Honours in General Linguistics

Research project

Does language make scents?

The interaction between verbal labels and olfactory perception

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1. Introduction

Olfaction is central to the human experience. As one of the five senses, it plays an integral role in our sensory experience of the world. Smells are known to evoke memories and strong emotional reactions, and there are whole industries dedicated to manufacturing scents. Despite this centrality of our sense of smell, little is known about the role of language in olfaction. Recently, this topic has gained more attention, most notably in studies concerning how different kinds of experience modulate the ability to name odours (Croijmans and Majid, 2016:1-21). The present thesis adheres to this new line of research and aims to contribute to reflecting the centrality of olfaction in the human experience, in theories of perception and language.

The relationship between language and human perception has long been a topic of academic investigation and debate. One recent theory of perception which includes the role of language is Lupyan and Clark's (2015) predictive processing framework, in which sensory input interacts with predictions facilitated by world knowledge to arrive at the most accurate possible perception of the world. The role of language, particularly verbal labels, within this framework can be explained by Lupyan's (2012) label-feedback hypothesis. According to this hypothesis, labels have a strong temporary effect on perceptual processing as described in the predictive processing framework. A point of commonality for these frameworks it that they focus almost entirely on visual perception; other modalities of perception, such as olfaction, are hardly mentioned.

However, within a different line of research, which is more concerned with the chemical senses, past studies have shown that language, particularly in the form of verbal labels, can have a significant effect on the way in which odours are perceived (Herz and Von Clef, 2001; De Araujo, Rolls, Velazco, Margot and Cayeux, 2005; Djordjevic, Lundstrom, Clément, Boyle, Pouliot and Jones-Gotman, 2008). Furthermore, Herz (2000) suggests that labels may exert an even stronger effect on olfaction than vision. Despite these studies done on the interaction between verbal labels and olfactory perception, olfactory perception is hardly mentioned in the formulation of the predictive processing framework, or the label-feedback hypothesis. It would therefore be beneficial to conduct a study on olfactory perception which takes this theory into consideration. Furthermore, all the aforementioned studies took place in Europe or North America and a similar study in the diverse South African context would be a valuable contribution to the understanding of the relationship between language and olfactory perception. Finally, the replication of previous findings in the cognitive sciences, especially landmark studies such as Herz and Von Clef's (2001) study, is becoming increasingly important, as highlighted by Nosek, Aarts, Anderson, Anderson and Kappes in their study investigating the replicability of findings in psychological science (2015).

The present research project aimed to investigate the influence of labels on olfactory perception. In order to achieve this, the study aims to answer two research questions:

1. To what extent does a verbal label influence perceived pleasantness, intensity and familiarity of an odour?
2. To what extent does a verbal label influence odour recognition, that is, what actions, memories and labels are associated with an odour?

This was done using an experiment in which participants were presented with labelled odours and then answered questions about their perception of the odours. Three of these odours were ambiguous, meaning that they were presented twice (unbeknownst to the participants), under different labels. The data captured by the perception questionnaire were analysed to answer the research questions above. This within-subjects design is based on the aforementioned studies on the relationship between labels and olfactory perception (Herz and Von Clef, 2001; De Araujo et al., 2005; Djordjevic et al., 2008).

The thesis is structured in the following way: First, existing literature on the relationship between language and olfactory perception is reviewed. Second, it is proposed that the predictive processing framework and the label-feedback hypothesis are appropriate theoretical points of departure for this study. Subsequently, the method of the experiment conducted for this study is outlined, followed by a presentation of the results yielded by this experiment. Finally, these results are analysed and discussed as to how they contribute to an understanding of the relationship between verbal labels and olfactory perception.

2. Literature review

Olfactory perception and the cognitive processes which underlie it, and particularly how language may influence these processes, has recently gained some attention as a topic of investigation and research. This literature review summarises the findings that have been made in this field, contextualises these findings within recent theories of human perception and highlights some knowledge gaps in the field.

2.1. The relationship between labels and olfactory perception

Herz describes the relationship between olfactory perception and language as "contradictory and complex" (2005:1). This is possibly because, unlike visual stimuli in general, odours are notoriously difficult to name when they appear on their own (Herz, 2005:1-2). This is not the case in all languages, however, as some recent research shows that speakers of some languages, such as Jahai (spoken in Malaysia), are just as good at naming olfactory stimuli as they are at naming visual stimuli (Majid and Burenhult, 2014:266-270). Nonetheless, verbal and non-verbal input and predictions have been shown to influence odour naming and research on these effects are reviewed below.

2.1.1. Non-verbal factors that influence odour naming

2.1.1.1. Colour

Olfactory perception and odour naming have been shown to be influenced by a variety of factors. These include colour, as was shown by a study in which participants were better at distinguishing between odour pairs (cherry and strawberry) when they were presented in appropriately coloured (red) water, as opposed to inappropriately coloured (green) water (Stevenson and Oaten, 2008:640-646).

Another study aimed to investigate whether labelling plays a role in odour perception in connection with colour (De Valk, Wnuk, Huisman and Majid, 2017:1171-1179). Participants from three different language groups, namely Dutch (Germanic), Thai (Tai) and Maniq (Jahaic), were required to smell an odorant and choose a colour they associated with it. After a break, they smelled the odorant again and were required to name it and rate it according to familiarity (De Valk et al., 2017:1173). It was found that when participants described an odour using source-related terms, such as "this smells like peanut butter", as opposed to more abstract descriptors such as "musty", the colour that they chose in the first part of the task tended to also be associated with the source. For example, participants who used "peanut butter" as a descriptor for an odour tended to choose light brown colour tiles after smelling that odour. This suggests that certain odours are associated with certain colours because the colour is connected to the label of the odour's source object (De Valk et al., 2017:1178). Furthermore, it was found that speakers of Maniq were less likely to use source-based odour terms because of their language's odour naming system. Therefore, the colours they chose were not as strongly correlated with the colours of the source object, in comparison with Dutch and Thai speakers.

However, these results should be treated with caution as they are based on cross-linguistic differences between speakers of Dutch and Thai and speakers of Maniq, the native language of small hunter-gatherer groups in Thailand. The differences in culture, lifestyle and education between the Dutch and Thai speakers and the Maniq speakers may also influence odour-colour associations and labelling, which makes it difficult to draw a definite conclusion about the connection between labelling, colour and odour from this data (De Valk et al., 2017:1178). Despite this, however, it is clear that research has shown that colour plays a role in olfactory perception and labelling.

2.1.1.2. Other visual cues

Other visual cues have also been shown to have an effect. A study by Dematté, Sanabria and Spence investigated the effects of both colour and shape cues on odour perception (2009:103-109). The findings supported those of Stevenson and Oaten (2008:640-646) regarding colour and olfactory perception. It was found that participants produced faster and more accurate responses when discriminating odours when the colour of a visual stimulus presented at the same time as the odour was compatible with the colour of the odour's source item (Dematté et al., 2009:106). Similar results were found regarding the shape of the visual stimuli: participants were faster and more accurate during the discrimination task when the shape of the visual stimulus was compatible with that of the odour's source item (Dematté et al., 2009:106). This suggests that shape as well as colour play a role in odour perception.

Furthermore, images of everyday objects have also been shown to influence olfactory perception. A study by Gottfried and Dolan (2003:375-386) found that in an odour detection task, accuracy and speed were increased when the odour was presented with a visual image that was semantically connected to the odour, as opposed to when it was presented with an image with little or no semantic connection to the odour. Therefore, visual stimuli other than colour have been shown to play a role in the perception of odours.

2.1.1.3. Exposure and experience

Exposure and experience have also been shown to play a role in odour perception, particularly in an individual's ability to name odours. In a study by Ayabe-Kanamura, Schicker, Laska, Hudson, Distel, Kobayakawa and Saito (1998:31-38), 40 Japanese participants and 44 German participants were compared according to their ability to provide appropriate descriptors for a selection of odours. It was found that the participants provided significantly more accurate descriptors for odours which were more typical in their culture than for those which were not. Pleasantness and edibility ratings also differed significantly between the groups according to the typicality of the odours in each culture (Ayabe-Kanamura et al., 1998:31-38).

Furthermore, expertise and training have been shown to play a limited role, as suggested by a study in which qualified wine and coffee experts were found to be better at naming odours and flavours within their fields of experience and expertise, but did not perform any better than novices when it came to other types of odours and flavours (Croijmans and Majid, 2016:1-21). This supports the results of the study by Ayabe-Kanamura et al. (1998:31-38), which shows a connection between experience and odour naming.

2.1.2. Olfactory perception versus visual perception in memory

Olfactory perception has been found to operate quite differently to visual perception, as evidenced in a direct comparison in a memory task (Herz, 2000:957-964). In this study, 36 participants were presented with an image of a painting at the same time as a familiar cue either in the form of an odour or a visual item. The cues included items like real pieces of banana (odour) and a plastic banana (visual). Then, once all stimuli were removed, they were required to rate their ability to visualise the painting and their emotional responses to the painting. They were also required to provide a written description of both the painting and their emotional responses. Then, 48 hours later, the same task was performed again by the same participants, but half the cues (half of the visual cues and half of the odour cues) were switched to verbal cues. For example, instead of smelling or seeing a banana, the participant repeatedly heard the word "banana" while looking at the painting (Herz, 2000:958-959). The results show that when odour cues were switched to their corresponding verbal cues, the participants' memory and emotional responses were significantly weaker. On the other hand there was no significant difference in these factors when visual cues were switched to their corresponding verbal cues (Herz, 2000:960). This therefore shows that, unlike visual perception, olfactory perception seems to operate independently of verbal labels during memory recall as well as emotional response to stimuli.

