Testing the Proust phenomenon:

Olfactory cues are most effective in triggering autobiographic memories.

M. J. de Bruijn

717383

Tilburg University

This empirical paper was written as a Master's Thesis to conclude the Research Master of Social and Behavioral Sciences at the Social Psychology department of Tilburg School of Social and Behavioral Sciences, Tilburg University. This thesis was supervised by Assistant Professor Dr. Michael Bender.

Abstract

The Proust phenomenon postulates that odors are potent triggers for autobiographical memory. Despite increasing attention for the effects of odors on cognition, a direct empirical test of the phenomenon does not exist. This study examines the effectiveness of odors as retrieval cues for meaningful autobiographical memories. In the main study, 170 participants were asked to express the vividness, detail and emotional intensity of two childhood memories using retrieval cues which consisted of either odors or images. Results showed that participants indeed reported more detail, vividness and emotion when presented with odors than images. The findings of this study support the notion that specific odors can elicit specific and rich memories, and open up numerous avenues for further exploration.

Keywords: *Scent; Olfaction; Odor; Autobiographical memory; Proust, Cognition.*

Introduction

In 1956, Proust published *Swann's Way*. In this literary work, Proust described how he relived a specific memory from his childhood after tasting a piece of cake dipped in tea. The release of *Swann's Way* has increased academic attention for the effects of olfaction on cognition. Since *Swann's Way*, attention to olfactory cognition has been growing steadily. Studies into potential effects of odors on cognition have shown that odors may influence, among others, consumer attitudes (Chebat & Michon, 2003), behavioral intention and actual behavior (Holland, Hendriks & Aarts, 2005) as well as language, attention and general cognitive functioning (Westervelt, Ruffolo, & Tremont, 2005). While this increase of attention for olfactory cognition cannot be attributed solely to Proust, his work does seem to have inspired researchers to examine the relation between odor and memory more closely. Research on olfactory memory has seen the emergence of topics such as olfactory processing, olfactory recall and imagery, duration of olfactory memory, implicit memory for odors, odor based context-dependent memory and odor-evoked olfactory memory (Herz & Engen, 1996). In fact, the influence of Proust on this field has been such that the (involuntary) triggering of an old and seemingly forgotten memory by an olfactory cue (as described in *Swaan's* Way) has now become known as the Proust phenomenon.

The Proust phenomenon resonates with popular wisdom that odors are potent reminders of past experiences, but empirical support for the existence of this phenomenon is surprisingly thin (Chu & Downes, 2000a; Chu & Downes, 2002; Jellinek, 2004). A number of researchers have attempted to test the Proust phenomenon, with varying degrees of success. Upon scrutiny, however, each of these studies have methodological weaknesses that keep them from truly testing the phenomenon. In fact, the authors of this paper argue that a true empirical test of the Proustian phenomenon does not exist. The central aim of the current study is therefore to

empirically test the Proustian phenomenon by examining whether odors are indeed the most effective cues for eliciting autobiographical memory. Autobiographical memory (AM) is defined here as personally experienced events that may be localized in space and time (Conway & Pleydell-Pearce, 2000). In order to achieve that aim, it is necessary to clarify what constitutes a 'true' Proustian study. Once this objective is clear, a review of previous studies is used to identify three empirical challenges along with their proposed solutions.

Different approaches to the Proust phenomenon

There are several reasons why previous research has not yet succeeded in truly confirming the Proustian phenomenon. One such reason is the lack of consensus between researchers on how to define the Proust phenomenon (Chu & Downes, 2002). Rubin, Groth and Goldsmith (1984) interpret it as a belief that odors evoke memories that are older than memories evoked by other cues and there is a significant body of research that supports this notion. For example, a large number of studies have shown that when participants are asked to indicate how old they are in their odor-evoked AM, they tend to indicate ages from the first decade of life (e.g.: Chu & Downes, 2000b; Herz, 2004; Larsson & Willander, 2009; Miles & Berntsen, 2011; Willander & Larsson, 2006; 2007; 2008), a phenomenon known as the *reminiscence bump* (Rubin & Schulkind,1997).

A second interpretation of the Proust phenomenon is offered by Engen and Ross (1973), who see it as the belief that odors are forgotten more slowly than memories of other sensory modalities. This prediction may also result in a reminiscence bump and is further supported by neuroanatomical research demonstrating that odor-invoked memories originating in childhood are related to stronger activation of the secondary olfactory cortex, whereas odor-invoked memories originating from young adulthood leads to activation in the left inferior frontal gyrus

(supporting semantic memory processing) (Arshamnian et al., 2013). This differential brain activation for odor-invoked memories of different ages, lends support to the notion that old olfactory memories are encoded differently and may therefore also be subject to different processes of retrieval and decay.

Herz & Cupchik (1995) state that memories triggered by olfactory cues are more emotionally loaded, which would be the basis for the Proust phenomenon. Their definition is supported by the findings of Herz (2004) that participants who were asked to retrieve positive memories using perfume, showed stronger neural activation in the amygdala and hippocampal regions than participants who were asked to recall memories using images of the same perfume. In a similar study, by Arshmanian et al., (2013) odor-evoked memory retrieval, compared to verbal-induced memory retrieval, also lead to activation a different region in the limbic system (however, see Ehrlichman & Bastone, 1992; and Willander & Larsson, 2006 for a more critical view of the odor-emotion link).

These different emphases on time, affect, and decay complicate the attempts of researchers to find empirical support for the existence of this phenomenon. One commonly accepted definition is that of Chu and Downes (2000a), who have summarized the differences into their definition of the Proust Phenomenon as "the ability of odors spontaneously to cue autobiographical memories which are highly vivid, affectively toned, and very old" (p. 111). According to Chu and Downes, a test of the Proust phenomenon should thus seek to demonstrate that olfactory retrieval cues outperform retrieval cues of other sensory modalities in terms of eliciting memories that are older, more emotionally intense and more vivid. This interpretation of the phenomenon is in agreement with Larsson et al.'s (2014) statement that odor-invoked AM is characterized as limbic, old, vivid, emotional, and rare (acronym LOVER). However, Jellinek

(2004) has criticized Chu and Downes for over-simplifying the Proust phenomenon, stating that a true test of the phenomenon should focus on confirming a larger number of hypotheses. For example, Jellinek stresses that Proust describes how the recalled memory is preceded by surprise and that this surprise prompts the search for the memory. Unfortunately, testing Jellinek's hypotheses is temporally complicated and beyond the scope of the current study. Included in the hypotheses formulated by Jellinek, for example, is that awareness of emotions preceeds awareness of the sensory stimulus and that awareness of physiological activation preceeds awareness of the memory. Since these cognitive events occur in quick succession, testing their order of occurrence would require elaborate neurological measurements of an individual's response to odor cues. This study will therefore aim to empirically confirm the Proust phenomenon as interpreted by Chu and Downes, because it is currently the most complete definition that still offers realistically testable hypotheses.

Methodological difficulties in testing the Proust phenomenon

Aside from ambiguities in defining the Proust phenomenon, research into its existence is hampered further by methodological challenges that researchers need to overcome. These challenges include the targeting of the correct type of memory, the person-specific nature of odor-memory associations and the elimination of rival hypotheses. It is thus appropriate to review previous studies that support the notion that odor is a potent retrieval cue, to identify strategies to overcome these challenges.

Challenge #1: Targeting meaningful naturalistic AM. One of the most common problems that Proustian research encounters, is the targeting of genuine naturalistic AM. A large body of odor-memory research consists, for example, of context-dependent memory studies. These studies typically provide participants with target information (most often a text or a list of

words) to remember while exposing them to peripheral stimuli such as ambient fragrances and later examine the effectiveness of the same peripheral cue by registering how much of the original information is recalled. Such context-dependent odor-studies have found that participants indeed remember information better when they receive the same odor as retrieval cue (Parker, Ngu & Cassaday, 2001), that this effect is augmented by salience of the odor (Herz, 1997) and that performance is better when participants receive odor-cues, compared to participants who receive visual cues (Pointer & Bond, 1998). The finding that peripheral information such as odor is encoded along with the target information and can be used as an effective retrieval cue is encouraging to the Proustian researcher. Though it is encouraging, context-dependent studies do not lend support to the Proust phenomenon, because a clear distinction should be made between semantic and episodic memories (Tulving, 1972). Context-dependent studies utilize semantic memory; the understanding of objects, and the knowledge of facts about the world. Conversely, episodic memories are more personal than semantic memories and refers to memories of events. As the focus of the Proust phenomenon is on AM, a study into Proustian phenomena should be targeting episodic memory instead of semantic memory.

