KARIANNE SNELL (BSc Hons)

INVESTIGATION INTO OLFACTORY MEMORY IN UNIQUE AMNESIA

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Acknowledgements

Firstly, I would thank the study participants, without whom this project would have been impossible. Thanks go especially to SI and his partner; it was an honour to meet you.

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Summary of MRP

Section A

Section A presents a systematic literature search and narrative synthesis of the literature on long-term olfactory recognition memory in a healthy adult human population. Searches produced 18 studies, which were subject to quality appraisals. Results revealed that olfactory recognition memory was not persistent over time but rather declined due to increased false alarm rates. Studies largely employed forced-choice and alternative forced-choice recognition tasks in investigating olfactory recognition memory. Several covariates influencing the recall of odours were also identified. Overall findings deviated from previous literature but may be reflective of the limitations of this current review. Clinical implications and directions for future research are discussed.

Section B

Section B presents an observational case-control study. A clinical participant with unique, medically unexplained amnesia (SI) was compared to eight age and education-matched controls for performance on tests of olfactory recognition memory, implicit skills (mirror maze task), and a neuropsychological test battery (Short Parallel Assessments of Neuropsychology Status [SPANS]). SI performed at a similar level to control participants within his memory retention window of 1 waking-day, but by day 2 of testing (unlike controls) SI did not demonstrate any retained learning. Clinical implications and future directions for research are discussed.

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Section A

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Section A

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Abstract

Olfactory memory has been suggested to be unique, and different to that of other senses. This review sought to systematically explore the literature on long-term olfactory recognition memory in a healthy adult human population, to understand if olfactory recognition memory is persistent over time, the methodology used to investigate this, and the influence of possible covariates on memory. 5821 studies were initially obtained and screened, of which 18 studies were included in this review. Studies were subjected to a critical quality appraisal and compared using narrative synthesis. Results revealed that olfactory recognition memory was not persistent over time but rather declined due to increased false alarm rates. Studies largely employed forced-choice and alternative forced-choice recognition tasks in investigating olfactory recognition memory. Several covariates influencing the recall of odours were also identified. Overall findings deviated from the previous relevant literature but may be reflective of the limitations of this current review. Clinical implications for neurodegenerative disease and olfactory training were suggested. Future research may benefit from further exploration of semantic and perceptual long-term olfactory memory, with the view to exploring populations with amnesia or brain injury for evidence of double dissociation in olfactory encoding.

Keywords: olfactory, memory, recognition, human, long-term.

Introduction

The human sense of smell (olfaction) is suggested to serve various functions, such as food-related behaviours (for example finding food sources and detecting if the food source is edible or not), hazard avoidance, and social communication (Stevenson, 2010). Human olfaction is more sophisticated than initially considered, and it has even been suggested that humans can distinguish over 1 trillion different smells (Bushdid et al., 2014).

Memory for smells, olfactory memory, has been proposed to be a unique memory system, different to other sensory memory (Herz & Engen, 1996). This is in part anatomical, as the olfactory cortex connects directly to the amygdala, avoiding the thalamus (unlike the other senses; Farbman, 1992; Herz & Engen, 1996). Neurons involved in olfaction, olfactory receptor neurons (or olfactory sensory neurons), are continuously regenerated and ensheathed in glial cells (and therefore unmyelinated unlike other neurons; Doucette, 1995; Graziadei & Graziadei, 1979). Olfaction is also considered one of the slowest senses in terms of processing information, possibly because of the differences in neurons (Schab, 1991).

Despite this proposed uniqueness, olfaction has typically had little research attention. Historically, olfaction has been considered less important than other senses and more greatly associated with social connotations of disgust (Low, 2006). Furthermore, on a methodological level, studying olfactory memory is currently more complex than the study of other sensory memory systems. Unlike other senses in which participants may be able to recall and recreate the stimuli they were exposed to (such as in tasks of verbal memory in which the participant can vocally reproduce what they were told previously), there is yet to be a technique developed to measure participants' odour recall by recreating the odour they were exposed to (Herz & Engen, 1996; White, 1998; White et al., 2015). Instead, tasks of olfactory memory tend to focus on odour recognition (for example: answering yes or no to questions about previous exposure), identification (such as naming the odour presented), and discrimination

(for example identifying which of two or more presented odours were shown before; White et al., 2015).

Some of the above techniques however rely on the use of other cognitive and sensory processes too, which again further complicates matters as to the nature of olfactory memory traces (perceptual or semantic, or both), and which is currently debated (Herz, 2000; Wilson & Stevenson, 2006). For example, odour naming has been associated with increased olfactory recognition; however, this might be testing verbal and semantic knowledge rather than pure olfaction as odour naming is a particularly difficult skill (Jönsson & Olsson, 2003; Öberg et al., 2002). Although Paivio (1986) hypothesised most memory systems have two pathways (dual coding theory), verbal and non-verbal, it is difficult for current study designs to separate out these verbal/semantic and non-verbal/perceptual components, and therefore difficult to study olfactory memory without utilising other memory pathways. An interesting double dissociation observed in the literature is that of Eichenbaum et al. (1983), who studied olfaction in the case of HM, an individual with bilateral hippocampal lesions following neurosurgery to control seizures resulting in anterograde amnesia (Scoville & Milner, 1957). HM was able to detect odours and discriminate for intensity and adaption, but could not discriminate for identical or different, and failed to perform in a match-to-sample task (Eichenbaum et al., 1983). This suggests that although he was able to perceive an odour, he was unable to compare this to semantic knowledge of the odour, hence giving evidence to a possible perceptual and semantic olfactory memory divide.

Some studies have attempted to address these methodological difficulties and questions about semantic/perceptual encoding in olfactory memory by utilising uncommon odours, which one would not have prior semantic or episodic knowledge of (White et al., 2015). Even unfamiliar, novel odours are often still remembered better than chance, again suggesting an element of pure perceptual olfactory memory (Møller et al., 2009; White et al.,

2015). Moreover, even without full recall of odour names, studies have found that a sense of knowing the odour (often referred to as familiarity) is associated with an increased chance of odour recognition (Jönsson & Olsson, 2003; Tulving, 1985). This brings into question whether olfactory memory is consistent with memory models such as the Working Memory Model (Andrade & Donaldson, 2007; Baddeley, 2000; Baddeley & Hitch, 1974); which proposes that working memory consists of a phonological loop, visuospatial sketchpad and episodic buffer that enables information to be maintained and manipulated until it can be moved into long-term memory or is otherwise forgotten; essentially a perceptual hold within each of the senses in which stimuli can be repeated or maintained before processing into long-term memory or being forgotten.