In order to confirm this interpretation, a second experiment was performed, in which 48 participants were given a similar task as in the first experiment, except they were given either odour cues or odour-imagine cues. For example, they would either be given real suntan lotion to smell, or would be instructed to imagine the smell of suntan lotion. In a second condition, half of the cues were switched and the other half were not (Herz, 2000:961). It was found that odour memory cues were far more effective than odour-imagine memory cues. This shows that verbal odour-imagine cues produce weaker effects on memory and emotion than odours themselves (Herz, 2000:961-962). This study therefore demonstrates that odours, even highly familiar odours, tend to be more removed from their verbal labels than visual items and that odours by themselves are more effective memory cues than visual or verbal cues.

2.1.3. Olfactory illusions

In generic terms, an illusion can be said to happen when, due to the context, a stimulus is perceived to be different to reality (Gregory, 1997). A study by Herz and Von Clef (2001:381-391) produces evidence of olfactory illusions brought about by verbal labels. There is some prior suggestion of olfactory illusions, such as the smell of garlic activating the perception of the smell of pizza (Engen, 1987:497-503). However, these "illusions" generally only take place when the two odours being confused are associated with one another in real life – in the case of pizza and garlic, the odour of garlic tends to occur with the odour of pizza in the world (Engen, 1987:497-503). In their study, Herz and Von Clef (2001:381-391) aimed to test whether these misperceptions can be activated by verbal labels alone, using ambiguous odours which may be associated with vastly different real-life sources. Eighty participants were given five different odorants and they were required to smell them and then rate them according to pleasantness (from "extremely unpleasant" to "extremely pleasant"), familiarity (from "unfamiliar" to "familiar") and intensity (from "weak" to "strong"). They were also required to answer a few questions regarding associations, memory and labels. These odorants, which could be associated with either a positive or negative real-world smell, were presented with verbal labels in the form of the investigators telling them what they were smelling. Two weeks later, the same procedure was followed, but with different labels for the odorants (Herz and Von Clef, 2001:384).

It was found that the participants' perceptions of the odours were different depending on their given labels. The most dramatic effect was found to be on I-B acid, which was, according to the given label, perceived to be either Parmesan cheese or vomit, and received corresponding positive and negative ratings and associations. Labels were found to have the least dramatic effect on menthol, which was labelled either as a breath mint or chest medicine (Herz and Von Clef 2001:388). Herz and Von Clef argue that differences in effects are due to differences in experience and the strengths of associations with the different odorants (2001:388). Therefore, this study shows that it is possible to manipulate olfactory perception in a dramatic way using verbal labels.

Other studies support the findings made by Herz and Von Clef (2001). De Araujo, Rolls, Velazco, Margot and Cayeux (2005:671-678) also investigated the influence of verbal labels on the perception of odours in terms of pleasantness from a neurocognitive perspective. Twelve male participants were presented with odorants alongside verbal labels and then asked to rate them according to their pleasantness. There were four odour conditions, namely a "pleasant" condition in which a certain odorant was labelled "flowers", an "unpleasant" condition in which a different odorant was labelled "burned plastic", a test condition in which a third odorant was labelled either "body odour" or "cheddar cheese" and a control condition of clean air labelled "air" (De Araujo et al., 2005:677-678). These label conditions were manipulated in a within-subjects design and the experiment took place in one session, unlike Herz and Von Clef (2001). Aside from the participants' ratings, their neurocognitive response was also recorded using fMRI (De Araujo et al., 2005:678). It was found that different areas of the brain were activated when different labels were used for the test odour. This correlated with pleasantness ratings. Therefore, participants perceived the odour to be more pleasant when it was labelled "cheddar cheese" than when it was labelled "body odour" (De Araujo et al., 2005:675). This supports Herz and Von Clef's (2001:381-391) findings that verbal labels alone can change the way in which odours are perceived.

Furthermore, Djordjevic, Lundstrom, Clément, Boyle, Pouliot and Jones-Gotman (2008:386-393) investigated the influence of verbal labels on the perceived pleasantness and intensity using two experiments. In the first experiment, 40 participants were presented with 15 odours. Each odour had three possible labels: a positive (typically pleasant) label, such as “banana bread”, a negative (typically unpleasant) label, such as “nail polish remover” and a neutral label, which was a number such as “forty-six”. These labels were manipulated in a within-subjects design and, like in De Araujo et al.’s (2005) study, the experiment took place in one session. The participants read the label from a card and were then presented with the odour. They then rated the odours on their intensity, pleasantness and arousal. In this experiment, arousal referred to the strength of the emotional reaction that the odour evoked, and was rated from “very calm” to “very excited” (Djordjevic et al., 2008:387). It was found that there was a significant effect of the odour’s label on its perceived intensity, pleasantness and arousal. When accompanied by their positive labels, odours were perceived to be more pleasant than when accompanied by their negative or neutral labels (Djordjevic et al., 2008:388). When accompanied by their negative labels, odours were perceived to be more intense than when accompanied by their positive or neutral labels. When accompanied by their positive or negative labels, odours were perceived to be more arousing than when accompanied by their neutral labels (Djordjevic et al., 2008:389).

In the second experiment, 30 new participants were presented with either odourless water or an odorant. The olfactory stimuli were labelled in the same way as in the first experiment. The water was also accompanied by labels, although participants were told when they were receiving an odourless stimulus. During the procedure, participants’ heart rate, skin conduction and sniffs were measured (Djordjevic et al., 2008:388). It was found that when odours were accompanied by positive or negative labels, skin conductance was greater than when odours were accompanied by neutral names. Skin conductance was decreased when the olfactory stimulus was odourless, which means that it was not the label alone that elicited the response. It was also found that when participants were presented with an odour with a positive label, their sniffing was increased in comparison with their sniffing when they were presented with an odour with a negative or neutral label. This suggests that an expectation of a positive odour increases sniffing, whereas the expectation of a negative or unknown smell causes more conservative sniffing. No significant effect of odour label on heart rate was found. This is expected to be because of the effect of breathing on the heart rate (Djordjevic et al., 2008:392-393). Overall, this study supports Herz and Von Clef’s (2001:381-391) findings that the perception of an odour can be affected by the label with which it is presented and further compares these effects with those of neutral labels on olfactory perception.

2.1.4. Verbal context and olfactory perception

It has also been shown that odour labels, particularly labels which reveal the source and natural or synthetic nature of an odour, influence hedonic ratings – i.e. concerning factors including and related to pleasantness and unpleasantness (Herz, 2003:595-606). In this study, 40 participants were presented with a total of 16 odorants under different labelling conditions. Four odours were considered to be unpleasant and four were considered to be unpleasant, and these were presented in both their natural and synthetic forms. They were accompanied either by no label, by simply the label "natural" or "synthetic" or by the label of the odour including whether it was synthetic or not. There was also a condition in which only the label was given, without an olfactory stimulus. Participants were required to rate these odorants according to pleasantness, familiarity and safety. In this study, safety referred to how safe an odorant was perceived to be for human consumption (Herz, 2003:597-603). It was found that the same odorants were rated differently when they were accompanied by verbal labels than when they were not (Herz, 2003:604).

It was found that in the presence of verbal labels, pleasant odours labelled as natural received the best ratings (Herz, 2003:604), probably due to the positive connotations of the concept of 'natural' (Herz, 2003:595-596). However, in the absence of verbal labels, synthetic pleasant odours received the most positive ratings. Herz argues that this may be due to the familiarity of these odours (2003:604). This supports the findings reported by Ayabe-Kanamura et al. (1998:31-38), which are further confirmed by Croijmans and Majid (2016:1-21). It was also found that when odours were labelled on the basis of their source (natural or synthetic), only the safety ratings showed a significant effect (Herz, 2003:604). Herz argues that this is because of the perceived danger associated with synthetic substances (2003:596), which relates to her proposed evolutionary argument, discussed in section 2.1.8. Therefore, source information is an important factor in the perception of odours. The findings thus show that verbal labels can influence the hedonic perception of certain odours. However, when verbal labels are not present, experiential familiarity seems to play an important role, although this was not directly tested in the study. It also shows that information about the source of an odour also influences the way in which it is perceived, albeit only with regard to safety.

2.1.5. Odour labels and mental imagery

Kaeppler (2019:18-31) aimed to investigate whether, when perceiving an odour without a label, participants would try to come up with a label for it, and whether this label would affect how they perceive it. 56 participants, all native German speakers, were required to rate 20 un labelled odorants on their familiarity, after which they were required to name the source of the odour. Once they had given it a label, they were required to rate the odour according to its intensity, familiarity and edibility (Kaeppler, 2019:21). Two weeks later, the same participants returned and were presented with a list of odour labels, which was personalised according to their responses in the naming task. They were required to imagine the odours as their labels were presented and rate them on 40 different descriptors, such as “sharp” or “fishy”. Finally, they were required to rate the odours referred to by each label according to the same criteria as in the first task two weeks prior, namely intensity, pleasantness and edibility (Kaeppler, 2019:21-22).