Within the body of research dedicated to odor and episodic memory, active association presents a new problem for the targeting of genuine and naturalisic AM. Herz and Cupchik (1995), for example, asked participants to memorize emotional paintings using words or odors. After being asked to describe the paintings later, they found that participants who received odor cues reported more emotionally toned recollections of their experience. The Proustian researcher may remember Chu & Downes' predictions concerning highly affective memories and thus appreciate Herz and Cupchik's finding that odors evoke more emotionally toned recollections. However, it is important to realize that the association between odor and the target experience in

the study of Herz & Cupchik was created very intentionally. Naturalistic AM, on the other hand, are generally created by a passive encoding process where the individual does not intentionally associate peripheral details with the central event (Chu & Downes, 2002). Additionally, by providing participants with target information, these studies examine recall of memories that are very recent, whereas the Proust phenomenon refers to the triggering of memories that can be decades old (Jellinek, 2004). Herz and Cupchik, therefore, cannot confirm that odor cues trigger emotionally toned naturalistic AMs.

Chu and Downes (2002) side-stepped active association asking participants to report personal memories for each of five auditorily presented odor-labels and then asked them to indicate how old, vivid, and emotionally intense these memories were after being presented with a visual odor-label, an odor congruent or incongruent with that odor label. The authors showed that reports of affect, detail, and age were generally higher in the congruent odor condition. In a second study, they compared odor-labels, (in)congruent odors and photographs, and found that the congruent odor cues led to more detailed memory descriptions. Together, Chu and Downes claim, the two studies provide true evidence of the Proust phenomenon. A similar study was conducted by Herz and Schooler (2002). In their study, participants selected a naturalistic childhood memory after being presented with a verbal label and were then given verbal, visual or olfactory cues to aid with retrieval of the selected memory. Results showed that participants presented with the olfactory cue reported more emotional memories and a stronger sense of being ‘brought back’ to the event. While these study do indeed target naturalistic AM, questions arise concerning the meaningfulness of the targeted naturalistic memories. Participants in Chu and Downes’ study were asked to report any memories they had about five presented odorous objects, such as parmesan cheese, lemon and ginger. In the study of Herz and Schooler, odors

included crayons, sunscreen, and play-doh. It is unlikely that these seemingly random odorous objects truly triggered strong memories, let alone a memory as powerful and vivid as that described by Proust. It is more likely that the reported memories, while genuinely naturalistic and autobiographical, were weak associations of limited personal significance to the individual participants.

To the author's knowledge, there is only one study that has tested potency of odor as a retrieval cue while using meaningful naturalistic AMs. Aggleton & Waskett (1999) conducted a study among visitors of a Viking-museum which used fragranced displays. They asked 45 visitors to report what they remembered of the Viking displays (average time since last visit was 6.7 years) with the aid of a congruent odor cue, incongruent odor cue, or no odor cue. With higher means for the congruent odor-condition, the result of Aggleton & Waskett's study was in the expected direction, but it failed to reach statistical significance. Furthermore, the study did not compare odor cues against cues of other sensory modalities. Therefore, Aggleton and Waskett's study, too, cannot be considered a true test of the Proustian hypothesis. A true test ought to examine differences between retrieval cues of different modalities with regard to their potency to trigger meaningful naturalistic AMs and should pay specific attention to the age, vividness and emotional tone of those memories.

Challenge #2: Odor-memory associations are unique and person-specific. The original memory-experience as described by Proust details how a specific olfactory cue (i.e. a morsel of a *petit madeleine* dipped in tea) unexpectedly and powerfully triggers an equally specific memory (i.e. Proust's aunt Leoní giving him the same cake on Sunday mornings) which had been buried so deep it had been considered forgotten. Clearly, the combination of cue and memory in this example is highly personal and applies only to Proust himself. Any other person

would likely have eaten the cake without encountering a detailed and emotional experience. This uniqueness creates the second challenge that Proustian researchers have to overcome; by their very nature, meaningful naturalistic and AMs are personal and different for each individual. Similarly, odor-memory associations are different for every individual. This makes the Proust phenomenon ill-suited for empirical testing in a standardized setting. Barring extensive and costly a priori research into the personal history of each individual participant, researchers have no way of knowing in advance which odors may evoke strong and meaningful AMs in participants. Additionally, specific odors may be highly complex and difficult to replicate (e.g.; the smell of a hallway in a childhood home). Furthermore, using different odors for each participant would complicate standardized experimental designs. Ideally, there would be a single odor that triggers meaningful AM in all participants. This ideal, however, is unattainable and a study into the Proust phenomenon exactly as it is described in *Swan's Way* therefore seems impossible and beyond the grasp of researchers. However, a close approximation of the phenomenon is attainable. While it may not be realistically possible to identify a specific odor that will evoke a meaningful naturalistic AMs in everybody, it is perhaps possible to identify odors that may evoke such memories in multiple people. After all, some odors may be more salient, may be encountered more often or may be more likely to be associated with life events than other odors. By identifying which odors may trigger meaningful AMs in a group of people rather than in all individuals, Proustian researchers can explore the phenomenon as closely as possible.

Searching for suitable odors that multiple people will associate with life events, it is important to consider how to target memories of personal significance and of relevance for formative memories (Challenge #1). Logically, AMs that are most relevant for identity formation

are childhood memories. After all, early experiences are more likely to impact the way we have formulated our identity narrative. Consequently, this study will search for salient and familiar odors that many people will have encountered during their childhood. A pre-test is devoted to identifying suitable odors for as true a Proustian test as possible.

Challenge #3: Eliminating alternative hypotheses and controlling for confounding effects. A third challenge for Proustian researchers is the existence of rival explanations for their results. One such explanation is that the effects of olfactory retrieval cues are driven by the thought of the odorous object rather than the odor itself (Chu & Downes, 2002). Researchers in the odor-memory field tend to use familiar and easily recognizable odors in their studies and recognition of an odor will also activate the concept of the odorous object. As a result, there can be uncertainty about the true driving force behind the memory retrieval: the presented odor or the activated concept of the odorous object. Since the activation of a familiar and easily recognizable odorous object can occur almost instantaneously, it can be difficult to disentangle the two rival explanations. However, a solution lies in the realization that recognition and awareness of the odorous object are key elements in the alternative explanation. Avoiding recognition and awareness of the object altogether (i.e.; by using unfamiliar odors) is unadvisable, since this is likely to increase error in the study. However, adding a verbal-label condition can help by offering a baseline against which the odor-cue condition can be compared (Chu & Downes, 2002). Alternatively, awareness and recognition in an experimental setting can be kept constant in all conditions by making the participant explicitly aware of the object *before* presenting them with the odor cue. This process is referred to as the double-cueing methodology (Chu & Downes, 2002, Herz & Schooler, 2002) and simply consist of presenting the participant with an odor-label, asking them to report a personal memory related to this label and then asking them for

further detail of that memory after presenting them with an odor cue (or a cue of another sensory modality). Because the participant is made explicitly aware of the odorous object in the first phase of the approach, any differences found between the conditions in second phase can no longer be explained by awareness. With the double-cueing methodology, a Proustian study's research question thus changes, from 'can odors elicit AMs?' to 'can odors elicit AMs *above and beyond awareness of the object*?'.

