intensity

Hypothesis 1 stated that perceived odour intensity would be significantly higher in a condition where the odour stimuli had varying intensities compared to a condition where the odour stimuli were the same. Hypotheses 2 stated that language bias would have an effect on perceived odour intensity between groups where odour stimulus 1 and 2 were the same, and groups where odour stimulus 1 and 2 were varied in intensity. These hypotheses were found not to be significant.

A mixed factorial ANOVA was carried out to evaluate whether the interaction between odour stimulus 1, odour stimulus 2 and language prime had a significant effect on perceived odour intensity. Sphericity was assured and the results of the analysis show that there was an interaction effect. There was an interaction effect for the odour stimuli and language prime ($F(1, 30) = 5.87, p = .02$) with an effect size of 16%. The language prime affected a change in perceived odour intensity from odour stimulus 1 to odour stimulus 2, and

it was found that when the participants were given a language prime, the perceived odour intensity was stronger in the second stimulus, and that intensity ratings increased between odour stimulus 1 ($m=5.13$, $SD=1.76$) and odour stimulus 2 ($m=6.63$, $SD=1.45$).

It was also found that in the absence of a language prime, perceived odour intensity dropped from odour stimulus 1 ($m=6.56$, $SD=1.63$) to odour stimulus 2 ($m=6.19$, $SD=1.22$). However, there was no main effect for odour stimulus 1 and odour stimulus 2 ($F(1, 30)=7.65$, $p=.194$) with an effect size of 6%, and it was found that there was also no main effect for language prime, ($F(1, 30)=1.77$, $p=.194$) with an effect size of 5%. Therefore hypothesis 1 and hypothesis 2 were found to be not significant.

Inferential Statistics

EEG Amplitude

Hypothesis 3 stated that there would be a significant difference in the EEG brainwave amplitude between a group where the intensity of an odour is manipulated, and a group where the intensity of an odour is not manipulated. Hypothesis 4 stated that language bias would have an effect on EEG brainwave amplitude between groups where odour stimulus 1 and 2 were the same, and groups where odour stimulus 1 and 2 were varied in intensity. These hypotheses were found not to be significant.

A mixed factorial ANOVA found that there was no main effect between EEG brainwave amplitude for odour stimulus 1 and odour stimulus 2, ($F(1, 30)=1.29$, $p=.265$) with an effect size of 4%. There was no interaction effect for odour stimulus 1 and odour stimulus 2 and language prime ($F(1, 30)=.27$, $p=.604$) with an effect size of .9%. It was also found that there was no main effects for language prime, ($F(1,30)=.454$, $p=.506$) with an effect size of 1%.

Discussion

The overall aim of this study was to investigate the effect that language priming has on perceived odour intensity by observing differences in EEG brainwave amplitude. This was also measured through a self-report odour intensity scale (Knaapila et al., 2008) where participants had to rate odour stimulus 1 and odour stimulus 2 against each other on a two scales between 1 and 9, anchoring the lowest number as the weakest possible intensity, and the highest number as the strongest possible intensity. Specifically the aim was to investigate whether there would be a difference in brainwave amplitude or perceived odour intensity across the conditions, and whether the presence or absence of a language primer had an effect on this. Firstly, the study aimed to investigate whether there would be a difference between the EEG amplitude and the perceived odour intensity scale when participants were presented with two odours of the same intensities between two conditions, one of which was in the absence of a language prime, and one which was in the presence of a language prime stating

that the second odour was stronger than the first odour stimulus. Secondly, the study aimed to investigate whether there would be a difference between EEG amplitude and the perceived odour intensity scale when participants were presented with two varying intensities, one condition with which there was no language prime present, and one where there was a language prime present, stating that the second odour stimulus had a higher intensity.

General Discussion

Statistically, the presence of language prime yielded no significant difference in both the perceived odour intensity scale and in the EEG average amplitude. Likewise, there was no significant effect in differences between the conditions with the same odour intensities and varying odour intensities for odour stimulus 1 and odour stimulus 2. Results showed that while language prime affected a change in the perceived odour intensity scale between odour stimulus 1 and odour stimulus 2 when an ANOVA was conducted across all conditions, this change could be attributed to conditions where there was a genuine manipulation in the odour intensities, therefore couldn't be attributed to the effect of a language prime alone.

Results showed that there was no significant difference in EEG average amplitude between odour stimulus 1 and odour stimulus 2 between odours of varying intensities, and the same intensities. Likewise, the presence or absence of a language prime did not affect a significant change across EEG amplitude between odour stimulus 1 and 2.