It was found that in most cases, participants were unable to give the odours the correct label. However, when considering labels which were almost, but not quite, correct, participants were able to identify odour sources in 58.75% of cases. It was also found that when actually smelling an odour, pleasantness, intensity and edibility ratings tended to be different to the ratings given when the odour was imagined. This demonstrates that, in concurrence with the results of the odour-imagine condition in Herz’s study mentioned above (2000:957-964), simply seeing or hearing a verbal label does not elicit the same response as actually perceiving an olfactory stimulus. It was also found that ratings across the two tasks were more similar when the labels in the second task corresponded with the labels produced in the first task than when they were replaced with the true label for the odorant in the second task (Kaeppler, 2019:28). Kaeppler’s study therefore shows that, despite it often being difficult to name odours, labels are often generated when one perceives a nameless odour. Once this label has been generated, this study suggests that it continues to influence the perception of the odour, even when the odour is no longer present and only a mental image of an odour with that label remains (Kaeppler, 2019:28).

2.1.6. Labels, olfaction and illusions

It is clear from the above that olfactory perception, and particularly the relationship between language and olfactory perception, is indeed complex. An individual’s ability to identify and name un labelled odours has been shown to be influenced by experience (Ayabe-Kanamura et al., 1998:31-38; Croijmans and Majid, 2016:1-21). When individuals are provided with already labelled odours, the labels have been shown to affect their perception of these odours. It has been shown that the presence and nature of verbal labels themselves influence the perception of odours, resulting in which Herz and Von Clef call "olfactory illusions" (2001:381-391). These findings are supported by other studies which focus on neurological (De Araujo et al., 2005:671-678) and psycho-physical (Djordjevic et al., 2008:386-393) responses to odours with regard to verbal labels. Additionally, linguistic information about the source of an odour also influences its perception (Herz, 2003:595-606). Furthermore, it has been shown that even self-generated labels for odours influence perception of these odours (Kaeppler, 2019:18-31).

2.1.7. A proposed evolutionary argument for odour perception

In her research on hedonic and emotional factors of olfactory perception, Herz (2005) proposes an evolutionary argument for the relationship between language and olfactory perception. She attributes the sparse odour vocabulary in many languages to necessity, arguing that it is not necessary to name odours to solve complex problems or have abstract thought processes. It is how a person reacts to a smell, not how they name it, that is of the most importance for survival. Thus, naming smells is not of great evolutionary importance (Herz, 2005:15). However, according to recent research mentioned above, speakers of some languages do not find odours more difficult to name than other sensory stimuli (Majid and Burenhult, 2014:266-270). Therefore, it cannot be assumed that odours are difficult to name by all people. This indicates that in some languages and cultures, naming odours – not simply reacting to them – is as important as naming other sensory stimuli. Overall, therefore, detailed naming practices are not prevalent, but there are some exceptions. With regard to verbal labels, however, Herz does note that when language is present, "cognitive processing of odors is guided by and can be over-ridden by verbal cues" (Herz, 2005:14). This view resonates with the conception of language as presented in the predictive processing framework (Lupyan and Clark, 2015:279-284) and the label-feedback hypothesis (Lupyan, 2012:1-13), which will be discussed next.

2.2. Theoretical framework

2.2.1. Predictive processing

Predictive processing, according to Lupyan and Clark, is "a framework in which mental representations – from the perceptual to the cognitive – reflect an interplay between downward-flowing predictions and upward-flowing sensory signals" (2015:279). According to this framework, there are two kinds of information. The first is bottom-up input in the form of sensory information gained from the empirical world, and the second is top-down predictions in the form of abstract knowledge and expectations regarding the world. Bottom-up sensory input is received and combined with top-down predictions to come up with the most accurate impression of the world. As more bottom-up input is received and new information comes to light, top-down predictions continue to adapt to arrive at the most accurate possible impression of the world (Lupyan and Clark, 2015:280). This process happens continuously and the proportions of top-down and bottom-up information used are highly flexible depending on the task or the situation. When sensory input is limited, such as when one is navigating one's kitchen in the dark, one relies more heavily on top-down predictions based on prior knowledge of the layout of the kitchen. Other tasks, in contrast, such as navigating a narrow, rocky cliff path, may require more reliance on bottom-up sensory input than prior knowledge. In order to adapt and deal with these different situations, the mind must constantly assess and re-assess its ability to rely on each of these kinds of information (Lupyan and Clark, 2015:281).

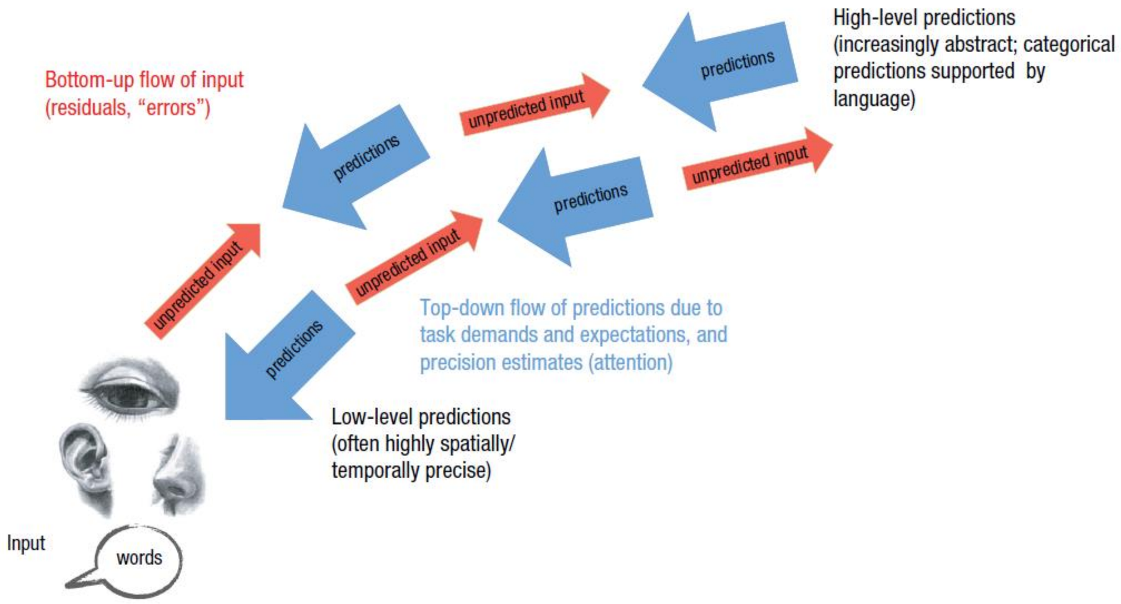

Figure 1: A simplified diagram illustrating perception according to the predictive processing framework (Lupyan and Clark, 2015:280).

2.2.1.1. Contradictions and illusions

Most of the time, this predictive process happens unconsciously and unnoticed. However, when sensory input directly contradicts predictions, they become noticeable. Lupyan and Clark (2015:281) use the example of drinking a liquid that one expects to be orange juice because it is orange, but when one tastes it, realises that it is milk. The difference between the prediction and sensory input becomes very noticeable here. In a similar way, the omission of a note in a familiar melody is jarring to the listener because they unconsciously predicted that it would be present (Lupyan and Clark, 2015:281). This predictive process also becomes noticeable when one considers certain illusions. Lupyan and Clark refer to the Cornsweet illusion (figures 2 and 3 below), in which adjacent tiles are perceived to be different shades of grey, but are in fact the same shade of grey. The tiles are perceived to be different because of their positioning in relation to one another. This is sensory input which combines with prior knowledge about how similar objects look when in a similar relation to one another. This top-down prediction interferes with the bottom-up sensory input (2015:279-280). The relationship between predictions and sensory input can therefore be seen when predictions are contradicted or when they result in an illusion.

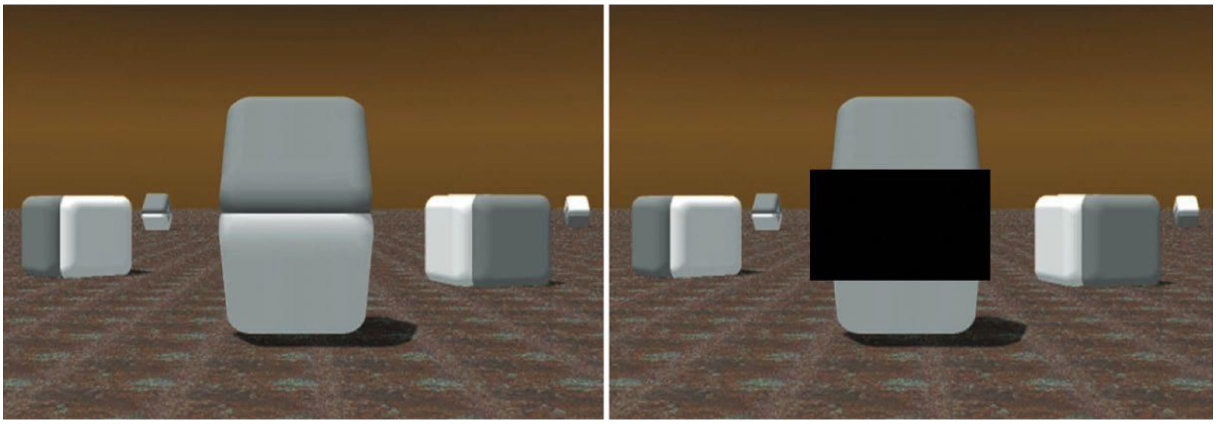

Figure 2: The Cornsweet illusion. The two central tiles seem to be completely different shades of grey, but when the border between the tiles is obscured, it is revealed that they are the same shade of grey (Purves et al., 1999:8549).