The abovementioned double-cueing method also solves a second alternative explanation for Proustian findings. This second explanation, put forth by Chu & Downes (2000a; 2002), is referred to as the *differential encoding bias hypothesis* and postulates that AMs triggered by odors are inherently different from AMs triggered by cues of other modalities in terms of complexity and detail. In other words; it argues that higher ratings of detail and vividness found in previous studies may not be due to the effectiveness of odor as a retrieval cue, but to differences in the underlying memories. According to Chu & Downes, this can occur because AMs are complex memories and complex memories encode more peripheral information. Because odors generally are peripheral information (olfactory details are rarely part of the central event) (Baddeley, 1982), odors are generally encoded in complex memories and not in less complex memories. Because odors are associated with more complex memories, Chu and Downes argue, using them as a retrieval cue may lead to more reported details. Cues of other modalities (e.g.: visual) are more likely to be encoded in less complex memories and may thus yield less detail. By suggesting that the targeted memories differ, rather than the effectiveness of the cues, the differential encoding bias hypothesis provides an alternative explanation. However, by using the double-cueing method, the target memory is determined before the retrieval cues are presented. The sensory modality of the cue thus has no impact on the selected memory. The

double-cueing method is able to eliminate both alternative explanations for the Proust phenomenon and, for this reason, was also applied in the current study.

The present study

The current study seeks to provide a direct test of the Proust phenomenon by applying the double-cueing methodology (Chu & Downes, 2002; Herz & Schooler, 2002. However, this study overcomes the limitations of previous studies by specifically targeting meaningful, naturalistic AMs. For that end, we carried out a pilot study in which we pretested and selected odors that multiple people associate with personally relevant life events from childhood. We then compared the selected odor cues with cues of other modalities to test if odor-evoked memories are more detailed, more vivid and more emotionally laden.

Hypothesis 1: Participants who receive olfactory retrieval cues will report more *detailed* memories, compared to participants who receive visual retrieval cues or no retrieval cues.

Hypothesis 2: Participants who receive olfactory retrieval cues will report more *vivid* memories, compared to participants who receive visual retrieval cues or no retrieval cues.

Hypothesis 3: Participants who receive olfactory retrieval cues will report more *emotional* memories, compared to participants who receive visual retrieval cues or no retrieval cues.

Unfortunately, because this study specifically targets AMs that originated during childhood, it is not possible to test predictions concerning differences in age.

Method

Pilot Study

In order to identify which odors are salient, familiar and strongly related to childhood, 17 students and staff members of a Dutch university were presented with ten odors. Five of these odors were chosen as odors commonly encountered during childhood. Childhood odors were selected either because previous research by Reid, Green, Wildschut & Sedikes (2015) showed they were effective triggers of nostalgia or because the researchers of the current study expected these odors to be especially familiar for the targeted Dutch sample[1] . The five selected childhood odors were: peanut butter, baby powder (perfumed, brand: Zwitsal), Vicks VapoRub, cinnamon, and lavender. The other five were selected to be non-childhood related and were previously used in studies by Chu and Downes (2002): coffee, vinegar, sunscreen, lemon, and onion. Participants were presented with these ten odors in random order. Odors were presented in metal cylindrical containers with perforated lids that allowed the participant to smell the odor without viewing the content. The containers were identical, save for their labels A to J. For each container, participants were asked to identify the content and to report on a five point-Likert scale how strongly they associated this odor with childhood (1 = not at all associated, 5 = strongly associated).

[1] The study of Reid et al. (2015) used (among others); pumpkin pie spice, lavender and baby powder. Instead of pumpkin spice, the current study used cinnamon as a 'holiday' odor, because the consumption of pumpkin is not as common in the Netherlands. Furthermore, this study used baby powder of the Zwitsal brand, because this brand is very well known in the Netherlands and uses a very distinctive odor. VapoRub and peanut butter were handpicked by the researchers.

Results of the pilot study are displayed in Figure 1. In the group of childhood-related odors, VapoRub was identified as both most easily recognizable (82.35 % of participants identified the odor correctly) and most strongly associated with childhood ($M_{VapoRub}$ = 4.12, SD = 1.05). In the group of non-childhood related odors, coffee and vinegar were most often correctly recognized (both 64.71 %), but vinegar alone was least associated with childhood ($M_{vinegar}$ = 1.44, $SD_{vinegar}$ = 0.61, M_{coffee} = 1.94, SD_{coffee} = 1.10). Hence, VapoRub and vinegar were selected to be used in the main study.

Figure 1 here

Participants seemed to have trouble identifying the content of the containers. For most odors, recognition rates were relatively low (overall $M_{\text{recognition}}$ = 48.24%, SD = 21.26), even though odors were selected specifically for being easily recognizable.[2] Awareness of the odor is an important alternative explanation for odor-cued retrieval and the pilot test thus illustrated the importance of avoiding confusion about the content of the containers during the main study.

Despite the low recognition rates, the reported association with childhood were in the expected direction, with $M_{\text{childhood odor}}$ = 3.26 (SD = 0.57) and $M_{\text{non-childhood odor}}$ = 2.34 (SD = 0.73). This trend was also true for odors with very low recognition rates. For example, with an accuracy of 17.65%, Zwitsal baby powder had the lowest recognition rate of all odors used in the pilot study. Yet, its association score with childhood was M = 3.53, which is well above the average of

[2] Many participants reported during the debriefing that they felt the task was more difficult than they had expected and that they strongly felt that they knew the odors even if they could not identify them.

childhood odors and the second strongest childhood-association overall. This finding suggests that the participants' odor associations were not dependent on recognition. In other words, these findings suggest that it is the odor itself, rather than awareness of the odor, that drives the odor-childhood association. However, since the pilot was not designed to test this hypothesis and the sample size was not large enough to allow for significance testing, no conclusions can be drawn concerning the (absence of) effects of recognition on association strength.

Participants

For the main study, 170 participants (35 males, M_{age} = 20) participated for partial fulfillment of a course requirement. Participants were recruited from a population of undergraduate psychology students at a Dutch university. A priori power analyses revealed that a sample of 200 participants was necessary in order to obtain sufficient power ($1-\beta = .80$) in a study expecting a conservative small to medium effect size ($f = .20$). This target sample size was approximated, but not fully obtained.

Design

In order to test if participants will generate AMs of greater detail, vividness and emotional content when presented with an odor cue, a 2 x 2 x 2 mixed factorial design was used, measuring sensory modality (between subjects factor: visual cue vs odor cue) as well as cue type (within subjects factor: childhood cue vs non-childhood cue) and controlling for cue order (between subjects factor: childhood cue presented first vs childhood cue presented last). Additionally, half of the participants (irrespective of the condition they were assigned to) were

asked for pre-cue measurements, thus creating a no-cue baseline which allowed for comparison with the two sensory modality conditions[3].

Materials

Based on the results of the pilot test, VapoRub and vinegar were used as childhood cue and non-childhood cue, respectively. For participants that were assigned to the odor-condition, these cues were presented to them in the same metal cylindrical containers that were used in the pilot. The containers were placed under the desk inside the test cubicle, in such a way that they would not be visible until the participant was instructed to look for them. The containers were placed in re-sealable plastic bags to keep the fragrances from dissipating inside the cubicle and potentially invalidating the results. Odor samples were refreshed every 4 hours (1 teaspoon of VapoRub and 10cc of vinegar absorbed by a single cottonpad). The containers were clearly labeled to ensure that participants could identify the content.

Participants assigned to the visual condition were not instructed to look for the containers, but were instead shown a 10 cm by 10 cm picture of either a bottle of vinegar or a jar of VapoRub, displayed in the center of a computer monitor. In both images, the product labels on the jar/bottle were clearly visible and readable to ensure that all participants were able to identify the object.

After being presented with cues, participants were asked to describe their memory in a text box with the following instructions: *"Describe your childhood memory in the box below.*

[3] This approach was chosen because a priori power analysis indicated that adding a no-cue condition to the sensory modality variable would raise the power requirements for this study such that it could not realistically be realized. By asking participants to answer the pre-cue items, a no cue baseline was created by means of a within-subjects variable (pre-cue vs post-cue measurement), while avoiding an increase in power demands. Of course, a comparison between the pre-cue, odor cue and visual cue conditions is possible only if there is no carry-over effect of the pre-cue measurement. Asking only half of the participants to fill in the pre-cue items allowed for a test for carry-over effects, the outcome of which can be found in the result section of this study.

Add as much detail as possible; the number of words you can use is unlimited." Furthermore, the quality of the elicited memory was measured using three 7-point Likert scale questions where they were asked to indicate the extent to which they would describe their memory as vivid/detailed/emotional, with 1 = not at all vivid/lively/emotional and 7 = very vivid/detailed/emotional.