Signal Detection Theory

Although the results were not found to be significant, when investigating the mean ratings of the perceived odour intensity scale across the conditions, it was found that participants rated odour stimulus 2 higher in Condition 3 in comparison to Condition 1. Both conditions were of equal intensity for both odour stimuli, therefore the presence of the language prime in Condition 3 may suggest the slight increase in perceived odour intensity. Likewise in Condition 4, the second odour stimulus saw a higher mean on the perceived odour intensity scale in comparison to Condition 2. This arguably could also be attributed to the presence of a language prime, as both conditions were higher in intensity for odour stimulus 2. The only conditions where there was an increase in perceived odour intensity were conditions where there was a language prime present. Although the results were not significant, the ratings for odour stimulus 2 in Condition 3 and Condition 4 indicate that language prime can have some effect on perceived odour intensity. Signal Detection Theory (Green & Swets, 1966) could help explain this as priming causes a shift in attentional resources. Green and Swets (1966) argue that the observer's detection goal as a result of priming will increase the likelihood that a signal will be received, as the criterion threshold is lowered. This has been supported in odour priming research such as Dalton (1996), where the same odour when labelled as hazardous increased intensity ratings in comparison to when it was labelled as healthy or neutral. Likewise, this can be seen to some extent in the present study in which participants have been informed that there has been an increase of intensity in the second odour stimulus, therefore creating a shift in attentional resources toward this expectation. Further from this, the results also tentatively indicate some adjustment of the perceived odour intensity scale in order to accommodate the effect of priming. Across all conditions odour stimulus 1 was the same, with 1 drop of rosemary. However, for condition 3 and 4 in which the language prime was present, participants rated odour stimulus 1 as lower

on average than they rated odour stimulus 1 in condition 1 and 2 in which there was no prime present.

Sensory Adaptation

Odour stimulus 2 in Condition 1 was rated lower in intensity than odour stimulus 1 even though they were both of equal intensity. Likewise, Condition 2 which had varying intensities saw equal perceived intensity scale ratings for odour stimulus 1 and 2. This could be attributed to sensory adaptation. Sensory adaptation has been noted in a number of previous studies, for example Dalton (1999) found that during continuous presentation of an odour stimulus, adaptation is more likely to happen. However, in the presence of a prime this decreases. For example, perceived odour intensity increased in the presence of a negative prime, however adaptation occurred for the same odour in a neutral prime. Likewise, while the results of this present study were not significant, the means for odour stimulus 2 in Condition 1 and Condition 2 indicate that sensory adaptation may have occurred.

The present study took measures to help minimise the effects of sensory adaptation. Research supports that continuous presentation of odour stimuli helps to increase the chances of sensory adaptation occurring, and concordantly, intermittent presentation of stimuli decreases it (Kobayashi et al., 2008). Therefore this study carried out intermittent presentations of the odour stimuli, including a thirty second break between odour stimulus 1 and 2. Despite this, the results suggest that adaptation occurred. There are a number of possible reasons for this. The two main ways in which olfactory research is commonly conducted involve either the administration of an odour through free use of a polypropylene squeeze bottle (Dalton, 1996; 1999; Distel et al., 2008), or through a computer controlled olfactometer (Kobayashi et al., 2008). The olfactometer can be set to a constant or

intermittent flow, and allows the experimenter increased control over the release of the stimulus, and the space with which the stimulus is released. The free use of a squeeze bottle with which the present study used, arguably increases the ecological validity of the administration of the odour as it is not reliant on computer control. However, because computer control is absent in the free use of a squeeze bottle, there is less control over the distance of the bottle from the nostrils, the rate of inhalation and the rate at which the bottle is squeezed, which all could have had an effect on sensory habituation.

Advantages and Disadvantages

The present study is easily replicable which is arguably one of its strengths. Likewise, measures were taken to minimise the effect of demand characteristics across the conditions. For all conditions except for Condition 3 which used deception, participants were informed that both odour stimuli could be either stronger, weaker or of equal intensity. This helped to prevent participants from only rating odours as higher or lower on the scale.

While the results of the perceived odour intensity scale indicated that the presence of a language prime may have had some effect on perceived odour intensity, this effect was minimal, and the hypotheses could not be supported. This is not reflective of previous odour priming research, therefore limitations of the study may have had an effect on the results.

One limit of the study is that odour threshold intensity ratings (Dalton, 1996) for each participant were not established in a pre-test. Investigating at what point every participant perceives a genuine change in odour intensity would help to inform a more accurate measure for the amount of rosemary essential oil drops needed in an odour stimulus to facilitate a change in perceived odour intensity. Secondly, investigating the perceived odour intensity scale specifically for rosemary essential oil in relation to checking for test-retest reliability

would strengthen the present study. It is suggested that for future research, a pilot study with the same participants should be conducted prior to the main experiment to facilitate these changes.