2.2.3. The label-feedback hypothesis

Within the framework of predictive processing, language supports top-down predictions (Lupyan and Clark, 2015:280). It therefore logically follows that perception is influenced by language. Lupyan (2012:1-13) argues for the ways in which language influences perception through labels in his label-feedback hypothesis, which falls within the predictive processing framework. The label-feedback hypothesis "proposes that language produces transient modulation of ongoing perceptual (and higher-level) processing" (2012:4). This means that language has temporary control over the continuous perceptual process outlined in the predictive processing framework.

Lupyan proposes this hypothesis in order to address a paradox regarding the effect of language on perception and cognition, which has arisen in experimental research. On the one hand, language has been shown to have strong effects on perceptual processing. An example of this is the effect of cross-linguistic differences in colour vocabulary on colour memory and perception. Winawer, Witthoft, Frank, Wu, Wade and Boroditsky (2007:7780-7785), for example, showed that native speakers of Russian, which has separate colour terms for what can be translated to English only as 'light blue' and 'dark blue', are better and faster at distinguishing between these colours than native English speakers. On the other hand, it was also shown that the effect disappeared when performing the colour discrimination task under verbal interference conditions (7780-7785).

The label-feedback hypothesis explains how language can have such a powerful and seemingly deep effect on perception, which can be abolished so easily. According to this hypothesis, labels influence sensory perception insofar as it is deemed necessary, useful and possible in that moment by the mind, as it assesses its ability to rely on linguistic information according to the predictive processing framework. Language therefore does not exert a deep, permanent influence on perceptual processes, but it can have a strong temporary effect. If the language system is recruited for another task (in the case of verbal interference, for example) it is no longer able to exert that influence on sensory perception in that moment, so the effect disappears (Lupyan, 2012:3-4).

2.2.4. Criticism of predictive processing

The predictive processing framework has not been immune to criticism. Firestone and Scholl (2016:1-77) argue that the studies claiming to provide evidence for top-down effects are unconvincing due to a few pitfalls. The first pitfall lies in the fact that most research focuses on situations in which it is predicted that top-down effects will be present. There is a lack of research on situations in which top-down effects are expected not to occur (Firestone and

Scholl, 2016:7). The second pitfall is that the line between perception and judgement is often blurred. Colour and shape, for example, can be both perceived and judged, and Firestone and Scholl argue that extant research cannot distinguish between the two. Perceptual effects attributed to top-down influence could therefore be judgement effects, the presence of which do not point to top-down influence (2016:9). The third pitfall is that the experimental environment could lead participants to produce responses that they believe the investigator wants, instead of responding as they would in any other environment (2016:10). The fourth pitfall is that effects may be attributed to low-level differences between experimental conditions, rather than the variables being manipulated to test for top-down effects (Firestone and Scholl, 2016:11-12). The fifth pitfall is that perceptual effects may be due to selective attention, rather than top-down predictions (Firestone and Scholl, 2016:13). However, Lupyan and Clark argue that within the predictive processing framework, attention, which causes a person to focus on certain task-relevant information, is the mechanism by which weighting of different types of information (top-down and bottom-up) is determined (2015:282). The sixth and final pitfall is that many studies claiming to find evidence for top-down effects deal with the recognition of stimuli. Firestone and Scholl argue that improved accuracy and speed of certain stimuli may be due to memory, rather than top-down perceptual effects (2016:15-16). It is therefore clear that arguments can be made against the validity of the predictive processing framework.

However, according to Lupyan, Firestone and Scholl base their argument on incorrect assumptions (2016:40). He argues that they try to distinguish between 'pure' perception and, for example, attention, memory and so forth. This is not only impossible, but also incorrect. Memory and attention are, according to him, very much part of perception itself and can thus not be used to explain away top-down effects. Instead, they interact with, and can contribute to, top-down effects (2016:40-41).

2.2.5. Predictive processing, labels and olfactory perception

From the above, it is clear that the predictive processing framework and the label-feedback hypothesis are mainly based on findings regarding visual perception, with little regard for other modalities of perception. This is surprising, as their diagram illustrating predictive processing (Figure 1) includes an image of a nose as part of the representation of bottom-up sensory input. Furthermore, Firestone and Scholl's (2016) criticism of predictive processing focuses solely on visual perception. In response, Keller (2016) points out that the different modalities of human perception, including olfactory perception, should be taken into account when formulating or criticizing theories of perception. Lupyan also notes that the influence of language should not be assumed to be the same on all non-verbal tasks, including different modalities of perception. He mentions that further research is required in order to determine which of these tasks are influenced by language, to what extent, and in what way (2012:3).

From the studies mentioned above (Herz and Von Clef, 2001; De Araujo et al., 2005; Djordjevic et al., 2008), it is clear that language, particularly verbal labels, have been found to influence the perception of odours. Therefore it is surprising that the relationship between olfactory perception and language has, not been explicitly investigated within the theoretical framework of predictive processing, nor with the label-feedback hypothesis in mind. This is despite the important role that this theory attributes to language and labels in perceptual processing. These theories benefit from an investigation of how they may account for olfactory illusions brought about by verbal labels.

Additionally, as mentioned above, some studies have shown that exposure and experience play an important role in a person's ability to name odours (Ayabe-Kanamura et al., 1998:31-38; Croijmans and Majid, 2016:1-21). People tend to be better at naming odours if they have been exposed to them often or on a regular basis in their culture (Ayabe-Kanamura et al., 1998:31-38), or if they have been trained to recognise and name specific types of odours (Croijmans and Majid, 2016:1-21). According to the predictive processing framework, language is a facilitator of top-down knowledge and predictions, which are gained through exposure to and experience of the world. This accounts for the role of experience in naming odours.

Finally, visual illusions have been an important subject of study for the development and substantiation of the predictive processing framework. Verbal labels have been shown to have a powerful effect on how odours are perceived, resulting in olfactory illusions (Herz and Von Clef, 2001:381-391; De Araujo et al., 2005:671-679; Djordjevic et al., 2008:386-393). Just as top-down predictions override bottom-down sensory input when it comes to visual illusions, top-down predictions facilitated by verbal labels have been shown to have an illusionary effect on olfactory perception. Therefore, it is relevant to study olfactory illusions to investigate how olfaction fits into this framework.

3. Method

3.1. Participants

Twenty-eight individuals with English as their native language participated in the present study. They were all between the ages of 18 and 35, with a mean age of 21.54 years. Participants were recruited using personal social media channels, mainly WhatsApp and Instagram. Prior to the experiment, they were screened to ensure that they did not smoke or had known allergies to any chemicals. On the day of the experiment, they were told not to wear any fragrances or eat strongly-flavoured foods. Participants were not compensated for taking part in this experiment.

3.2. Materials

In total, 19 odorants were used: three experimental odorants and 16 distractor odorants. The experimental odorants and their labels were selected based on Djordjevic et al.'s (2008) study and obtained from the Department of Food Science at Stellenbosch University. The distractor odorants were obtained from Kerry Foods and were selected based on availability. The odorants were diluted by the author in a laboratory at the Department of Food Science at Stellenbosch University, using standard laboratory equipment and adhering to standard procedures for odorant preparation. Odorants diluted with distilled water were freshly prepared every two days throughout the data collection period to prevent them from becoming stale. These odorants, their concentrations, and labels are summarised in the tables below. The experimental odorants were given two labels each: one "positive" label and one "negative" label. This terminology is based on Herz and Von Clef (2001) and Djordjevic et al. (2008), in which labels were categorised as typically positive or typically negative, although it could be said that objectively speaking neither banana bread nor nail polish remover are any more or less positive or negative than the other. The dosages are based on recommendations by the suppliers of the odorants and were altered if necessary to ensure that the odour would be sufficiently perceptible when presented. The odorants were stored in 50ml amber glass bottles and presented using strips of 120gsm acid-free paper, measuring approximately 1cm x 10.5cm, which were dipped into the odorant liquid.

Table 1: Experimental odours

Odorant	**Positive label**	**Negative label**	**Dosage**
Eugenol	“Dried cloves”	“Dentist’s office”	0.05% in PG
2-heptanone	“Banana bread”	“Nail polish remover”	0.05% in PG
Citral	“Squeezed lemons”	“Insect repellent”	0.05% in PG

Note: PG = propylene glycol

Table 2: Distractor odours

Odorant	**Label**	**Dosage**
cis-3-hexen-1-ol	Cut grass	0.05% in PG
Orange flavour liquid	Orange	0.2% in distilled water
Cucumber flavour liquid	Cucumber	0.15% in distilled water
Granadilla flavour liquid	Granadilla	0.15% in distilled water
Grapefruit flavour liquid	Grapefruit	0.15% in distilled water
Banana flavour liquid	Banana	0.15% in distilled water
Peppermint flavour liquid	Peppermint	0.15% in distilled water
Raspberry flavour liquid	Raspberry	0.15% in distilled water
Peach flavour liquid	Peach	0.15% in distilled water
Apple cider flavour liquid	Apple cider	0.15% in distilled water
Butterscotch flavour liquid	Butterscotch	0.15% in distilled water
Spray-dried garlic oil (powder)	Garlic	0.05% in distilled water
Cheese powder and cheddar flavour powder	Cheese	0.1% in distilled water
Fish flavour powder	Fish	0.2% in distilled water
Black pepper flavour powder and oleoresin	Black pepper	0.1% in distilled water
Cinnamon oil	Cinnamon	100%

Note: PG = propylene glycol

A questionnaire was used to record the participants' perception of the odorants. It included a rating section, in which participants rated each odour on a 9-point scale according to pleasantness (from extremely unpleasant to extremely pleasant), intensity (from extremely weak to extremely intense) and familiarity (from extremely unfamiliar to extremely familiar),. Participants then had to answer three questions about their associations with odour, the first being "What actions do you associate with this smell", the second being "Do you have a memory associated with this smell? If so, describe it briefly" and the third being "What would you call this smell". This questionnaire is based on the one used by Herz and Von Clef (2001:384) and was completed on a laptop on Google Forms.