All items and instructions were presented to the participants through an online questionnaire. Since the sample was recruited from a population of Dutch students; all materials were presented in Dutch.

Procedure

The study was conducted by five student experimenters, all of whom received a detailed script for standardizing purposes. All participants were welcomed and seated in individual cubicles, where they received instructions about general lab procedure.[4] Next, participants received instructions about the current study on screen and gave informed consent. Regardless of condition, all participants were asked to recall and briefly describe a childhood memory for both the childhood and the non-childhood odor. Afterwards, 50% of participants were asked to answer the three Likert-scale questions about both memories in order to generate a baseline measurement. The remaining 50% of participants instead read a short line of instructions introducing the subsequent questions. Next, all participants were randomly sorted into either odor or visual conditions, and received their first cue. Participants in the odors condition were instructed to look for the container placed under the desk, smell the content and put the container back inside the bag before continuing to the questions. Participants in the visual conditions

[4] This study was conducted in combination with three other (unrelated) studies. These other studies commenced after the completion of the current study and have therefore not interfered with the results.

viewed an image for 10 seconds, before continuing to the questions. Due to counterbalancing, 50% of the participants received the childhood-cue, while the other half received the non-childhood cue. After the appropriate cues were presented, all participants were asked to describe their memory concerning that cue in as much detail as possible. They also indicated the vividness, emotional ladenness and detail of their memory. The same procedure was then repeated for the second memory. After completing the second memory description, participants were asked to answer demographic and control items. Participants were asked what they thought the purpose of the study was, whether they had encountered problems during the procedure, if they had any difficulties retrieving memories and whether they had noticed an odor in the cubicle upon entering. Finally, participants were thanked and debriefed.

Results

Data preparation and reliability analysis

Inspection of the control items revealed that 15 participants reported having detected an odor in the cubicle upon entering; a binary control variable (*noticed scent*) was created to control for potential adverse effects of those odor detections. Furthermore, six participants misunderstood the instructions. Four participants had smelled the vinegar and VapoRub containers in the wrong order, leading to their answers for the two memories being switched. Another participant mistakenly smelled the VapoRub container twice; this participant's data for the non-childhood odor cue (vinegar) was dropped. Lastly, once participant reported a memory not associated with the VapoRub retrieval cue; this person's data for the childhood-cue was dropped.

Reliability analysis was used to examine the internal consistency of the remaining valid dataset. The measures of vividness, emotional ladenness and detail were strongly correlated.

Reliability analyses yielded all Crohnbach's α's > .82. Due to the similarities between the memory measures, they were collapsed and averaged to create a single composite variable reflecting memory quality.

In order to compare the memory quality scores in different cue conditions, scores of memory quality were collapsed across the pre-cue measurement condition. To this end, a potential carryover effect of the pre-cue measurement was examined. T-tests revealed no such effect, except in two specific cases. Pre-cue measurements may have affected the scores of participants when they described their memory related to the non-childhood cue (vinegar); only for participants who received this vinegar memory first, scores of detail ($t(89) = -2.109$, $p = .04$) and vividness ($t(89) = -1.97$, $p = .05$) were higher for those who did answer the pre-cue items compared to those who did not. These carryover effects disappeared when the composite variable was used rather than the individual memory measures. Furthermore, the carryover effect was absent when no distinction was made between cue order. Scores of the pre-cue participants were merged with the other participants, despite the detected carryover effects, because the impact of the effect appears limited. While this order effect could be spurious, conclusions concerning the non-childhood cue should be interpreted with caution.

Main analysis

Comparison of the three cue conditions showed that means were in the expected direction. For all variables (including the composite variable, but with the exception of *detail)* in the non-childhood cue condition, means in the odor condition were higher than both the mean in the no cue condition and the mean in the visual condition. In order to test the significance of each of the three hypothesis, a repeated measures analysis (controlling for *noticed scent*) was first used to examine differences between the cue and no-cue conditions. Secondly, an ANOVA (also

controlling for *noticed scent)* was used to examine differences between the odor and the visual cue.

Hypothesis 1: vividness. Participants in the cue conditions reported more vividness than participants in the no-cue condition ($F_{childhood\ cue} = 39.78$, $p < .001$ and $F_{non\text{-}childhood\ cue} = 12.99$, $p = .001$). An ANOVA showed that participants who received the childhood odor ($M_{odor} = 4.58$, $SD_{odor} = 1.57$) reported memories of more vividness than participants who received the childhood image ($M_{image} = 3.85$, $SD_{image} = 1.92$) ($F(1) = 7.17$, $p = .01$). This effect was not found for participants who received the non-childhood cue ($M_{odor} = 4.20$, $SD_{odor} = 1.84$, $M_{image} = 3.98$, $SD_{image} = 1.82$) ($F(1) = .68$, $p = .41$). These findings are in agreement with hypothesis 1.

Hypothesis 2: detail. Participants in the cue conditions reported more detail than participants in the no-cue condition ($F_{childhood\ cue} = 30.17$, $p < .001$ and $F_{non\text{-}childhood\ cue} = 44.21$, $p < .001$). An ANOVA showed that participants who received the childhood odor ($M_{odor} = 4.18$, $SD_{odor} = 1.77$) did not report memories of more detail than participants who received the childhood image $M_{image} = 3.75$, $SD_{image} = 1.87$) ($F(1) = 1.79$, $p = .18$). This effect was also not found for participants who received the non-childhood cue ($M_{odor} = 4.05$, $SD_{odor} = 1.83$, $M_{image} = 4.11$, $SD_{image} = 1.71$) ($F(1) = .11$, $p = .75$). These findings are not in agreement with hypothesis 2.

Hypothesis 3: emotional intensity. Participants in the cue conditions reported more emotional intensity than participants in the no-cue condition ($F_{childhood\ cue} = 33.03$, $p < .001$ and $F_{non\text{-}childhood\ cue} = 13.23$, $p < .001$). An ANOVA showed that participants who received the childhood odor ($M_{odor} = 3.51$, $SD_{odor} = 1.58$) did not report memories of more emotional intensity than participants who received the childhood image $M_{image} = 3.11$, $SD_{image} = 1.75$) ($F(1) = 1.95$, $p = .17$). This effect was also not found for participants who received the non-childhood cue

(M_{odor} = 3.09, SD_{odor} = 1.60, M_{image} = 3.01, SD_{image} = 1.61) ($F(1) = .04$, $p = .85$). These findings are not in agreement with hypothesis 3

Differences on the composite variable. Repeated measures analyses on the composite variable revealed that participants in the cue conditions indeed reported higher memory quality than participants in the no-cue condition ($F_{childhood\ cue} = 49.73$, $p < .001$ and $F_{non\text{-}childhood\ cue} = 35.49$, $p < .001$) (see Figure 2). More importantly, an ANOVA (controlling for odor detection in the cubicle) showed that participants who received the childhood odor reported memories of higher quality than participants who received the childhood image ($F(1) = 4.29$, $p = .04$). This effect was not found for participants who received the non-childhood cue ($F(1) = .79$, $p = .79$) (see Figure 3). Though no specific hypothesis was formulated for the composite variable, these findings are in agreement with the Proustian phenomenon.

In sum, results show that recall of a childhood memory is aided by an odor cue only when this odor cue is associated with childhood. This trend is found to be significant for the composite measure of memory quality as well as for the measure of memory vividness. While differences for memory detail and emotional intensity are in the expected direction, they fail to reach statistical significance.

Figures 2 and 3 here

LIWC analysis

In order to verify the robustness of the above effect, the detailed descriptions of both childhood memories were processed with the Dutch version of the Linguistic Inquiry and Word

Count (LIWC) program (Pennebaker, Francis, & Booth, 2001). This LIWC program counts words to analyze the content of texts, based on the assumption that an angry text, for example, will contain more angry wordstems. As the incidence of wordstems in a text increases, so does its variable score. LIWC 2001 variable scores are expressed as percentages to reflect the incidence of counted hits, relative to the total word count. Results of the LIWC analysis are presented in Table 1.