Likewise, the results of the EEG amplitude did not show any significant effects for varying intensities, or the effect of a language prime. Current olfactory priming research commonly investigates the effect of priming through ERP components. While the present study did not have the equipment to conduct this type of research, it is evident that investigating the average amplitude of EEG is not sufficient to observe the effects. However, a suggestion for future studies in investigating ERP components is to examine the likelihood that it might be possible to elicit readings of both the N400 and P300. This is because the priming in the present study is based on construal priming, which may elicit the N400 component due to its association with decision making in the presence of congruent and incongruent stimuli (Grigor et al., 1999) or the P300 which is also associated with decision making (Lorig, Turner, Matia, & Warrenburg, 1995).

Future Research

There are a number of avenues for potential future studies. As research indicates that dimensions of odour are heavily interlinked (Ayabe-Kanamura, et al., 1998; Sulmont, Issanchou & Koster, 2002), including subjective mood tests, hedonic and familiarity ratings in conjunction with varying odour intensities may help inform whether perceived intensity can have an effect or be affected by these variables. Previous research indicates that odour can have an effect on mood, for example Sayorwan and colleagues (2013) found that inhaling rosemary oil had a significant effect on subjective mood in comparison to a control odour. A potential area of research is to investigate whether varying the intensity of rosemary can have

a corresponding effect on subjective mood. Further investigation can be conducted as to whether perceived odour intensity can have an effect on these variables when participants are primed to believe that odours are varied in intensity when they are actually the same.

Likewise, Diego and colleagues (1998) found that inhaling rosemary increased alertness in participants and increased the speed at which participants completed mathematical equations. A potential area of study would be to investigate whether varying intensities of odour can have a corresponding effect on alertness. Similarly, change in alertness and speed can be investigated in a condition where participants are primed to believe that odour intensities are varied when they are same, and conditions where there has been a genuine manipulation in odour intensities.

Expanding on this, another area of potential research could be to investigate the effect of odour intensity between a healthy population and a population suffering from anosmia. This could be investigated in relation to subjective mood, and alertness for varying intensities of rosemary essential oil, it could also investigate the extent of top down influences in odour processing in comparison to the physiological effects of odour. Changes in the influence of top down processing between the anosmia group and the healthy population could have an effect on subjective mood scores, and alertness. Research in relation to lavender essential oil on mice found that in that both the healthy group and anosmia group there was a reduction in anxiety following inhalation (Chioca, Antunes, Ferro, Losso & Andreatini, 2013). Therefore this could be investigated in relation to rosemary essential oil.

Conclusion

The present study investigated whether language priming could have an effect on perceived odour intensity in both EEG amplitude and a self-report odour intensity scale. The

present study did not find any significant changes in EEG alpha wave amplitude, and it is recommended for future studies to investigate any possible effect through ERP components. Likewise, the present study did not yield any significant results for the effect of language priming, however, there was a minor increase in means for perceived odour intensity scale scores in conditions where the prime was present. An issue which may have had an effect on perceived odour intensity is sensory adaptation which may have decreased the effects of perceived intensity, therefore it is recommended that future studies establish odour intensity threshold ratings (Dalton, 1996) prior to the main experiment in order to yield more definitive results on perceived odour intensity.

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Appendix

Information Sheet

Information Sheet for study on Olfactory Perception and Odour Intensity.

Please note: All participants taking part in this study must be over 18

My name is Clare Cassidy and I am in the final year of my BA (Hons) Psychology degree in Dublin Business School. As a part of my final year thesis I am conducting a project which will look at olfactory perception and odour intensity and I would like to invite you to take part in my study.

Please read the following information before you decide if you would like to take part.

This research will investigate whether odour intensity perception declines with age. During this study you will have your EEG measured while inhaling odours of varying intensities. You will also be requested to fill out a short questionnaire where you will be asked to evaluate the intensities of the odours, and provide your age. This study will take approximately 25 minutes and will be conducted in the laboratories on Balfe Street.

The nature of this study requires participants to be naïve to the exact research question, as information about the research may influence your responses and behaviour. A complete debriefing will be offered after participation, where I will be happy to answer any of your questions.

If you would like to participate:

-You must be over the age of 18

-You must be right-handed

-You must not be suffering from a cold or flu at the time of the experiment

-You must not have a neurological disorder, long-term psychiatric illness or have suffered from a traumatic brain injury.

There is minimal risk involved in the undertaking of this study.