3.3. Procedure

The experiment took place at the Department of Food Science and followed standard procedures used in olfactory studies. The experiment consisted of one 40-minute session per participant. The participant sat at a desk in a well-ventilated, evenly-lit room. The investigator stood behind them and dipped a smelling strip into an odorant contained in a bottle. The investigator then held the strip of paper under the nose of the participant while verbally giving them the label for the odour by saying, for example, "orange". The participant then sniffed twice, after which the odorant was immediately removed.

The participant then completed the smell questionnaire, in which they rated the odours and answered three written questions about them. The answers to each of the three questions for each of the three experimental odours were analysed and coded separately by the author to determine whether the odorant was perceived to be different as a function of label. Each pair of answers was viewed in isolation. Answers which were different were coded "different" and those that were the same were coded "same". Answers which were not exactly the same but very similar, such as "lemon" and "citrus", were also coded as "same". In cases where the participant did not answer the question, a comparison could not be made. This was coded as "missing data". Participants were encouraged to respond on instinct and not think too hard about their responses.

A practice round using a raspberry flavour with the label "raspberry" was included to familiarise participants with the procedure and to provide opportunity for questions. During the session, each of the experimental odours were presented twice, once under each possible label. The distractor odours were presented once, resulting in a total of 21 trials. There were three experimental blocks of 7 trials each. Once the experiment was finished, the participant was required to fill in a short language background questionnaire and answered a debriefing questionnaire.

3.4. Design

This study makes use of a within-subjects experimental design. Each participant was presented with each of the three experimental odours twice, under different labels, in set positions between distractor odours. Each participant received the experimental odours in the same order: first eugenol, then 2-heptanone, and finally citral. This order was repeated, with different labels. Participants were assigned one of two conditions, the first being positive labels first and the second being negative labels first. The distractor odours were fully randomised.

3.5 Ethical considerations

This experiment involved human participants and therefore there were some ethical considerations for this study. All participants signed an informed consent form. Before the start of the experiment, participants were informed that their participation was entirely voluntary and anonymous, and that the data would not be recorded or presented in such a way that they would be personally identifiable. All the materials used in this experiment were certified completely safe for human consumption by the suppliers and participants were screened for chemical allergies and asthma. Individuals with chemical allergies and asthma were not allowed to participate. Ethical clearance for this experiment was obtained from the Research Ethics Comittee: Humanities (project number REC-2019-11062).

4. Results

The results of the experiment are presented below in two sections. The first concerns the results recorded in the rating section of the questionnaire, and the second details the results recorded in the action, memory and name association section.

4.1. Pleasantness, intensity and familiarity ratings

4.1.1. Pleasantness

In order to analyse the effect of the labels on the pleasantness, intensity and familiarity ratings, paired samples t-tests were conducted. It was found that the eugenol was rated as significantly more pleasant when it was labelled "dried cloves" than when it was labelled "dentist's office" (t = -2.78, p = 0.01). This was a medium-sized effect (Cohen's d = -0.53). Likewise, it was found that citral was rated as significantly more pleasant when it was labelled "squeezed lemons" than when it was presented with the label "insect repellent" (t = -4.51, $p < 0.001$). This was a large effect (Cohen's d = -0.85). Labels had the strongest effect on the citral, which had a mean pleasantness rating of 6.43 when it was labelled "squeezed lemons", but a mean rating of 5.07 when it was labelled "insect repellent". However, unlike for the eugenol and the citral, it was found that for the 2-heptanone there was no significant interaction between the label condition and the pleasantness ratings (t = -0.86, p = 0.399). The relationship between the label and the mean pleasantness ratings are illustrated in Figure 3 below.

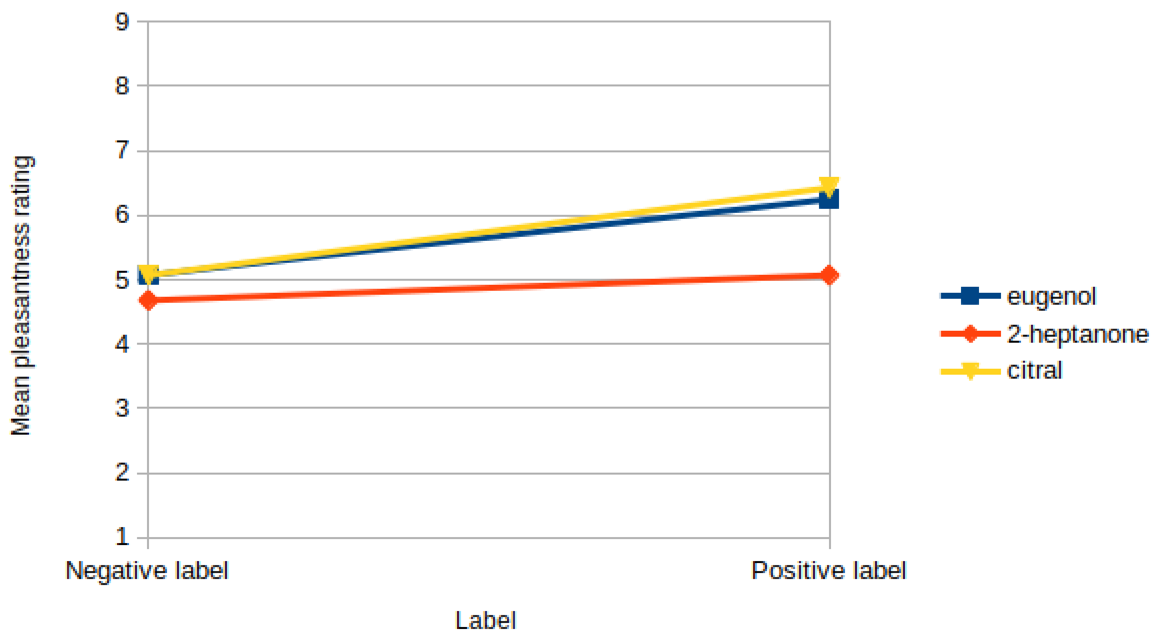

Figure 3: Odour pleasantness rating by label interaction. Rating scale: 1 = extremely unpleasant, 9 = extremely pleasant.

4.1.2. Intensity

No significant effects of label on intensity ratings were found on the eugenol (t = -0.2, p = 0.844), the 2-heptanone (t = 1.05, p = 0.303), or the citral (t = 0.33, p = 0.748). These ratings are illustrated in Figure 4 below, in which it can be seen that there were only slight differences in the mean intensity ratings as a function of label.

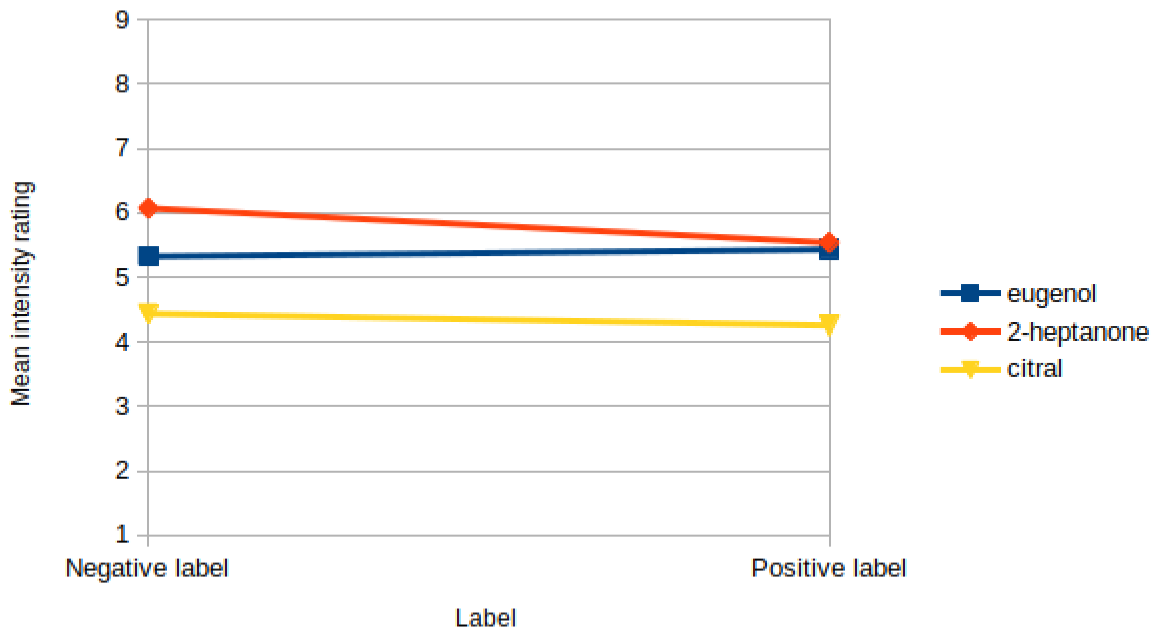

Figure 4: Odour intensity rating by label interaction. Rating scale: 1 = extremely intense, 9 = extremely weak.