Fifteen participants used the memory description box to report that they could not think of an appropriate childhood memory. These participants' descriptions were set to missing, and were not used in the LIWC analysis.

Table 1 here

Because the percentage scores in the LIWC output were strongly skewed, they were log transformed before further analysis. For both the childhood cue and the non-childhood cue, t-tests revealed no differences between the visual and odor cue conditions in terms of affect, positive emotion or negative emotion.

Discussion

The current study set out to test the Proust phenomenon by examining whether odor are more potent cue for AM than cues of other sensory modalities. In accordance with the definition formulated by Chu & Downes (2000a), this study specifically tested if odor-evoked AMs score higher on vividness, detail and emotional intensity. Results of the current study indicate that olfactory cues indeed yield richer AMs, compared to visual cues. This effect was found only when the odor was congruent: non-childhood odors did not affect the reported quality of

childhood memories. While participants who received a childhood odor reported more emotional ladenness, they did not write more emotionally toned memory descriptions of these memories.

The current findings are in agreement with previous empirical research (e.g.: Aggleton & Waskett, 1999; Chu & Downes, 2002; Herz & Cupchick, 1995; Willander & Larsson, 2007; 2008) and provides additional support for the Proust phenomenon. The current study extends the existing empirical evidence for the phenomenon by eliminating important alternative explanations for the findings that odor cues yield richer memory descriptions. For example, by using Chu & Downes' double cueing methodology, we can eliminate the possibility that the activation of the concept of the odorous object (rather than the odor itself) is the driving force behind the results, because awareness of the object is held constant in all conditions. Additionally, the double cueing methodology allows us to reject the *differential encoding bias hypothesis* (Chu & Downes, 2002). This hypothesis postulates that Proustian differences arise because the memories that tend to get triggered by odor are qualitatively different from memories that are triggered by cues of other sensory modalities. By ensuring that the memories used in this study were encoded before the participants were exposed to the cues, we can be certain that no differential encoding bias could have affected the results of the current study. Lastly, the current study distinguishes itself from previous studies by explicitly targeting personally meaningful AMs. This was done by explicitly targeting childhood memories and by using odors that many people associate with their childhood. By focusing on meaningful AM, the current study is able to approximate as closely as possible a true test of the Proustian phenomenon.

Limitations

It is important to notice that the aforementioned choice for childhood memories made it impossible for the current study to test one of the core assumptions of the Proust phenomenon; namely that AMs triggered by odor are old memories. This assumption, referred to as the *reminiscence bump,* has frequently been supported by research (e.g.: Chu & Downes, 2000b; Herz, 2004; Larsson & Willander, 2009; Miles & Bernstsen, 2011; Willander & Larsson, 2006; 2007; 2008). Given the available evidence for the existence of the reminiscence bump and the scarcity of odor-studies targeting meaningful AMs, the authors of the current study have chosen to target meaningful memories at the expense of testing memory age. Ideally, however, a Proustian study should test all aspects of the phenomenon simultaneously and with the same methodological rigor.

A second limitation of the current study is the detected carry-over effect of the pre-cue measures on subsequent measurements. Participants in the non-childhood cue conditions reported higher detail and vividness of the recollected memory when they were exposed to pre-cue measurements. This finding is likely due to the additional recall opportunity presented to participants. The differential findings between the childhood and non-childhood odor may be caused by the ease with which memory details could be retrieved. It is possible that childhood memories related to vinegar were more difficult to retrieve than those related to VapoRub, since the vinegar odor was chosen specifically for being unrelated to childhood. In turn, memories that are difficult to retrieve may profit more from the additional recall-opportunity, compared to easily retrieved memories. Hence, participants who had difficulty recalling details of their childhood memory may have reported higher detail and vividness as a result of the pre-cue items. It should be noted, however, that reports of difficulty of memory retrieval showed negligible differences between the childhood and non-childhood conditions. Regardless of the cause, the

differences between participants who receive a non-childhood cue and participants that receive no such cue may be an overestimation as a result of the carry-over effect. Conclusions about the effectiveness of the non-childhood memory cues should be interpreted with caution. It is important to note that the participants in the pre-cue measurements were randomized. Therefore, the carry-over effect has had no impact on differences between the odor and visual cue conditions and, thus, has had no negative consequences for the main findings of this study.

The insignificant results of the LIWC analysis, in contrast, does impact the main findings of this study. LIWC results are surprising, because they showed no differences between emotion in the visual and odor conditions, while these differences did exist with the Likert item measuring emotional ladenness. This inconsistency could perhaps be explained by the small correlations found between the Likert item and the LIWC variables[5]. Reliability of the LIWC-scale is sufficient, with $\alpha = .81$ for the childhood-odor measures and $\alpha = .76$ for the non-childhood measures. The conflicting findings for the Likert and LIWC items therefore seems most likely due to internal validity of either the Likert-item or the LIWC items. To the knowledge of the author, no information on the validity of the Dutch LIWC currently exists.

Lastly, the current study used a unimodal cueing approach, meaning that participants were exposed to cues of only one sensory modality (either visual or olfactory). Larsson et al., 2014; Willander, Sikstrom, & Karlsson, 2015) are proposing a multimodal cueing methodology where participants are exposed to, for example, visual, olfactory and auditory cues. Exposing participants the cues of multiple modalities allows researchers to better examine differential

[5] For the childhood-odor (VapoRub), correlations between de Likert-item and the three LIWC items were $r = .24$, $p = .002$ for affect, $r = .22$, $p = .004$ for positive emotion and $r = .09$, $p = .23$ for negative emotion. Among the non-childhood odor memories, correlations were $r = .32$, $p < .001$ for affect, $r = .27$, $p < .001$ for positive emotion and $r = .19$, $p = .01$ for negative emotion.

memory retrieval. Using multimodal cueing, Willander et al. (2015) found that memory retrieval was driven primarily by visual and auditory information and to a lesser extent by olfactory information. Because the Proust phenomenon predicts that odors are more effective retrieval cues than cues of other modalities, the study of Willander and collegues thus contradicts our predictions. It should be noted that multimodal cue research is currently in its infancy (to the knowledge of the author, only one such study currently exists); yet it may present interesting implications for Proustian research.

Future research

The main aim of the study is to shed light on the influence that odors may have on AM retrieval. To distinguish itself from previous research, the current study targeted meaningful naturalistic AMs. However, no variable measuring such meaningfulness was added to study. As a result, the authors of this study have to assume the meaningfulness of the memories on the basis of the high odor-childhood associations found in the pilot study. This is undesirable, given the small sample of the pilot study. Future research in this field should add a measure for the meaningfulness of the memories to ensure that the methodology used in this study is successful in its intended goal.

Future researchers are also advised to examine the cultural validity of the effects found in this study. As mentioned, some of the odors used in the pilot study were hand-picked by the authors, because they were expected to resonate with the target population of Dutch undergraduate students. Depending on age or ethnicity, for example, participants are likely to have encountered very different odors in their childhood. Therefore, age and ethnicity should be considered when determining odors that trigger similar associations in a large group of people.

Researchers are therefore advised to not blindly use odors that proved themselves to be potent retrieval cues in previous studies. Instead, researchers ought to carefully consider their target population and use a pilot to identify those odors best suited for use in their study.

In addition to carefully selecting the appropriate (culture-specific) odors, future researchers are also advised to avoid small enclosed spaces when conducting studies involving odors. The current study was conducted in a University laboratory which contained several small cubicles with computers. However, by placing the odor-containers inside the cubicles for the participants to find, there was a risk that the odors might diffuse and spread inside the cubicle. In order to avoid this problem, containers were placed in sealed (and sealable) bags and testleaders were instructed to frequently ventilate the cubicles. Additionally, participants were asked if they noticed any odors inside the cubicle upon entering. In the current study, six participants were eliminated from analysis for this reason. However, detection of odors was only reported when these odors were strong enough to be salient. It is possible that a non-salient odor may have escaped detection whilst still influencing participants' answers. Future researchers ae therefore advised to utilize well-ventilated areas and avoid small, enclosed spaces.