Evidence for and against the existence of a working memory model of olfaction is dependent on findings of serial position effects and interference effects. Studies suggest mixed evidence about current serial position effects for olfactory memory, with either little evidence demonstrated or only a slight suggestion of recency effects (in the absence of primacy effects; Johnson & Miles, 2009; Miles & Hodder, 2005; White, 1998; White et al., 2015). Furthermore, even interference effects are inconsistently reported in the literature (White et al., 2015). Moss et al. (2018, 2019) suggested that the existence of interference effects is determined by the quality of the odours, with verbalisable odours being found to be more subjected to proactive interference than non-verbalisable odours. Collectively, this questions the concept of olfactory working memory.

Despite this working memory debate, there is less dispute in the literature about the permanence of long-term olfactory memory. Generally, long-term memory has been proposed to be a potentially infinite and permanent store of information (Atkinson & Shiffrin, 1968). Long-term studies of olfactory memory have suggested that odours are recalled better than chance over significant time delays, as they are subjected to limited forgetting compared to

other sensory memories (Herz & Engen, 1996; Schab, 1991). For example, Lawless (1978) found that olfactory memory was above chance at 4 weeks post-exposure and remained stable at this level at 4 months post-exposure, whereas memory for visual stimuli declined at a faster rate. Furthermore, perceptual qualities of the odours, such as being more unpleasant, irritable, and intense, have been associated with even greater long-term olfactory memory retention than hedonically neutral, mild odours (Larsson et al., 2009). This might provide evolutionary benefits, increasing survival through avoidance of threats and adverse environments (Kensinger, 2007; Soussignan et al., 1997).

Additionally, episodic memories, especially those with emotional content, are said to be more persistent in long-term olfactory memory. For example, olfaction has been suggested to allow quick and detailed recall of emotionally salient autobiographical memories, known as the Proust phenomenon (Chu & Downes, 2002; Proust, 1928). Again, this may be understood through consideration of the brain's anatomy. The primary olfactory cortex connects directly to the amygdala, which is involved in emotions and threat detection, therefore olfaction and emotions being connected is comprehensible (Aggleton, 1993; Carmichael et al., 1994; Zhou et al., 2021). This has been supported in research utilising functioning Magnetic Resonance Imaging scans, such as that of Herz et al. (2004) who found when participants were asked to recall personally significant memories cued by an odour, there was significantly greater activation of the amygdala, than when the cue was visual in nature.

Although olfactory memory may be considered to have greater long-term retention than other sensory memory pathways, across the human lifespan however it is suggested that olfactory memory decreases (Doty & Kamath, 2014). This is largely due to a decline in general olfaction as humans age, as measured on a number of tests such as odour detection threshold, odour identification, and measures of olfactory memory (Schubert et al., 2012;

Tzeng et al., 2021). Reasons for this effect of age on olfactory ability may include a reduction in grey matter volume for brain regions involved in olfaction, increased risk of diseases that affect the human nasal tract and reduced synaptic connectivity as humans age (Schubert et al., 2008; 2012; Seubert et al., 2020; Tzeng et al., 2021; Yang & Pinto, 2016). This reduced olfactory ability is more prominent in men than women, possibly because of the increased risk of brain injury in men, arguably superior verbal abilities of women (and thus other pathways of olfactory information), and anatomical differences between the sexes (Brand & Millot, 2001; Öberg et al., 2002; Schubert et al., 2008, 2012).

Although a degree of decline in olfactory functioning is expected with age, excessive decline has been associated with a variety of neurodegenerative conditions, such as Parkinson's disease and Alzheimer's disease (Devanand et al., 2015; Ponsen et al., 2009), and even increased risk of mortality (Pinto et al., 2014). In regard to dementia, several studies have demonstrated how low olfactory identification rates in older adults can predict cognitive decline in cognitively typical older adults, and conversion from Mild Cognitive Impairment to Alzheimer's disease (Conti et al., 2013; Devanand et al.., 2008; Schubert et al., 2008). This increased risk of cognitive impairment with a decline in olfactory functioning may be associated with decreased grey matter volume, increased hyperphosphorylated tau, increased β-amyloid plaques, and decreased somatostatin in the olfactory cortex, as well as the presence of an APOE-ε4 allele (Bhatia-Dey & Heinbockel, 2021; Brozzetti et al., 2020; Larsson et al., 2016; Saiz-Sanchez et al, 2010; Tzeng et al., 2021). This suggests that olfactory memory could be relevant to clinical conditions and suggests a need for continued research.

Rationale and Aims

Overall, although long-term memory is generally considered more enduring than other sensory memory pathways, inconsistent approaches to measuring olfactory memory and overlap with other memory processes (such as semantic memory) have provided a need for a

review of the literature to be undertaken. As recognition tests are commonly used in the literature and require less semantic and verbal processing (compared to identification tests), this review will focus on olfactory long-term recognition memory (White et al., 2015).

Therefore, this review aimed to systematically explore the existing literature on olfactory recognition memory, with the view to answering the following questions:

1) Is olfactory recognition memory persistent over time in a healthy adult population?
2) What methods of experimental design are employed to investigate olfactory recognition memory in a healthy adult population?
3) What covariates influence olfactory recognition memory?

Based on the findings of the above questions, this review aimed to identify the current implications of olfactory memory research and suggested directions for future exploration.

Methodology

A systematic search of four databases was conducted on 25th October 2022. The databases selected for this review were: MEDLINE (OVID), PsycINFO, Web of Science, and Journal Storage (JSTOR). These databases were selected due to their relevance to the topic area, providing literature on Psychology, Medicine, Social Sciences, and Neuropsychology topics. JSTOR was selected to broaden the scope of the search, to reduce the risk of bias. Additionally, the Journal of Neuropsychiatry and Clinical Neuroscience was searched in the preliminary stages of the review, producing 115 papers, however, no further papers were found for this review relative to the inclusion and exclusion criteria utilised here.

No time limitations were applied to the publications.

All search terms were generated from keywords of influential papers, search terms used in other systematic reviews on similar topics, and synonyms of initial keywords identified (Chu & Downes, 2002; Herz, 2000; White et al., 2015; Zucco, 2003). For

MEDLINE (OVID), PsycINFO, and Web of Science, the search terms consisted of: olfact* OR smell* OR odour* OR odor* AND memor* OR remember* OR recall AND permanen* OR dura* OR fixe* OR fixi* OR stable OR stabili* OR endur* OR non-decay* OR persist* OR imperish* OR constant* OR preserv* AND recogni*. Due to the large numbers of identified papers in scoping searches, the final literature review searches were run with filters for humans, in the English language, and peer-reviewed (applied where possible within PsycInfo).