Your participation in this study is completely voluntary, and you have the right to withdraw at any time.

If you would like to take part in my study, or have any further questions please do not hesitate to contact me via my email: 10022846@mydbs.ie

Consent Form

Please note: All participants taking part in this study must be over 18

Thank you for considering taking part in my study. My name is Clare Cassidy and I am in the final year of my BA (Hons) Psychology degree in Dublin Business School. As a part of my final year thesis I am conducting a project which will look at olfactory perception and odour intensity.

Please read the following information before you decide if you would like to take part.

This research will investigate whether odour intensity perception declines with age. During this study you will have your EEG measured while inhaling odours of varying intensities. You will also be requested to fill out a short questionnaire where you will be asked to evaluate the intensities of the odours, and provide your age. This study will take approximately 25 minutes.

The nature of this study requires participants to be naïve as to the exact research question, as information about the research may influence your responses and behaviour. A complete debriefing will be offered after participation, where I will be happy to answer any of your questions.

If you would like to participate:

-You must be over the age of 18

-You must be right-handed

-You must not be suffering from a cold or flu at the time of the experiment

-You must not have a neurological disorder, long-term psychiatric illness or have suffered from a traumatic brain injury.

There is minimal risk involved in the undertaking of this study.

Your participation in this study is completely voluntary, and you have the right to withdraw at any time.

All data collected including your signature will be kept confidential. Your data will be matched with a private identification code to help ensure confidentiality. Only the researcher will have access to your signature. All data will be stored on a password protected computer when not in use. Data may be used in submission for examination and presentation. All data will be stored until April of 2017, following this it will be shredded. Participants have the right to withdraw their data from this study at any time.

I have read the above information and I consent to taking part in this study.

Signature of consent: _____

Debrief Sheet

Thank you for your participation in this research

This experiment used some deception as to the true nature of the study. This research is looking at the effect of language on perceived odour intensity. The purpose of this research is to investigate whether language bias can have an effect on how the intensity of an odour is perceived. The request

for the age of the participant was to help mislead the participant as to the true nature of the study. Age is not necessary for the data collection and will not be used in the study.

If anything in this study has led you to feel distressed and you wish to speak to someone, please contact the Samaritans on 116 123.

If you have any further questions regarding the research or findings, please don't hesitate to contact me via email: 10022846@mydbs.ie

ID _____

AGE _____

ODOUR INTENSITY SCALE

After you have smelled both odours, please rank each odour between the scores of 1 and 9 by circling the selected number.

1 is ranked as NO ODOUR and 9 as EXTREMELY STRONG ODOUR. Please mark your age at the top of the page.

ODOUR 1

1 2 3 4 5 6 7 8 9

ODOUR 2

1 2 3 4 5 6 7 8 9

Protocol

Materials

Odour Intensity Scale (Knaapila et al., 2008), Innavir Rosemary Essential Oil 100ml, pipette, two 8oz clear plastic squeeze bottle condiment dispensers, 30ml water per bottle, sticky labels, a measuring container, pen, information sheet, consent form, debrief sheet,

biofeedback unit, computer, blunted syringe, cables, EEG cap, electrodes, electrode gel, wet wipes.

Apparatus

EEG machine, Powerlab ML856 26T biofeedback unit, Labchart v7.3.7., SPSS v22.

Procedure

For All Conditions

Two squeeze bottles were set on a table labelled 1 and 2 prior to the arrival of the participant. They were both filled with 30ml of water and drops of rosemary essential oil. Participants were greeted and shown the information sheet and consent form. Two consent forms were signed, one copy for the participant, one for the researcher. Once the consent forms were signed and the procedure explained the electrode cap was fitted onto the participant and the electrode gel applied to the F3 and F4 connection points. Participants were then given verbal instructions as listed below. Once Participants had completed what was instructed, the electrode cap was removed, the participant was provided with a full debriefing and thanked.

Verbal Instructions Given to Participants Across All Conditions:

I am going to ask you to smell from these two bottles, please inhale from bottle one first, then bottle two. You will inhale from bottle one for ten seconds at a time, followed by a 3-5 second break. This will occur ten times for the first bottle. We will then take a 30 second

break. Then we will repeat the same process with the second bottle. When you are finished with the second bottle please fill out the odour intensity scale for both bottles. The scale is rated from 1-9 with 1 being the weakest possible intensity, and 9 being the strongest.

Verbal Instructions for Control Condition, Condition 1 and 2

The odours might be weaker in intensity, stronger, or equal to each other.

Verbal Instructions for Condition 3 and 4

The second odour will be stronger than the first odour.