4.1.3. Familiarity

Lastly, it was found that the familiarity ratings were not significantly affected by label for the eugenol (t = 0.24, p = 0.811) or the 2-heptanone (t = -0.47, p = 0.645). The familiarity ratings of citral were also not robustly affected by the labels "squeezed lemons" or "insect repellent" (t = -1.99, p = 0.057), but because $p < 0.1$, this can be considered a marginal effect. Citral had a mean familiarity rating of 5.68 when it was labelled "squeezed lemons", as opposed to a mean familiarity rating of 4.57 when it was labelled "insect repellent". The mean familiarity ratings for each of the odorants are depicted in Figure 5 below.

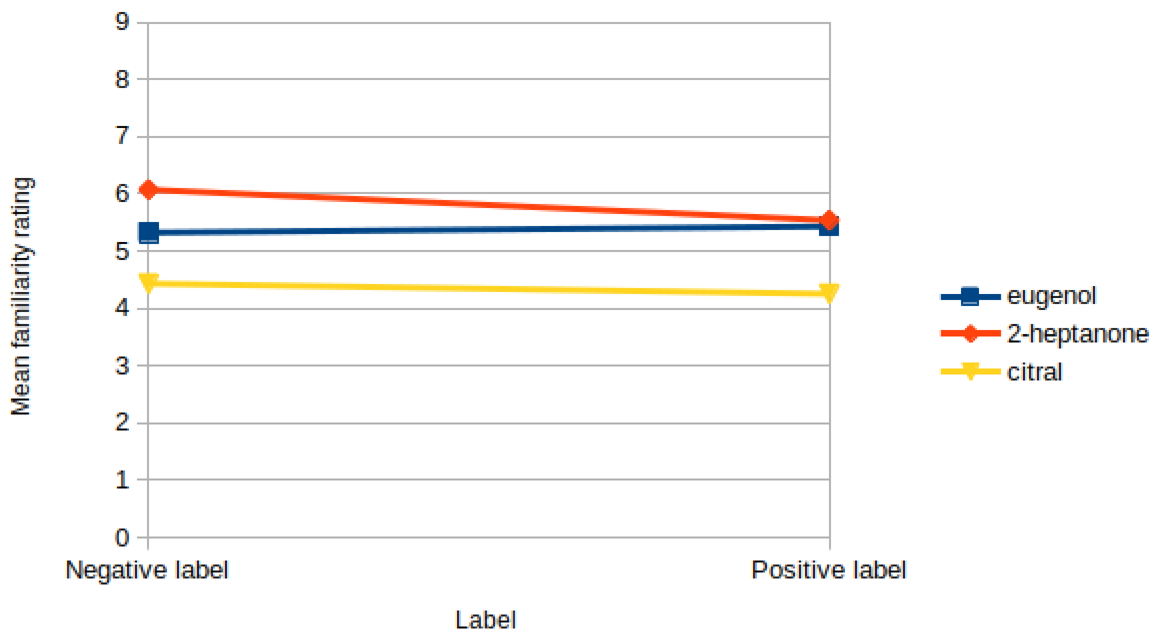

Figure 5: Odour familiarity rating by label interaction. Rating scale: 1 = extremely unfamiliar, 9 = extremely familiar.

4.2. Interpretation of odours

The next step in the analysis consisted of analysing the response to the three written questions in order to determine the labels influenced participants to perceive the experimental odours differently in terms of associated actions, memories and names. Figure 6 below seems to suggest that the participants indeed provided varied responses as a function of label.

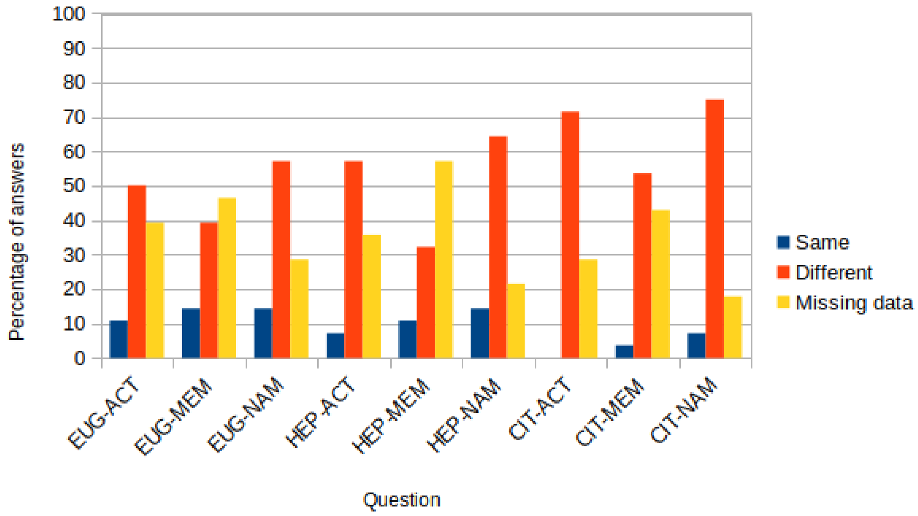

Figure 6: Percentage of participants that perceived the eugenol (EUG), the 2-heptanone (HEP) and the citral (CIT) to be different in terms of associated actions (ACT), memories (MEM) and names (NAM) as a function of label.

4.2.1. Significant differences in associations

In order to test whether the outcome depicted in Figure 7 was statistically robust, a series of binomial tests was performed. This included a total of 27 comparisons, and the output is presented in Table 4 in the Appendix. To summarise, these analyses found that although the number of "same" answers was smaller than the number of "different" answers for all the questions, it was not always significantly smaller. With regard to eugenol, significantly more participants had different action associations (p = 0.013) and name associations (p = 0.012). With regard to 2-heptanone, the actions (p = 0.001) and names (p = 0.004) associated with the odour were significantly more different than the same. The associated actions (p = < 0.001), memories (p = < 0.001) and names ($p < 0.001$) of citral were also very significantly more different than the same.

4.2.2. Action associations

Fourteen participants (50%) associated different actions (e.g. "baking" and "brushing teeth") with eugenol when it was labelled "dried cloves" than when it was labelled "dentist's office", whereas only 3 participants (10.7%) mentioned the same associated actions. Eleven participants (40%) did not provide complete answers. The number of participants who associated different actions (e.g. "baking" or "doing nails") with the 2-heptanone in the different labelling conditions was slightly higher at 16 (57.1%). Two participants (7.1%) associated the same actions with the odour in both labelling conditions and 10 participants (35.7%) did not fully answer the questions. Citral was associated with different actions (e.g. "making lemonade" and "camping") in the different labelling conditions by the most participants: 20 (71.4%). No participants associated the same actions with citral across labelling conditions and 8 participants (28.6%) did not provide answers.

4.2.3. Memory associations

For memory, the eugenol was associated with different memories (e.g. "preparing for Christmas" and "childhood dentist visits") by 11 participants (39.3%) when it was presented under the different labels. Four participants (14.3%) associated the same memories with the odour and 13 participants (46.4%) did not complete these questions. For the 2-heptanone, 16 participants (57.1%) did not complete the question. However, 9 participants (32.1%) associated different memories (e.g. "baking with Grandma" and "going to a nail salon before an event") with the odour when presented with different labels, and only 3 participants (10.7%) associated the same memory with the odour in both labelling conditions. Only 1 participant (3.6%) associated the same memory with the citral under the different labelling conditions. Fifteen participants (53.6%) associated the odour with different memories (e.g. "making lemonade with friends" and "spraying the house during an insect infestation") depending on the label, and 12 participants (42.9%) did not complete the questions.

4.2.4. Name associations

Finally, with regard to the names that participants gave to the odours, 16 participants (57.1%) gave eugenol different names ("e.g. "spice" and "disinfectant") in the different labelling conditions. Four participants (14.3%) gave eugenol the same or similar names across the two labelling conditions and 8 participants (28.6%) did not complete the questions. The 2-heptanone was named differently (e.g. "acetone" and "artificial banana") under the different labelling conditions by 18 participants (64.3%). Four participants (14.3%) gave the 2-heptanone different names under the different labelling conditions and 6 participants (21.3%) did not complete the questions. Citral was given different names (e.g. "lemons" and "mosquito repellent") by 21 participants (75%) and the same names by 2 participants (7.1%) in the different labelling conditions. Five participants (17.9%) did not complete the questions.

4.2.5. Missing data

Binomial tests were performed to compare the missing data from each of the experimental odours (Table 3 below). It was found that there was no significant difference between the number of "missing" associations for each of the odours.