Due to limitations of the search tools (inability to process large numbers of search terms) within JSTOR, the following search terms were used: olfact* OR smell* OR odour* OR odor* AND memor* OR remember* OR recall AND recogni*. Additionally, the results were filtered to be in the English language, of the item type ‘articles’, ‘research reports’, and within the discipline of Psychology (biology, health sciences, and science and technology disciplines were also checked in initial scoping searches with no new relevant results found).

Eligibility Criteria

In order to be considered for this review, the study had to meet the following eligibility criteria:

1. The study had to be empirical research, published in the English language, by a peer-reviewed journal.
2. Olfactory recognition memory had to be (at least one of) the dependent variable within the study, with the inclusion of at least one time point of long-term memory (defined as ≥ 24 hours).
3. The participants of the study were adult-age (18 years and above) human subjects.

Exclusion Criteria

Studies were removed from this review if they met any of the following exclusion criteria:

1. The participants of the study were non-human animals, such as rats and mice.
2. The human participants were diagnosed with any form of cognitive impairment and/or neurodegenerative disease.
3. The participants were experiencing any mental health difficulties.
4. The participants were experiencing any form of congenital sensory processing difficulties (such as congenital blindness).
5. The study was exploring the effects of COVID-19 on olfaction.

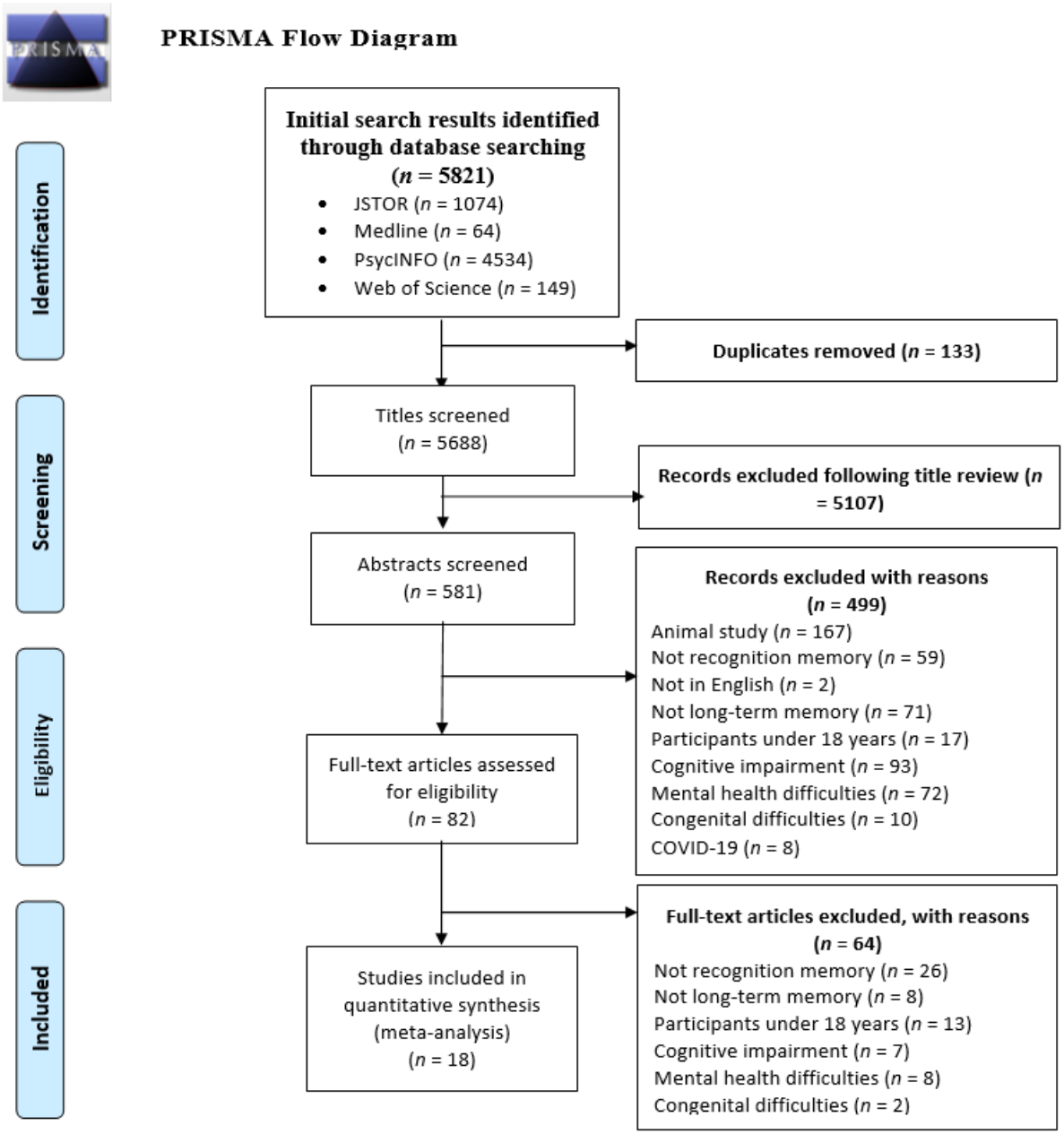
Prisma Diagram

The PRISMA diagram (Moher et al., 2009) in Figure 1 below displays an overview of the screening process for the studies reported in this review. Once a search was conducted on each database, the list of citations (including abstracts) was imported into reference management software (RefWorks).

RefWorks was used throughout the screening of the literature, in order to collate the citations from the database searches. Once imported to RefWorks, duplicates among these results were removed (n = 133). Titles were initially screened for eligibility, followed by abstracts of potentially relevant results. Finally, full-text papers were reviewed, resulting in 18 papers being included in this review.

Figure 1

PRISMA Diagram



Style Note

Of the 18 studies included in this review, some studies contained multiple experiments. Only the experiments that met the above inclusion and exclusion criteria were included in this review, see Appendices A and B for the full breakdown of which experiments from the studies were included, and more information about the studies' characteristics.

Unless otherwise stated, where there were important differences between experiments to highlight, different experiments within studies will not be indicated in this review.

Assessment of Quality

To assess the quality of the final papers, three assessment quality tools were utilised: the Clinical Appraisal Skills Programmes (CASP; 2018) Cohort Study checklist, the Joanna Briggs Institute (JBI; 2020b) Randomised Control Trial (RCT) and the JBI Quasi-Experimental Design checklists (2020a). A summary of the results of the appraisal checklists can be seen in Tables 1-3 below.