Lastly, the current study exclusively studied salient odors. Participants were explicitly made aware of the odor and the nature of the odor, in order to eliminate the rival hypothesis that activation of the odor object, rather than the odor itself, was the driving force behind the Proust effect. However, if may be of interest to examine the effects of unidentified odors on cognitive processes. Results of the pilot study revealed that reported strength of childhood-associations did not depend on correctly identifying the content of an odor container. For example, many participants failed to correctly identify the perfumed baby powder, yet the reported strength of childhood associations for this odor were high (second only to VapoRub). This finding suggests

that explicit awareness of the odor may not be a necessary requirement for the Proust phenomenon. This suggestion is supported by literature on memory retrieval, which has identified a generative and a direct retrieval strategy (Moscovitch, 1995; Conway and Pleydell-Pearce, 2000; Conway, 2005). According to Larsson et al. (2014), verbal cues lead to generative search strategies where the process is intentional, elaborative and effortful, while perceptual cues (such as odors) lead to direct recollections which are immediate and effortless. This prediction was supported by neuroanatomical research into retrieval process by Arshamian et al. (2013), who found that memories cues by words and odors both resulted in activation of brain regions generally associated with AM, but that word cues also resulted in increased activity in the prefrontal cortex, while odor cues did not. Together, these findings show that the memory retrieval process induced by odors is much more direct and subconscious than verbal-cues processes and they may explain why odors in the pilot study were able to generate the expected associations while their verbal label remained unidentified. Future research should examine the effects of non-salient and unidentified odors on cognition, in order to increase our understanding of the mechanics behind the Proust effect.

Implications

As mentioned, the authors of the current study intended to contribute to the field of olfaction and cognition by further developing a methodology suitable to properly test the Proust phenomenon. To this end, the methodology as developed by Chu & Downes (2002) was adapted to target meaningful AMs by identifying and using odors which can be expected to elicit similar associations in a large body of people. Using this approach has allowed us to conclude, in a test that is as close to the (impossible) ideal as possible, that the Proust effect indeed exists.

Understanding the Proust effect helps us understand the effect of odors on cognition in general. Odors are ubiquitous (though not always salient). Because we can now conclude that odors facilitate the retrieval of specific memories, this facilitation of specific memory retrieval may thus also be a ubiquitous process. This realization opens up avenues for research about self-perception, but also mood and decision making may be influenced by the elicitation of specific (valenced) memories. The finding that odors indeed facilitate the retrieval of rich AMs may also be of interest to companies. After all, the valence of the elicited memory could influence people's attitude toward the odor object. Dual processing theories such as the Elaboration Likelihood Model (ELM) (Petty & Cacioppo, 1986) and the heuristic-systematic model of processing (HSM) (Eagly & Chaiken, 1993) postulate that the non-effortful process of attitude formation can be influenced by heuristics such as affect ('I like this because it makes me feel good'). In the case of attitude formation and the Proust phenomenon, an odorous object may elicit a specific rich and valenced AM. The valence of said memory could then influence a person's attitude toward the odorous object ('I like this because it makes me remember happy times'). While this effect is purely speculative at the current stage of odor-memory research, its potential existence may be relevant for companies dedicated to selling odorous products. For example, the brand of perfumed baby powder which was used in the pilot study, may profit from fond memories of people's own childhood or, in case of older clientele, memories of their children. The brand of VapoRub used in this study could experience a more negative effect, because their product is associated with nasal congestion and the common cold.

The abovementioned array of potential new avenues of exploration underlines the importance of an understanding of the effect of odor on cognitive processes. This study contributes to that goal by empirically testing the Proust phenomenon and by improving the

methodology used in the field of Proustian research.

Conclusion

In conclusion, the main aim of this study was to empirically test the Proust phenomenon while avoiding the common pittfalls of research in this field. This study has replicated earlier findings about the effectiveness of odor as an AM retrieval cue, and it has also contributed to the improvement of methodology in this field. Further research is required to examine the cultural validity of the methodology and to determine to what extent awareness and recognition of the odor is a necessary aspect of the Proust phenomenon.

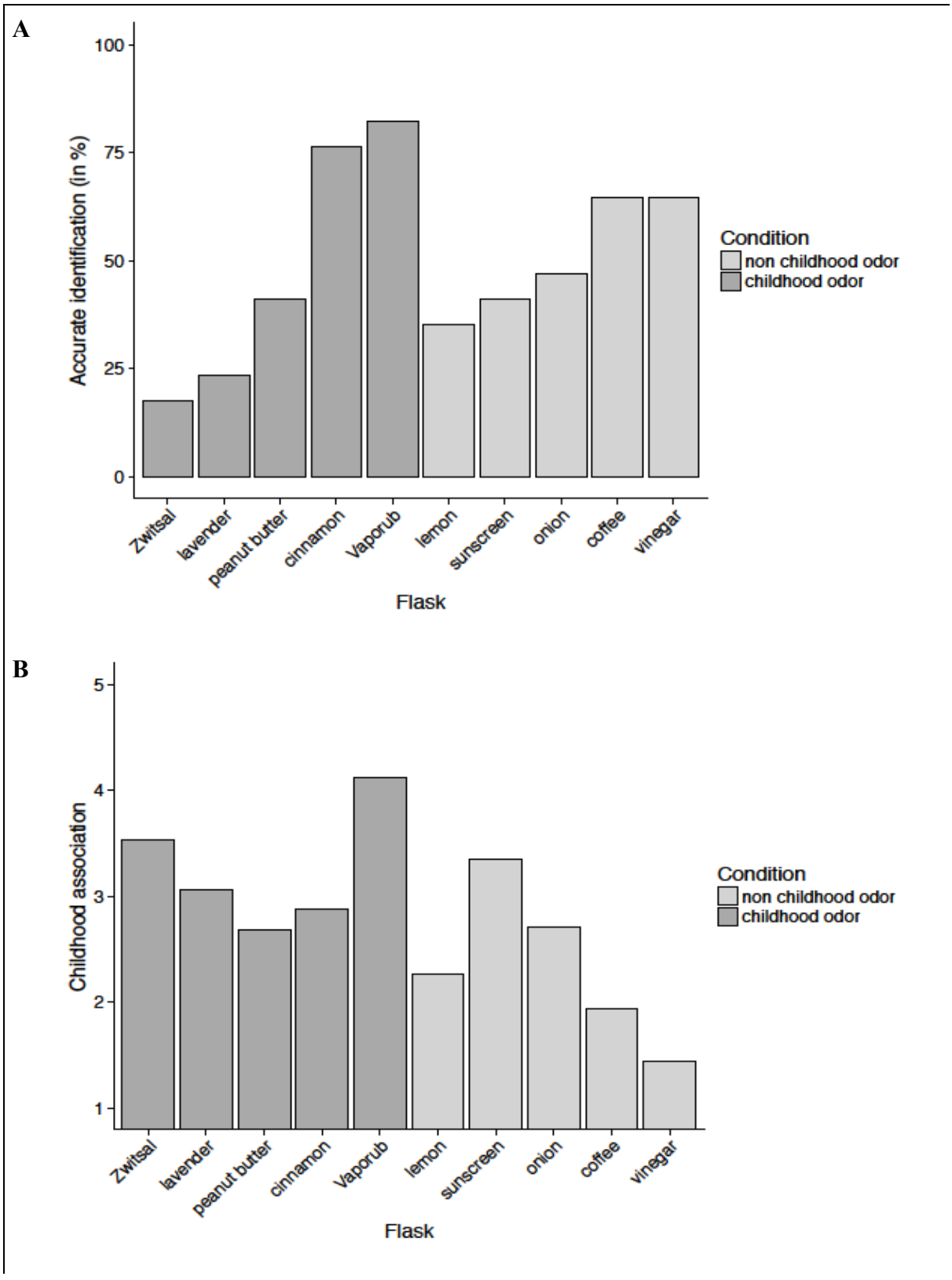
A
Accurate identification (in %)
100
75
50
25
0
Zwitsal
lavender
peanut butter
cinnamon
Vaporub
lemon
sunscreen
onion
coffee
vinegar
Flask
Condition
non childhood odor
childhood odor
B
Childhood association
5
4
3
2
1
Zwitsal
lavender
peanut butter
cinnamon
Vaporub
lemon
sunscreen
onion
coffee
vinegar
Flask
Condition
non childhood odor
childhood odor

Figure 1. Pre-test results.