Table 3: Comparisons between the "missing" data for each experimental odour

Comparison	**Experimental odours**	**N**	**Proportion**	***p***
EUG-HEP	eugenol	41	0.488	0.913
	2-heptanone	43	0.512	0.913
EUG-CIT	eugenol	41	0.423	0.155

	citral	56	0.577	0.155
HEP-CIT	2-heptanone	43	0.434	0.228
	citral	56	0.566	0.228

Note: Proportions tested against the value 0.5

N = Number of answers

5. Discussion

In this chapter, the results will be discussed as to how they answer the research questions posed at the beginning of this study. The significance of these results and their implications for olfaction, predictive processing and the label-feedback hypothesis will then be discussed. Finally, limitations of this study as well as suggestions for future studies are also outlined.

To reiterate, the first research question asked to what extent a verbal label influences the perceived pleasantness, intensity and familiarity of an odour. The data indicates that for some odours, namely eugenol and citral, a verbal label does influence the perceived pleasantness of an odour. No significant effect was found on 2-heptanone. However, the data does not indicate the same for perceived intensity and familiarity, besides a marginal effect of label on the perceived familiarity of citral. Therefore, verbal labels have some effect on perceived hedonic factors of odours, but this effect is not observed in all odours, and is limited mainly to perceived pleasantness.

The second research question concerned the extent to which a verbal label influences odour recognition, that is, what actions, memories and labels are associated with an odour? The data indicates that a verbal label does influence the actions, memories and labels associated with an odour to a varying extent. Significant differences were observed in the action and name associations of eugenol and 2-heptanone, as well as in the action, name, *and* memory associations of citral. In other words, verbal labels influenced associations with citral to the greatest extent.

5.1. The significance and implications of the findings

5.1.1. Perceived pleasantness, intensity and familiarity

With regard to previous research on olfactory illusions, Herz and Von Clef (2001) found a significant effect of verbal label on perceived pleasantness, intensity and familiarity of odours. These findings are supported by De Araujo et al. (2005), who measured only pleasantness ratings, and Djordjevic et al. (2008), who measured pleasantness, intensity and arousal. The experimental odours used in this study were also used in Djordjevic et al.'s (2008) study. Of these three odours, the effect of label on pleasantness ratings was significant in that study for eugenol and citral ($p < 0.01$), but not 2-heptanone (2008:389). These results are replicated by the present study. However, unlike the previous studies, this study was unable to produce an effect of verbal label on intensity or familiarity, besides a marginal effect on the perceived familiarity of citral. It makes sense that the most robust effects were on perceived pleasantness because the experimental odorants were chosen specifically because their ambiguity lay in their two possible labels being either positive or negative. This 'positive-negative' terminological distinction is implied to correspond with a 'pleasant-unpleasant' hedonic distinction (Djordjevic et al., 2008).

5.1.2. Action, memory and name associations

Herz and Von Clef's (2001) study, upon which the written questions of the questionnaire in the present study were based, found that most participants perceived the odours to be different with regard to action, memory and name associations. The present study replicated these findings, as it was found that according to a separate analysis of answers to each question, more participants associated the experimental odours with different actions, memories and names than the same actions, memories and names. The greatest effect was observed to be on citral, for which over 50% of the participants had different associations with the odour for all three categories. It is notable that not all odours have the same associative weight. Odour recognition and naming has been shown to be greatly influenced by exposure to and experience with these odours (Ayabe-Kanamura et al., 1998; Croijmans and Majid, 2016). In the present study, therefore, larger effects were found on the odours that are familiar and have strong associations. Herz and Von Clef also note this (2001:388).

5.1.3. Implications for olfaction, predictive processing and the label-feedback hypothesis

From the above, it is clear that there is some effect of verbal labels on the perception of ambiguous odours. According to the predictive processing framework, top-down predictions are activated when bottom-up sensory information is weak or noisy. Greater perceptual weight is also afforded to top-down predictions when the bottom-up sensory information is not sufficient to complete the task at hand (Lupyan and Clark, 2015). The findings of previous studies on olfactory illusions as well as some of the findings of the present study can be explained by predictive processing in the following way: the bottom-up sensory input from the stimulus in this experiment, namely the ambiguous odour itself, was weak or noisy due to its ambiguity. In order to make up for this weak sensory input and arrive at a more accurate impression of the stimulus, top-down predictions had a greater influence on the perception of the stimulus. This was in order to complete the task at hand, which was answering the questions in this experiment. Following the label-feedback hypothesis (Lupyan, 2012), these top-down predictions were activated by the verbal labels given to the participants for each odour.

However, the findings do not reflect a significant effect of verbal labels on the perception of the experimental odours for all the tasks. It is clear from the above that although labels did not have a significant effect on all the odours for perceived pleasantness, intensity and familiarity, they did have an effect on the actions, memories and names associated with all the experimental odours. This difference may be because of the difference in task demands. For the written part of the task, participants had to access actions, memories and names which were not presented to them in the bottom-up sensory stimulus. In order to complete the task, therefore, participants had to rely on episodic memory and were therefore unlikely to be further effected by sensory input. As mentioned previously, language involves higher-level processing and facilitates top-down predictions (Lupyan and Clark, 2015:280). This is how, according to the label-feedback hypothesis, labels can have an effect on perception (Lupyan, 2012). The hedonic evaluations, however, did not require the participant to access top-down predictions to the same extent. In order to complete the task, therefore, the participant was able to rely on bottom-up sensory input to a greater extent and the verbal labels had a smaller overall effect.

As noted above, the differences between the effects found on the different odours can be due to varying degrees of experience with and exposure to these odours in the everyday life of the participants. The label-feedback hypothesis offers related explanation. Labels have been shown to activate top-down feedback more strongly when the stimulus is typical (Lupyan, 2012:7-8). The experimental odours varied in typicality, resulting in a weaker activation of top-down feedback. The weakest effect of verbal label was found on the perception of 2-heptanone, which was presented with the labels “banana bread” and “nail polish remover”. The strongest effect was found on citral, which was labelled “squeezed lemons” and “insect repellent”.

According to the label-feedback hypothesis, this difference in effects could be because 2-heptanone does not smell like typical banana bread nor typical nail polish remover, as much as citral may smell like typical squeezed lemons or insect repellent. This is supported by an a priori impression that 2-heptanone is not very typical of either of the labels it was presented with. In the association section of the questionnaire, some participants expressed that although they could not tell what the smell was, they could say that it was not banana bread or nail polish remover (depending on the label they were given). This type of answer was not given for any other experimental odour. However, 2-heptanone did not have significantly more “missing” associations than any of the other experimental odours (Table 4). This indicates that associations were not significantly weaker for 2-heptanone.

5.2. Limitations

This study had some practical limitations. A limitation of this study is the participant number, which was relatively low at only 28. Although Djordjevic et al. (2008) had 40 participants in Experiment 1 and 30 participants in experiment 2, which is not much more, Herz and Von Clef had 80 participants (2001:383). This type of study would benefit from a larger number of participants to result in greater statistical weight of the findings. However, since Herz and Von Clef (2001) found robust effects of labels on olfactory perception, subsequent studies should not need very large sample sizes to detect such robust effects. Another practical limitation is the fact that the odorants that could be used were limited due to availability and safety.

Another limitation of this study is that in order to control the presentation of the odours and their labels, the investigator had to be constantly supervising the participant. Responses, particularly to the questions about actions, memories and names, could have been affected by what the participants thought the investigator wanted, instead of how they actually perceived the odour. This was mitigated for by not telling the participant the aim of the experiment and none of the participants guessed the aim. Furthermore, the experiment took place at the

Department of Food Science, not the Department of General Linguistics, and was not advertised as a study about language. This reduced the risk of participants suspecting the true aim of the study. Nonetheless, this type of study would benefit from an increased distance between the investigator and the participant.

5.3. Suggestions for future research

Because the relationship between language and olfactory perception is still largely unexplored, there are many gaps for future research to fill. It has been shown that odour naming systems are not the same in all languages (Majid and Burenhult, 2014; De Valk et al., 2017), and therefore a study with a similar design comparing speakers of a language with a source-based odour naming system with speakers of a language with an abstract odour naming system would be beneficial to the field. Categorisation is central to the label-feedback hypothesis (Lupyan, 2012:4) and such a study could provide important insights as to how abstract, odour-specific labels influence categorisation and perception of odours.

Additionally, as mentioned above, the predictive processing framework and the label-feedback hypothesis have been formulated mainly on the basis of studies on visual perception. These visual perception studies could be adapted for the study of olfactory perception to test the limits of theoretical approaches that are largely modelled on visual phenomena. An example of this would be a study on novel category learning that tests the effect of labels on a participant's ability to learn and classify unfamiliar smells, based on Lupyan, Rakison and Mcleland's (2007) study involving classification of aliens based on invented names. Such a study could involve a comparison between participants' ability to learn and classify labelled odours and un labelled odours. Such a study could also aim to determine the effect of iconic labels on participants' ability to learn and classify odours. An iconically labelled odour could, for example, be a "sharp" odour, such as a sharp cheese or chemical solvent, presented with an invented label containing "sharp" letters such as "z". This is similar to Lupyan and Casasanto's (2014) study on category learning through iconic labels.

Furthermore, as mentioned above, different odours are susceptible to influence of verbal labels to varying degrees. Future studies could be done to investigate which measures, such as intensity, can be used to predict how susceptible a certain odour would be to verbal label effects.

6. Conclusion

This thesis aimed to investigate the effect of verbal labels on the perception of odours. More specifically, it set out to investigate the extent to which verbal labels influence, first, the perceived pleasantness, intensity and familiarity of odours, and second, the actions, memories and labels associated with these odours.