Each of the checklists included questions which were not relevant to this review and were therefore removed from inclusion in the quality appraisal used here. Specifically, in the CASP (2018) question 6 (a and b) regarding follow-ups was not included, in the JBI (2020b) RCT questions 4-6 and 8 regarding blinding of participants and researchers and follow-ups were removed, and in the JBI (2020a) Quasi-Experimental checklists questions 3 (regarding participants use of other treatments) and 6 (regarding follow-ups) were removed, whilst question 5 (regarding pre- post- outcome measures) was treated as if asking whether or not the participants experienced an immediate recognition test in addition to delayed recognition tests (due to the effect to interest, time).

Of the two studies included in the CASP (2018) checklist (Cain & Potts, 1996 [experiment 1]; Olsson et al., 2009), both were considered to be of good quality following the use of the checklist. However, neither provided sufficient information regarding the recruitment of participants and Cain and Potts (1996) included participants of an unrepresentative quota for gender which was not considered in their analyses or as a potential confounding variable for their results.

Of the 12 studies included in the JBI (2020b) RCT checklist, five were considered to be of good quality (Ayabe-Kanamura & Kikuchi, 1997; Jehl et al., 1995; Lyman & McDaniel,

1990; Rabin & Cain, 1984; Zucco, 2003). None of the 12 studies included sufficient information regarding the randomisation of participants to groups, however.

Furthermore, seven studies were highlighted as having limitations, such as not including sufficient detail about the participant's characteristics (Cain & Potts, 1996 [experiment 2]; Davis, 1977; Engen & Ross, 1973 [experiments 1-3]; Jehl et al., 1997; Lawless & Engen, 1997), no control group utilised (Cain & Potts, 1996 [experiment 2]), provided little information about the statistical analyses used (Engen & Ross, 1973 [experiments 1-3]), had an unequal gender ratio of participants that was insufficiently considered in the analysis (Cornell Kärnekull et al., 2015; Lawless & Engen, 1997), and unfairly attributed pleasantness to that of emotion (Saive et al., 2014). Despite these limitations, all 12 studies were included in this review.

Of the five quasi-experiments, all five were considered to be of good quality following the use of the JBI Quasi-Experimental Design Checklist (2020a; Chrea et al., 2007; Larsson & Bäckman, 1993, 1997; Lehrner, 1993; Murphy et al., 1991).

Table 1

Quality Appraisal Using the CASP Cohort Study Checklist

Study	Did the study address a clearly focused issue?	Acceptable recruitment?	Exposure accurately measured?	Outcomes accurately measured?	Confounding factors identified?	Designed/analysed to account for confounding factors?	Results	How precise are the results?	Do you believe the results?	Generalisable results?	Fits with other available evidence?	Implications?	Overall Appraisal
Cain & Potts (1996) [experiment 1]	Yes	Cannot tell	Yes	Yes	No	No	Semantic processing influences recognition for memory odours.	Precise, low SD around recognition mean.	Yes	Yes	Yes	Labelling can influence recognition, semantic/olfactory overlap	Include
Olsson et al. (2009)	Yes	Cannot tell	Yes	Yes	Yes	Yes	Odour recognition memory is better for identified odours, and decreases overtime	Precise, small CI and significant p values.	Yes	Yes	Yes	Episodic odour memory was aided by identification.	Include

Table 2

Quality Appraisal Using the JBI Randomised Controlled Trials Checklist

Study	True randomization of participants to assigned treatment groups?	Was allocation to treatment groups concealed?	Were treatment groups similar at the baseline?	Were treatment groups treated identically other than the intervention of interest?	Were participants analysed in the groups to which they were randomized?	Were outcomes measured in the same way for treatment groups?	Were outcomes measured in a reliable way?	Was appropriate statistical analysis used?	Was the trial design appropriate, and any deviations from the standard RCT design accounted for in the conduct and analysis of the trial?	Overall Appraisal
Ayabe-Kanamura & Kikuchi (1997)	Unclear	Unclear	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Include
Cain & Potts (1996) [experiment 2]	Unclear	Unclear	Unclear	Yes	Yes	Yes	Yes	Yes	Yes	Include
Cornell Kärnekull et al. (2015)	Unclear	Unclear	No	Yes	Yes	Yes	Yes	Yes	Yes	Include
Davis (1977)	Unclear	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Include
Engen & Ross (1973) [experiment 1]	Unclear	Unclear	Unclear	No	No	Yes	Yes	Unclear	No	Include
Engen & Ross (1973) [experiment 2]	Unclear	Unclear	Unclear	Yes	Yes	Yes	Yes	Unclear	Yes	Include

Study	True randomization of participants to assigned treatment groups?	Was allocation to treatment groups concealed?	Were treatment groups similar at the baseline?	Were treatment groups treated identically other than the intervention of interest?	Were participants analysed in the groups to which they were randomized?	Were outcomes measured in the same way for treatment groups?	Were outcomes measured in a reliable way?	Was appropriate statistical analysis used?	Was the trial design appropriate, and any deviations from the standard RCT design accounted for in the conduct and analysis of the trial?	Overall Appraisal
Engen & Ross (1973) [experiment 3]	Unclear	Unclear	Unclear	Yes	Yes	Yes	Yes	Unclear	Yes	Include
Jehl et al. (1995)	Unclear	Unclear	Yes	No	Yes	Yes	Yes	Yes	Yes	Include
Jehl et al. (1997)	Unclear	Unclear	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Include
Lawless & Engen (1977)	Unclear	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Include
Lyman & McDaniel (1990)	Unclear	Unclear	Yes	No	Yes	Yes	Yes	Yes	Yes	Include
Rabin & Cain (1984)	Unclear	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Include
Saive et al. (2014)	Unclear	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Include
Zucco (2003)	Unclear	Unclear	Yes	No	Yes	Yes	Yes	Yes	Yes	Include

Table 3

Quality Appraisal Using the JBI Quasi-Experimental Studies Checklist

Study	Is it clear in the study what is the 'cause' and what is the 'effect' (i.e., there is no confusion about which variable comes first)?	Were the participants included in any comparisons similar?	Was there a control group?	Were there multiple measurements of the outcome both pre and post the intervention/ exposure?	Were the outcomes of participants included in any comparisons measured in the same way?	Were outcomes measured in a reliable way?	Was appropriate statistical analysis used?	Overall Appraisal
Chrea et al. (2007)	Yes	Yes	No	No	Yes	Yes	Yes	Include
Larsson & Bäckman (1993)	Yes	No	No	Yes	Yes	Yes	Yes	Include
Larsson & Bäckman (1997)	Yes	Yes	No	Yes	Yes	Yes	Yes	Include
Lehrner (1993)	Yes	Yes	No	Yes	Yes	Yes	Yes	Include
Murphy et al. (1991)	Yes	Yes	No	Yes	Yes	Yes	Yes	Include

Search Results

Summary of Included Studies

The methods and outcomes of the final 18 studies are summarised in Table 4 below.