Image A (top) shows percentage of accurate identifications of the odor. Image B (bottom) shows childhood association rates on a five-point Likert scale.

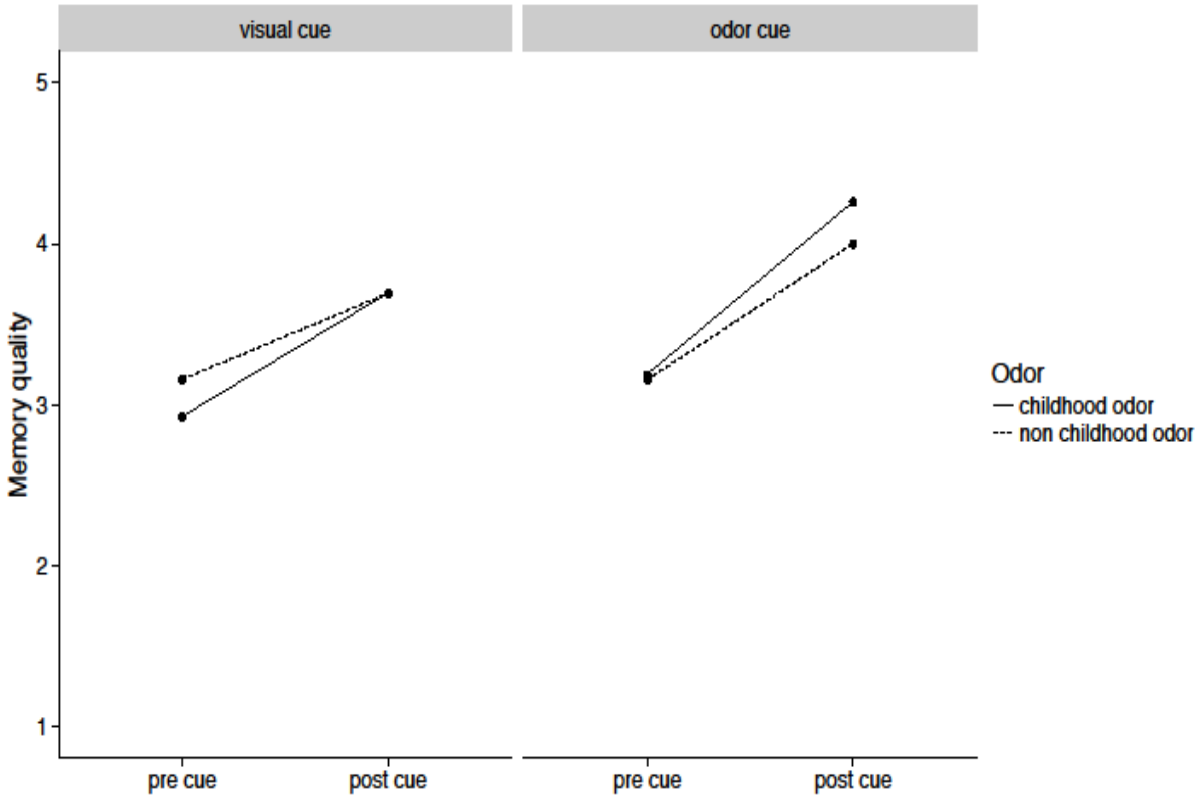

Figure 2. Pre cue and post cue comparison per cue type

Note: The figure shows group means on the composite variable *memory quality*, which is the averaged score of the *vividness*, *detail* and *emotional ladenness*. Item is expressed on a range of 1 – 5. The post-cue group consists of both the visual and the odor cue conditions.

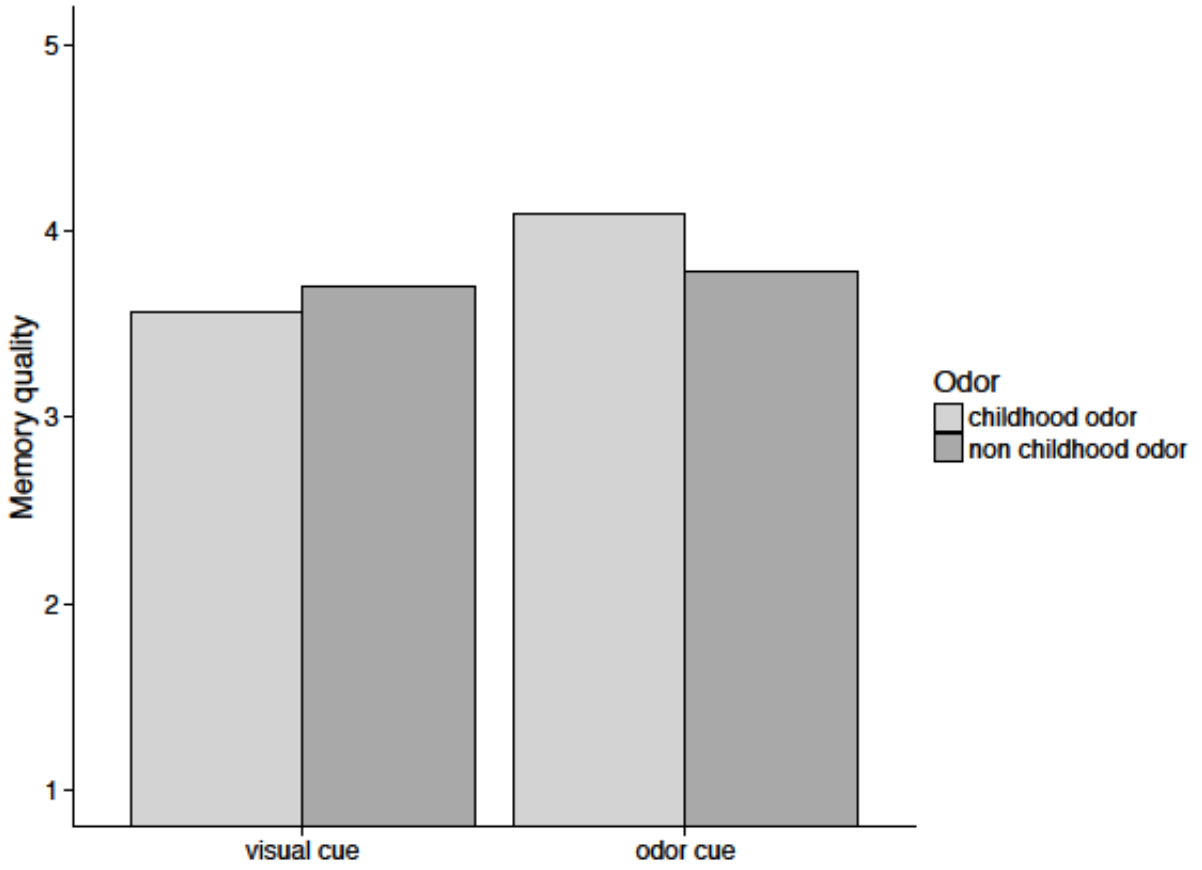

Figure 3. Visual cue and odor cue comparison

Note: The figure shows group means on the composite variable *memory quality*, which is the averaged score of the *vividness*, *detail* and *emotional ladenness*. Item is expressed on a range of 1 – 5.

Table 1: Descriptives of LIWC analysis

LIWC	Visual cue (n = 89) *M (SD)*	Odor cue (n = 81) *M(SD)*
Childhood scent (VapoRub)		
Affect	2.85 (2.75)	2.68 (2.27)
Positive emotion	1.31 (1.62)	1.23 (1.49)
Negative emotion	1.41 (2.18)	1.36 (1.48)
Non-childhood scent (Vinegar)		
Affect	1.72 (2.02)	2.00 (2.01)
Positive emotion	0.67 (1.05)	0.94 (1.19)
Negative emotion	0.99 (1.53)	1.00 (1.32)

Note: Baseline-participants did not write a detailed description of both their memories during the pre-cue measurement. Therefore, no LIWC data on pre-cue measures exist.
Note: None of the differences between the visual cue condition and the odor cue condition are statistically significant.