Previous research showed that verbal labels have a significant effect on factors such as perceived pleasantness, intensity and familiarity (Herz and Von Clef, 2001; De Araujo et al., 2005; Djordjevic et al., 2008). The results of this study confirm this in part. The only significant effects were found on the perceived pleasantness of eugenol and citral, but otherwise the effects were insignificant or merely marginal, as on the familiarity rating of citral. Previous research has also shown that verbal labels have an effect on the memories, actions and names associated with odours (Herz and Von Clef, 2001). The results of this study confirm this view.

The findings of the current study support the predictive processing framework and particularly the label-feedback hypothesis in that labels were found to influence the perceived pleasantness of eugenol and citral, as well as the action, memory and name associations of eugenol, 2-heptanone and citral, resulting in olfactory illusions. However, verbal labels did not have as strong an effect on the hedonic evaluations as on the associations. This was argued to be because hedonic evaluations do not require as great a reliance on top-down predictions, facilitated by labels, as action, memory and name associations, according to the predictive processing framework.

Language and olfactory perception is clearly under-researched. As evidenced by the current thesis, there is enormous potential for testing predictions about verbal labels and the sensory system, and future research along this line has the potential to generate important knowledge about the human mind.

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Appendix A: Smell questionnaire

SMELL QUESTIONNAIRE

Please sniff twice and then rate the smell and answer the questions below:

Pleasantness

Extremely unpleasant 1----2----3----4----5----6----7----8----9 Extremely pleasant

Intensity

Extremely weak 1----2----3----4----5----6----7----8----9 Extremely intense

Familiarity

Extremely unfamiliar 1----2----3----4----5----6----7----8----9 Extremely familiar

What actions do you associate with this smell?

Do you have a memory associated with this smell? If so, describe it briefly.

What would you call this smell?

Appendix B: Language background questionnaire

Age: _______
Gender: _______

(1) Please indicate which language(s) you speak and rate your proficiency in each one of them, using the following scale:

1 < - - - - - - 2 - - - - - -3 - - - - - - 4 - - - - - - > 5
Rudimentary Excellent

Language: ________________ Self-rated proficiency (1-5): _____
Language: ________________ Self-rated proficiency (1-5): _____
Language: ________________ Self-rated proficiency (1-5): _____
Language: ________________ Self-rated proficiency (1-5): _____

(2) Please indicate how often you use these languages in your everyday, oral communication, using the following scale:

1 < - - - - - - 2 - - - - - -3 - - - - - - 4 - - - - - - > 5
Seldom Almost all the time

Language: ________________ Frequency of use (1-5): _____
Language: ________________ Frequency of use (1-5): _____
Language: ________________ Frequency of use (1-5): _____
Language: ________________ Frequency of use (1-5): _____

(3) Which language(s) did you learn first, that is, as a baby? ___________________________________

(4) If you speak any other languages than the one(s) you learnt first, please indicate which ones, where you learnt them (e.g., school, playground etc.) and at what age you learnt them.

Language: ____________ Where it was learnt: _______________ Age of learning: _____
Language: ____________ Where it was learnt: _______________ Age of learning: _____
Language: ____________ Where it was learnt: _______________ Age of learning: _____
Language: ____________ Where it was learnt: _______________ Age of learning: _____

(5) What do you think the purpose of this experiment was?

Appendix C: Consent form

UNIVERSITEIT•STELLENBOSCH•UNIVERSITY
jou kennisvennoot • your knowledge partner

STELLENBOSCH UNIVERSITY
CONSENT TO PARTICIPATE IN RESEARCH

You are invited to take part in a study conducted by Talya Beyers, from the Department of General Linguistics at Stellenbosch University. You were approached as a possible participant because you are a first language English speaker between the ages of 18 and 30, who does not smoke or have any known chemical allergies.

1. PURPOSE OF THE STUDY

The purpose of this study is to investigate how people perceive smells.

2. WHAT WILL BE ASKED OF ME?

If you agree to take part in this study, you will be asked to smell some odours and answer questions about them. You will then be asked to fill in a short language background questionnaire about the languages you speak and have been exposed to.

These tasks will be performed in one session, which will take between 40 and 60 minutes. They will be performed in the sensory laboratory at the Department of Food Science at Stellenbosch University.

3. POSSIBLE RISKS AND DISCOMFORTS

Some of the smells you will be exposed to might be unpleasant. However, you will be exposed to each smell for a very short time only. If this causes you discomfort, you are permitted to withdraw your participation in the study without any consequences.

If you experience any symptoms of an allergy or hypersensitivity, or shortness of breath, you will be taken to the Campus Health Service clinic immediately.

4. POSSIBLE BENEFITS TO PARTICIPANTS AND/OR TO THE SOCIETY

This study will not directly benefit you as a participant. However, it will contribute to an understanding of language and cognition.

5. PAYMENT FOR PARTICIPATION

You will not receive any payment or compensation for participating in this study.

6. PROTECTION OF YOUR INFORMATION, CONFIDENTIALITY AND IDENTITY

Any information you share with me during this study and that could possibly identify you as a participant will be protected. This will be done by coding data into an Excel spreadsheet in a way that you cannot be identified by your data. The data will be stored in the Principle Investigator's (Talya Beyers) personal password-protected device and only she and her supervisor (Prof Emanuel Bylund) will have access to it. Any outcomes of the study (research papers, articles, etc.) will use the data in such a way that individuals are not identifiable.

7. PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you agree to take part in this study, you may withdraw at any time without any consequence. You may also refuse to answer any questions you don't want to answer and still remain in the study.

8. RESEARCHERS' CONTACT INFORMATION

If you have any questions or concerns about this study, please feel free to contact Talya Beyers at 19903561@sun.ac.za, and/or the supervisor, Prof Emanuel Bylund at mbylund@sun.ac.za.

9. RIGHTS OF RESEARCH PARTICIPANTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research participant, contact Ms Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

DECLARATION OF CONSENT BY THE PARTICIPANT

As the participant I confirm that:

- I have read the above information and it is written in a language that I am comfortable with.
- I have had a chance to ask questions and all my questions have been answered.
- All issues related to privacy, and the confidentiality and use of the information I provide, have been explained.

By signing below, I ________________________________ agree to take part in this research study, as conducted by Talya Beyers.

____ ______________________

Signature of Participant **Date**

DECLARATION BY THE PRINCIPAL INVESTIGATOR

As the **principal investigator,** I hereby declare that the information contained in this document has been thoroughly explained to the participant. I also declare that the participant has been encouraged (and has been given ample time) to ask any questions. In addition I would like to select the following option:

	The conversation with the participant was conducted in a language in which the participant is fluent.
	The conversation with the participant was conducted with the assistance of a translator (who has signed a non-disclosure agreement), and this "Consent Form" is available to the participant in a language in which the participant is fluent.

____ ______________________

Signature of Principal Investigator **Date**

Appendix D: Table 4

Table 4: Comparisons between "same", "different" and "missing" answers each of the association questions for each of the odorants

Question	Comparison	N	Proportion	*p*
EUG-ACT	Same	3	0.176	0.013
	Different	14	0.824	0.013
EUG-ACT	Missing	11	0.786	0.057
	Same	3	0.214	0.057
EUG-ACT	Missing	11	0.440	0.690
	Different	14	0.560	0.690
EUG-MEM	Same	4	0.267	0.118
	Different	11	0.733	0.118
EUG-MEM	Missing	13	0.765	0.049
	Same	4	0.235	0.049
EUG-MEM	Missing	13	0.542	0.839
	Different	11	0.458	0.839
EUG-NAM	Same	4	0.200	0.012
	Different	16	0.800	0.012
EUG-NAM	Missing	8	0.667	0.388
	Same	4	0.333	0.388
EUG-NAM	Missing	8	0.333	0.152
	Different	16	0.667	0.152
HEP-ACT	Same	2	0.111	0.001
	Different	16	0.889	0.001
HEP-ACT	Missing	10	0.833	0.039
	Same	2	0.167	0.039

HEP-ACT	Missing	10	0.385	0.327
	Different	16	0.615	0.327
HEP-MEM	Same	3	0.250	0.146
	Different	9	0.750	0.146
HEP-MEM	Missing	16	0.842	0.004
	Same	3	0.158	0.004
HEP-MEM	Missing	16	0.640	0.230
	Different	9	0.360	0.230
HEP-NAM	Same	4	0.182	0.004
	Different	18	0.818	0.004
HEP-NAM	Missing	6	0.600	0.754
	Same	4	0.400	0.754
HEP-NAM	Missing	6	0.250	0.023
	Different	18	0.750	0.023
CIT-ACT	Same	0	0	< 0.001
	Different	20	1	< 0.001
CIT-ACT	Missing	8	1	0.004
	Same	0	0	0.004
CIT-ACT	Missing	8	0.286	0.036
	Different	20	0.714	0.036
CIT-MEM	Same	1	0.063	< 0.001
	Different	15	0.938	< 0.001
CIT-MEM	Missing	12	0.923	0.003
	Same	1	0.077	0.003
CIT-MEM	Missing	12	0.444	0.701
	Different	15	0.556	0.701

CIT-NAM	Same	2	0.087	< 0.001
	Different	21	0.913	< 0.001
CIT-NAM	Missing	5	0.714	0.453
	Same	2	0.286	0.453
CIT-NAM	Missing	5	0.192	0.002
	Different	21	0.808	0.002

Note: Proportions tested against the value 0.5

N = Number of answers