Table 4

Summary of Studies' Methodology and Outcomes

Author (Year)	Methods	Outcome
Ayabe-Kanamura & Kikuchi (1997)	3 groups (of 19-20 participants) learned odours which were presented with a pleasant or unpleasant label, or no label was given (control group).	Groups were not significantly different in their rates of hits, false alarms and adjusted scores for odour recognition tests. Hits significantly decreased between the first (after a 15-minute retention) and second (after 1-week retention) recognition tests for all three groups. Consistent label use resulted in a higher number of recalled odours. Labelling groups tended to judge odours as more familiar than controls.
Cain & Potts (1996) [experiment 1]	Participants engaged in a switch and bait test, in which they were presented with odours, tested for their recognition of odours on a second testing day (some of which had been switched for incorrectly labelled items)	First session - participants identified 44% (*SD* = 11) of odours on average. 9.24 (out of a scale of 10) items were correctly identified in the first session (*SD* = 0.84), incorrectly identified items equated to 6.46 (out of 10, *SD* = 2.25). Second session - participants identified 51% (*SD* = 11) of the odorants, 45% of the new items, 92% of previously correctly identified items and 20% of previously incorrectly identified items. Semantic processing influences recognition for memory odours.
Cain & Potts (1996) [experiment 2]	Participants were assigned to either a 'switch-and-bait' or a 'sham-bait' condition. In the switch-and-bait condition, participants performed recognition tests on day 2 in which incorrectly identified odour stimuli from day 1 had been switched out for the actual odour they had previously named in the misidentification. In the sham-bait condition, these incorrectly identified odours were identified by researchers, but not switched out.	Participants failed to notice the switched odours and identified the switched items as 'old' (more so than other distractors in the set) and with the veridical names. Participants recognised inconsistently labelled odours as well as items labelled consistently in the switch-and-bait groups.
Chrea et al. (2007)	Participants from America, Vietnam and France took part in a recognition study of 40 odorants of varying degrees of codability.	Regressions for codability were only significant to the French group for recognition of odours. Hit rate in the American group as significantly higher than in the Vietnam group, but no other comparisons were significant.

Author (Year)	Methods	Outcome
Cornell Kärnekull et al. (2015)	Tested olfactory memory and memory for faces over long durations: immediately, 4 days, 16 days and 64 days after encoding. Participants took part in only one of the four testing sessions.	Significant forgetting of odours and faces across the 64 days. However, the recognition rate of odours was still significantly above chance at 64 days. Odour false alarm rates increased significantly between 16 and 64 days. The more familiar the odour and face, the more likely it was to be better remembered. Odours consistently identified across sessions were better recognised. Men and women did not differ significantly in their odour nor face recognition memory.
Davis (1977)	Participants were randomly assigned to experimental conditions. Five experimental conditions were included, dependant on the stimuli provided (odours or free forms, in various degrees of similarity).	Paired-associate acquisition improved over time. Odours were less likely to be paired successfully in the paired associates acquisition task than forms. No significant effect was found for stimuli group or similarity rating for the recognition test. The forms group had fewer false alarms compared to the odours. The more similar the stimuli, the less likely it was recalled.
Engen & Ross (1973) [experiment 1]	Participants engaged in a delayed odour-pairs odour recognition memory test. Participants were divided into four groups of various delayed recognition test times (however there was overlap between participants in groups).	Recognition score t-tests indicated scores for percentage of correct recognitions was above chance at all retention intervals. Recognition difference between 1 and 30 days retention intervals were not significantly different. Recognition rates did not significantly decrease across the retention intervals. 53% of odours were rated as familiar, 47% unfamiliar. Results of the effect of familiarity on recognition rates were non-significant. No significant findings were found on the influence of whether the odour was rated as liked/indifferent/disliked on odour recognition.
Engen & Ross (1973) [experiment 2]	This study was designed to test effects of similarity of stimuli on olfactory recognition judgements. Participants were either provided with pairs of odours that were considered 'similar' or 'different' and their odour recognition memory tested across various time points.	The 'different odours' group recognition rate was 77%. The 'similar odours' group recognition rate was 64%, significantly different from the different odours group. Odours in the different odours group were rated as significantly less similar than odours in the similar odours groups. Label identifications for the odours increased overtime.
Engen & Ross (1973) [experiment 3]	Participants were randomly assigned to one of two groups, where odours were learnt with lists of odour labels of either common names or frequent odour-associations.	Common-odours group produced more correct label matches initially than the associations group. The recognition score for participants was significantly higher for those in the common-odours group than the associations group (76% versus 70%).

Author (Year)	Methods	Outcome
Jehl et al. (1995)	Participants were randomly assigned to one of 11 groups. Groups differed on the number of familiarisation sessions (up to three) and whether they were familiarised with target odours, distractors or target-distractor odours. 2 control groups were also included (who performed only the discrimination test, and were counterbalanced for order of stimuli presentation).	More familiarisations sessions resulted in fewer false alarms. This result was independent of intensity ratings and whether or not the familiarisation was of the targets or distractors or both odours. Hits scores were not significantly affected by the number of familiarisation sessions nor type of familiarisation sessions. Similarity judgements were more correctly identified than intensity judgments.
Jehl et al. (1997)	Participants learned odour and label associations. Participants were put into 10 groups, which varied on the label condition (chemical label, generated-name, veridical label, no-learning group, no-label group) and retention interval memory testing (short-term or long-term).	Hit scores for long-term memory were significantly lower for no-label and chemical-label groups, compared to the other three label groups. False alarm scores were significantly higher in long-term memory in the no-label group than the no-learning group, and in the generated-name group than the veridical-name group. False alarms were significantly higher in short-term memory for the no-learning condition than in the veridical-name condition. Discrimination was better with verbal label training, particularly veridical-label training. Verbal encoding aids odour recognition if it incorporates semantic information, hence the chemical-label group did not aid odour recognition. Odour identification was lower for the chemical-label group, than for veridical- or chemical-label groups. Results from the no-labelling group versus the no-learning group suggest that familiarisation alone does not aid odour recognition memory, recognition scores were lower for the no-labelling group were lower than the no-learning group for long-term memory. Correct identifications decreased from the first recognition test to the third recognition test, regardless of group (decreased on average by 20.45). This could be because of a decrease in long-term memory of olfactory information, or because of the experimental design. Verbal memory tests did not significantly decrease across the testing sessions, but identification tests did.