References

Ache, B. W., & Young, J. M. (2005). Olfaction: Diverse species, conserved principles. *Neuron, 48*(3), 417-430. doi: 10.1016/j.neuron.2005.10.22

Aggleton, J. P., & Waskett, L. (1999). The ability of odours to serve as state-dependent cues for real-world memories: can Viking smells aid the recall of Viking experiences? *British Journal of Psychology.*, 90, 1-7.

Arshamian, A., Iannilli, E., Gerber, J. C., Willander, J., Persson, J., Seo, H. S., ... & Larsson, M. (2013). The functional neuroanatomy of odor evoked autobiographical memories cued by odors and words. *Neuropsychologia*, *51*, 123-131. doi: 10.1016/j.neuropsychologia.2012.10.023

Baddeley, A.D. (1982). Domains of recollection. *Psychological Review*, 89, 708-729.

Chebat, J. C., & Michon, R. (2003). Impact of ambient odors on mall shoppers' emotions, cognition, and spending: A test of competitive causal theories. *Journal of Business Research*, *56*(7), 529-539. doi: 10.1016/S0148-2963(01)00247-8

Chu, S., & Downes, J. J. (2000a). Odour-evoked autobiographical memories: psychological investigations of Proustian phenomena. *Chemical Senses*, *25*(1), 111-116. doi: 10.1093/chemse/25.1.111

Chu, S., & Downes, J. J. (2000b). Long live Proust: the odor-cued autobiographical memory bump. *Cognition,* 75, B41-B50. doi: 10.1016/S0010-0277(00)00065-2

Chu, S., & Downes, J. J. (2002). Proust nose best: Odors are better cues of autobiographical memory. *Memory & Cognition*, *30*(4), 511-518. doi: 10.3758/BF03194952

Conway, M. A. (2005). Memory and the self. *Journal of Memory and Language,* 53, 594–628. doi: 10.1016/j.jml.2005.08.005

Conway, M. A., & Pleydell-Pearce, C. W. (2000). The construction of autobiographical memories in the self-memory system. *Psychological Review,* 107, 261–288. doi: 10.1037/0033-295 X.107.2.261

Eagly, A. H., & Chaiken, S. (1993). *The psychology of attitudes*. Harcourt Brace Jovanovich College Publishers.

Ehrlichman, H., & Bastone, L. (1992). Olfaction and Emotion. In *Science of Olfaction* (pp. 410–438). New York, NY: Springer New York. Doi:10.1007/978-1-4612-2836-3_15

Engen, T., & Ross, B. M. (1973). Long-term memory of odors with and without verbal descriptions. *Journal of experimental psychology*, *100*(2), 221.

Herz, R. S. (1997). The effects of cue distinctiveness on odor-based context-dependent memory. *Memory & Cognition*, *25*(3), 375-380.

Herz, R. S. (2004). A Naturalistic Analysis of Autobiographical Memories Triggered by Olfactory Visual and Auditory Stimuli. *Chemical Senses, 29*, 217-224. doi: 10.1093/chemse/bjh025

Herz, R. S., & Cupchik, G. C. (1995). The emotional distinctiveness of odor-evoked memories. *Chemical Senses*, *20*(5), 517-528.

Herz, R. S., & Engen, T. (1996). Odor memory: review and analysis. *Psychonomic Bulletin & Review*, *3*(3), 300-313.

Herz, R., & Schooler, J. (2002). A naturalistic study of autobiographical and visual evoked by olfactory memories the Proustian cues : Testing hypothesis, *115*(1), 21–32. doi.org/10.2307/1423672

Holland, R. W., Hendriks, M., & Aarts, H. (2005). Smells Like Clean Spirit Nonconscious Effects of Scent on Cognition and Behavior. *Psychological Science*, *16*(9), 689-693. doi: 10.1111/j.1467-9280.2005.01597.x

Jellinek, J. S. (2004). Proust Remembered: Has Proust's Account of Odor-cued Autobiographical Memory Recall Really been Investigated? *Chemical senses*, *29*(5), 455-458. doi: 10.1093/chemse/bjh043

Johansson, B. G., & Jones, T. M. (2007) The role of chemical communication in mate choice. *Biological Reviews, 82*(2), 265-289. doi:10.1111/j.1469-185X.2007.00009.x

Larsson, M., Willander, J., Karlsson, K., & Arshamian, A. (2014). Olfactory LOVER: behavioral and neural correlates of autobiographical odor memory. *Applied Olfactory Cognition*, 41, 1-5. doi: 10.3389/fpsyg.2014.00312

Larsson, M., & Willander, J. (2009). Autobiographical odor memory. *Annals of the New York Academy of Sciences*, *1170*(1), 318-323. doi: 10.1111/j.1749-6632.2009.03934.x

McAdams, D. P. (1985). Power, intimacy, and the life story. *Homewood, IL: Dorsey*.

Miles, A. N., & Berntsen, D. (2011). Odour-induced mental time travel into the past and future: Do odour cues retain a unique link to our distant past? *Memory, 19*(8), 930-940. doi: 10.1080/09658211.2011.613847

Moscovitch, M. (1995). Recovered consciousness: a hypothesis concerning modularity and episodic memory. *Journal of Clinical Experimental Neuropsychology,* 17, 276–290. doi: 10.1080/01688639508405123

Pennebaker, J. W., Francis, M. E., & Booth, R. J. (2001). Linguistic inquiry and word count: LIWC 2001. *Mahway: Lawrence Erlbaum Associates*, *71*, 2001.

Parker, A., Ngu, H., & Cassaday, H. J. (2001). Odour and Proustian memory: Reduction of context-dependent forgetting and multiple forms of memory. *Applied Cognitive Psychology*, *15*(2), 159-171. doi: 10.1002/1099-0720(200103/04)15:2%3C159::AID-ACP694%3E3.0.CO;2-D

Petty, R. E., & Cacioppo, J. T. (1986). The elaboration likelihood model of persuasion. In *Communication and persuasion* (pp. 1-24). Springer New York.

Pointer, S. C., & Bond, N. W. (1998). Context-dependent memory: colour versus odour. *Chemical Senses*, *23*(3), 359-362.

Proust, M. (1928/1956). Swann's Way [Remembrance of things past, Vol. I, trans. C. K. Scott Moncrieff]. New York, NY: Random House.

Reid, C. A., Green, J. D., Wildschut, T., & Sedikes, C. (2015). Scent-evoked nostalgia, *Memory, 23*(2), 157 – 166. doi: 10.1080/09658211.2013.876048

Rubin, D. C., Groth, E., & Goldsmith, D. J. (1984). Olfactory cuing of autobiographical memory. *The American journal of psychology*, 493-507.

Rubin, D. C., & Schulkind, M. D. (1997). Distribution of important and word-cued autobiographical memories in 20-, 35-, and 70-year-old adults. *Psychology and Aging, 12*(3), 524-535.

Tulving, E. (1972). Episodic and semantic memory 1. *Organization of Memory. London: Academic*, *381*(4), 382-404.

Westervelt, H. J., Ruffolo, J. S., & Tremont, G. (2005). Assessing olfaction in the neuropsychological exam: The relationship between odor identification and cognition in older adults. *Archives of Clinical Neuropsychology*, *20*(6), 761-769. doi: 10.1016/j.acn.2005.04.010

Willander, J., & Larsson, M. (2006). Smell your way back to childhood: Autobiographical odor memory. *Psychonomic bulletin & review*, *13*(2), 240-244. doi: 10.3758/BF03193837

Willander, J., & Larsson, M. (2007). Olfaction and emotion: The case of autobiographical memory. *Memory & Cognition, 35*(7), 1659-1663. doi: 10.3758/BF03193499

Willander, J., & Larsson, M. (2008). The Mind's Nose and Autobiographical Odor Memory. *Chemosensory Perception,1ournal*. 210-215. doi:10.1007/s12078-008-9026-0

Willander, J., Sikström, S., & Karlsson, K. (2015). Multimodal retrieval of autobiographical memories: sensory information contributes differently to the recollection of events. *Frontiers in psychology*, *6*, 1-8. doi: 10.3389/fpsyg.2015.01681