Author (Year)	Methods	Outcome
Larsson & Bäckman (1993)	Young (18 – 30 years old), young-old (60 – 69 years old), and old (70 – 79 years) groups of female participants engaged in tests of their episodic memory. Participants were assigned to one of three different encoding categories: name-only, odour-only, odour-name.	Young group participants had higher hit rates than both of the older groups. Odour-name condition testing produced more hits than other conditions. Name-only condition resulted in the lowest level of hits. Hit rates significantly decreased across immediate and delayed retention intervals in the odour-only condition, regardless of age. The young-group made fewer false alarms than the other two groups (there was no difference in young-old and old groups). False alarm rates increased across the retention intervals, which was at a significant rate in young-old and old groups. Familiarity and naming were associated with recognition scores in all age groups. Differences in the three groups were influenced by naming, and when this was accounted for in the statistical model – the difference in recognition scores between the age groups was removed. Odour-name presentation produced the highest number of hits, followed by odour-only and then name-only. Odour-name condition produced significantly higher d' scores than the other encoding conditions. D' scores decreased from immediate to delayed testing significantly, independent of age. D' scores were equal at both times of testing in the name-only condition, however decreased across testing in the odour-only and odour-name conditions. Odour naming varied significantly with age, with young group outperforming the two older groups. Naming was also affected by encoding condition, naming was higher in the odour-name condition.
Larsson & Bäckman (1997)	Young, young-old, and old groups of female participants were tested for their semantic memory and olfactory recognition memory. Participants engaged in two sessions of testing.	Young group had significantly higher hit rates, fewer false alarm rates, and higher d' scores than the young-old and old groups (the latter two of which did not differ significantly on hits, false alarms or d' scores). Hit rates decreased across time, and were lower for less familiar items; independent of age. The young group produced more veridical labels than the young-old or old groups, and the two latter groups made more omissions than the young group. When odour-naming ability was controlled for, the difference between groups for odour recognition reduced below significance

Author (Year)	Methods	Outcome
Lawless & Engen (1977)	A total of eight conditions: practice (same odour-pitcure pairings on both days), control (no second session testing), retroactive interference (RI; received the same odours in the learning phase but pairings varied in presentation order), RI control group (for session 2 testing they smelled the 'interference' odours planned for final testing in the interference groups and were not tested on those), proactive interference (PI; received the same odours in the learning phase but pairings varied in presentation order), PI control group (for session 2 testing they smelled the 'interference' odours planned for final testing in the interference groups and were not tested on those), recognition A (forced-choice recognition tests with distractors similar to odours, recognition test on day 1 instead of the PA acquisition), recognition B (recognition test on session two instead of the PA test).	Group size had no significant effects on test performance. Across practice and interference groups, recognition scores significantly increased across sessions. Groups significantly effected the final test performance. There was no difference between practice groups and control and the RI group and RI control, however there was a proactive effect. First-learned associations were better remembered than second-learned associations in the subsequent trials. Proactive interference increased with time. Lawless & Engen suggest this is due to an evolutionary need to remember initial odours to avoid poisonous foods. Improved discrimination over the two days. Participants reported use of a mediator to remember odours, which general resulted in more correctly identified odours (53.3%). There was no pattern to which odours had mediators used with them.
Lehrner (1993)	Participants were divided into four subgroups (14 participants in each), dependant on the retention interval. Performed a recognition memory task. Uses of label analysed.	Women had significantly higher rates of percentage of correct recognition and hit rates than men, across all retention intervals, but no significant differences in false alarms. Significant decreases in recognition scores were seen between 30 minutes and 7 days, 1 day and 7 days, 1 day and 21 days; differences between the other retention intervals were not significant. Initial recognition of odours was relatively poor, hits decreased over time, and false alarm rates increased over time. Odour forgetting rates were rather slow overtime however. Consistent label use resulted in a significantly higher percentage of correct odour recognitions. Inconsistently labelled odours were still remembered better than chance. Women did not label odours more consistently than men.

Author (Year)	Methods	Outcome
Lyman & McDaniel (1990)	Processing task (name-only, odour-only, odour-name, odour-picture, odour-name-picture) x test order (recall or recognition first).	Hits, false alarms, and *d'* scores were calculated for each participant. The encoding condition had a significant effect on the d's scores in the recognition tests. Odour-name-picture groups had significantly highly d' scores than other groups. Name-only groups had the lowest d' scores. No effect of test order was found. Odour-only group had lower hit rates and higher false alarms than the odour-picture, odour-name, and odour-name-picture groups. Test order was also significant, those tested first for recognition recalled more words than those tested for recall first. More odour names were recalled by the odour-name-picture groups than any other groups. Odour-only groups had the lowest word recall.
Murphy et al. (1991)	Investigated memory for odours, faces and symbols, in young, and elderly participant groups. Participants engaged in four sessions: a learning session and immediate testing, and three further sessions of testing.	The young group and the elderly group recognition scores for symbols and faces were very similar for symbols and faces, however, the elderly group performed below the young group on odour recognition. This effect was significant for odours and symbols, not faces. Odour recognition for the elderly group fell and stayed below chance after the 2-week retention interval. In both groups, false alarm rates across stimuli increased overtime, however this was at a slower rate than the fall in hit rates. For odours, decline in odour recognition memory scores fell at a faster rate for the elderly group than the young group. Olfactory threshold tests revealed higher odour sensitivity in the young than the elderly. Threshold tests were not significantly related to odour recognition scores for any retention interval. Both groups rated odours as more familiar than faces or symbols. The elderly rated odours significantly less familiar than the young group. Lower familiarity ratings in the elderly group was significantly related to lower olfactory recognition memory. Odours that were identified were more easily remembered.

Author (Year)	Methods	Outcome
Olsson et al. (2009)	Participants were shown odours and words and had to distinguish if they were edible or not. In two sessions of testing, their recognition for these odours/words was examined.	Recognition memory was higher for identified odours than unidentified odours, but highest in the words condition. Recognition memory decreased over time with the retention interval. Odours were more likely to be a 'guess' response than words. 'Recollection' responses were more common for identified odours than unidentified odours, and more common for words. Recollection rates reduced over the retention interval. 'Knowing' responses were not significantly different between the stimuli categories or across the retention interval. Familiarity estimates were significantly higher for words and identified odours. The short-term memory condition was associated with higher familiarity estimates than the long-term retention interval. Forgetting was therefore found for both identified and unidentified odours.
Rabin & Cain (1984)	Participants engaged in a task of odour recognition, investigating influence of familiarity, identifiability and encoding consistency. There was overlap between the groups regarding how many testing sessions they engaged in.	D' scores declined significantly across retention intervals, which were largest between 10 minutes and 1 day, and between 1 and 7 days. In the initial identification task in the familiarisation set, participants identified an average of 41% veridical labels for the odours, 22% near miss, and 36% far miss. Accurately labelled items in initial exposures were more accurately recognised in later testing. Label consistency decreased over retention intervals however but did not fall below chance (even with inconsistently labelled items). The more familiar the odour was rated, the more likely it was to be correctly recognised (higher d' scores).
Saive et al. (2014)	Participants engaged in a computer-generated laboratory episode in which they learnt an unfamiliar odour association with a location and visual context. Odours recognition was then investigated for it's potential to trigger recall of the other location and visual context information.	Participants produced significantly more correct responses (hits and correct rejections) than incorrect responses (miss or false alarm). Correct responses were given more quickly than incorrect responses, and were associated with shorter and higher frequency breathing. Pleasant and unpleasant odours were recognised significantly more accurately than neutral odours and allowed for greater episodic retrieval.
Zucco (2003)	Participants were divided into four encoding conditions: visual imagery, label-plus-definition, life-episode, or control. Participants smelled each odour and created an image/label/episodic memory/no association.	No encoding strategy increased recognition of odours significantly more than another.

Review Synthesis

The studies included in this review were of great heterogeneity. The studies utilised vastly different experimental methods, samples, time points, statistical models, and poorly reported raw data. Although attempts were made to contact surviving authors for further information to overcome some of these difficulties, further data were not provided upon request. Consequently, a meta-analysis of the 18 studies could therefore not be conducted (Boland et al., 2017), and instead the studies were narratively synthesised using guidance from Campbell et al. (2020) and Popay et al. (2006).

Although 11 studies utilised signal detection theory as their statistical analysis, these studies were heterogeneous regarding the reporting of results (for example some included only hits, some included only discrimination [d'] scores for encoding groups and not time, and some only included results in a graph). Only three papers included sufficient information regarding the number of hits, false alarms, and d' scores across time, and this was considered insufficient for a meaningful summary table.

As the time points utilised in the studies varied greatly, the below narrative synthesis is conducted across all studies. After a summary of the participants, stimuli, encoding tasks, retention intervals, and recognition tasks used in the studies, the narrative synthesis is grouped by time points of testing (single or multi), followed by groups of covariates. This decision was taken as it aligned most with the aims of this review and predictions regarding possible underlying influences on recognition memory in healthy adult populations (McKenzie et al., 2020).

Participants

Over the 18 studies, an approximate total of 1243 participants were included. Only one paper, Davis (1977) failed to provide any characteristic information about participants, including the total number of participants in the study.

From the studies that reported the sex of participants (Ayabe-Kanamura & Kikuchi, 1997; Cain & Potts, 1996; Chrea et al., 2007; Cornell Kärnekull et al., 2015; Jehl et al., 1997; Larsson & Bäckman, 1993, 1997; Lawless & Engen, 1997; Lehrner, 1993; Lyman & McDaniel, 1990; Murphy et al., 1991; Olsson et al., 2009; Rabin & Cain, 1984; Saive et al., 2014; Zucco, 2003), the majority of the participants were female (n = 583), compared to male (n = 374). Three studies failed to report sex characteristics (Davis, 1977; Engen & Ross, 1973; Jehl et al. 1995). Ten studies recruited participants exclusively from universities, including undergraduate and graduate students, and university faculty staff (Ayabe-Kanamura & Kikuchi, 1997; Cain & Potts, 1996; Chrea et al., 2007; Cornell Kärnekull et al., 2015; Davis, 1977; Engen & Ross, 1973; Lawless & Engen, 1997; Lehrner, 1993; Rabin & Cain, 1984; Zucco, 2003). None of the 18 studies utilised additional standardised screening measures for participants, however, several specified additional participant inclusion and exclusion criteria (Table 5).

Table 5

Additional Participant Inclusion/Exclusion Criteria

Study	Additional Inclusion/Exclusion Criteria
Ayabe-Kanamura & Kikuchi (1997)	Participants omitted for "old" responses to all odours
Cornell Kärnekull et al. (2015)	Self-reported health, normal sense of smell, normal visual acuity
Jehl et al. (1995)	Normal sense of smell
Jehl et al. (1997)	Normal sense of smell
Larsson & Bäckman (1993)	Self-reported health, normal sense of smell
Larsson & Bäckman (1997)	Self-reported health, normal sense of smell
Lawless & Engen (1977)	Participants omitted for failure to perform above chance level
Olsson et al. (2009)	Self-reported health, normal sense of smell
Saive et al. (2014)	Self-reported health, normal sense of smell, normal visual acuity, right-handed
Zucco (2003)	Normal sense of smell

Stimuli

The 18 studies varied on the characteristics of the olfactory stimuli used in the experiment(s), see Table 6. One study (Lawless & Engen, 1997) failed to provide further descriptive information about the stimuli other than the name of the odours selected.

Common or Uncommon Odours

The majority of studies utilised common odours (Cain & Potts, 1996; Chrea et al., 2007; Engen & Ross, 1973; Larsson & Bäckman, 1993, 1997; Lehrner, 1993; Lyman & McDaniel, 1990; Murphy et al., 1991; Olsson et al., 2009; Rabin & Cain, 1984; Zucco, 2003).

In contrast, four studies purposefully utilised unfamiliar odours (Ayabe-Kanamura & Kikuchi, 1997; Jehl et al., 1995, 1997; Saive et al., 2014) and a further study utilised odours that were difficult to name (Cornell Kärnekull et al., 2015). Davis (1977) reported only the chemical names for the odours utilised.

Odour Characteristics

Several studies controlled the odour stimuli for certain characteristics. Two studies excluded the use of unpleasant odours (Larsson & Bäckman, 1993, 1997), two studies utilised neutrally pleasant odours (Jehl et al., 1995, 1997), and Zucco (2003) was the only study to use both neutral and pleasant odours. Three studies (Jehl et al., 1995, 1997; Olsson et al., 2009) controlled for the intensity of odours, and one study (Lyman & McDaniel, 1990) counterbalanced the identifiability and discriminability of odours across odour sets.

Comparator Stimuli

Additionally, four studies compared odour memory to that of memory for other alternative stimuli, such as visual free forms (Davis, 1977), faces (Murphy et al., 1991),

symbols (Murphy et al., 1991), words (Olsson et al., 2009), and pictures of foreign countries from travel magazines (Lawless & Engen, 1997).

Table 6

Stimuli Characteristics

Study	Stimuli
Ayabe-Kanamura & Kikuchi (1997)	40 unfamiliar odorants (single chemical substances) were used, divided into four sets of odours (10 odours in each set). Sets were balanced for familiarity and pleasantness ratings from a prior pilot study. Sets 1 and 2 were used as target odours in the learning phase, sets 3 and 4 were used as 'distractors' in later recognition testing.
Cain & Potts (1996)	40 common odoriferous items were used as targets, 24 odours were used as possible distractors.
Chrea et al. (2007)	40 common manufactured odorants (20 targets, 20 distractors). Target odours consisted of those with a high codability score across cultures, those with a low codability scores across cultures, and odours with high codability in one or two cultures. Targets and distractors were balanced for pleasantness and similarity.
Cornell Kärnekull et al. (2015)	Odours: 24 odours, 12 of which had high familiarity and 12 had low familiarity. Odours were difficult to name and verbalise. Faces: 80 target faces and 80 distractor faces of famous (high familiar) and non-famous (low familiar) Swedish persons.
Davis (1977)	18 odorants used. Visual stimuli consisted of 24 'free forms'. Stimuli were rated for similarity in a previous study, and grouped as either 'similar', 'medium similar', or 'dissimilar' for odours; or 'similar', 'dissimilar' for the free forms.
Engen & Ross (1973) [experiment 1]	48 initial odorants selected at random from a total set of 110 odorants representing odours of familiar household products. Second part – target odorants were identified from 21 pairs of odorants (half 'old' from the 48 odours, and half 'new' from remaining odours of the 110 set).
Engen & Ross (1973) [experiment 2]	20 target odorants, presented in pairs with distractor odours (40 odorants total) during the recognition task.
Engen & Ross (1973) [experiment 3]	20 target odorants
Jehl et al. (1995)	30 simple pure aliphatic and aromatic compounds. Odorants were selected for their low familiarity, neutral pleasantness, diversity in odour qualities, and moderate intensity.

Study	Stimuli
Jehl et al. (1997)	20 low-familiarity and neutral-pleasantness chemical odorants.
Larsson & Bäckman (1993)	Two sets of stimuli were used, those for an olfactory threshold test and those for the recognition test. Recognition test odours consisted of 32 (16 targets, 16 distractors) common real-world substances. Unpleasant odours were excluded. Odour order presentation was varied randomly in four sets, three participants in each encoding group were assigned to each odour order presentation set.
Larsson & Bäckman (1997)	32 common odours used (16 targets, 16 distractors). Extremely unpleasant odours were not included in the study. Odour presentation was counterbalanced in each age group (6 participants in each of the four odour presentations).
Lawless & Engen (1977)	12 odours, 12 pictures (scenes from foreign countries obtained from travel magazines)
Lehrner (1993)	60 (undiluted) odours of familiar household products, chemical compounds, and commercial fragrances.
Lyman & McDaniel (1990)	30 target odours and 30 distractor odours.
Murphy et al. (1991)	Odours: 76 common household odorants (20 of which were target odours). Faces: 50 black-and-white images of American presidents and vice presidents (20 of which were target faces). Symbols: 50 uncommon engineering and electrical designs (20 of which were the targets).
Olsson et al. (2009)	48 items presented as an odour or as a word. Items were either more or less common, and either edible or inedible objects. Odorants had a intermediate odour intensity. Written words were presented in black and white ink, on white paper.
Rabin & Cain (1984)	80 common substances with diverse odour qualities. These stimuli were divided into four sets (20 odours each). Set 1 were the target odours, sets 2-4 were distractor odours.
Saive et al. (2014)	18 distinctive and low identifiability and low-familiarity odorants were selected. Odorants consisted of essential oils and single or

Study	Stimuli
	mixtures of monomolecular chemical compounds. The odorants were subdivided into two sets (Sets 1 and 2) of nine odours each.
Zucco (2003)	60 pleasant and neutral olfactory stimuli. 30 stimuli were used in the odour-acquisition phase and the other 30 as distractors for the recognition test.

Encoding Tasks

Across the 18 studies, several different encoding tasks were used (see Table 7).

The most popular encoding method was a judgement of odour quality such as familiarity or pleasantness, on either a categorical scale (for example 'familiar' or 'unfamiliar') or an ordinal scale (e.g., '0 – 100, how pleasant is this odour?'). This method was employed by seven studies (Cornell Kärnekull et al., 2015, Engen & Ross, 1973; Larsson & Bäckman, 1993, 1997; Lehrner, 1993; Murphy et al., 1991; Rabin & Cain, 1984).

Other quality judgements for the odours were used in some studies, such as the similarity of odour pairs (Olsson et al., 2009), whether or not the odour source was edible (Olsson et al., 2009), whether or not the odour was liked (Engen & Ross, 1973), and pleasantness of the odours (Lyman & McDaniel, 1990; Lehrner, 1993).

The second most popular encoding task was that of an identification task. This varied between studies but largely involved either the generation of a label for the odour (Cain & Potts, 1996; Lehrner, 1993; Rabin & Cain, 1984; Zucco, 2003) or attempts to provide the veridical name of the odour (Cornell Kärnekull et al., 2015; Engen & Ross, 1973).

Several studies utilised a paired-associates based task, in which participants would be asked to encode the odour paired with another stimulus, such as an image (Lawless & Engen,

1977; Lyman & McDaniel, 1990), or a label or association from a list provided (Engen & Ross, 1973), a digit (Davis, 1977), or a name or picture or life event (Zucco, 2003).

Four studies required participants to learn the odour with a provided label (Ayabe-Kanamura & Kikuchi, 1997; Jehl et al., 1997; Larsson & Bäckman, 1993; Lyman & McDaniel, 1990).

Three studies employed exposure-only techniques, in which only the odour was presented to them, and participants were instructed to memorise this (Chrea et al., 2007; Jehl et al., 1995; Larsson & Bäckman, 1993). Similarly, Saive et al. (2014) encouraged the free discovery of a computer-generated environment.

Lastly, two studies employed olfactory threshold tests and verbal skill tests as part of their encoding tasks (Larsson & Bäckman, 1993, 1997).

Table 7

Encoding Tasks

Study	Encoding Task(s)
Ayabe-Kanamura & Kikuchi (1997)	In the label groups, participants were instructed to learn the odours with the label.
Cain & Potts (1996)	Participants gave each odour a label.
Chrea et al. (2007)	Participants were instructed to memorise each odour.
Cornell Kärnekull et al. (2015)	Encoding of odours: familiarity rating and asked to identify each. Encoding for faces: familiarity rating and asked to name the person shown.
Davis (1977)	Paired-associates task, in which stimuli were paired with a digit. Self-correction (feedback) was used in the encoding task.
Engen & Ross (1973) [experiment 1]	Encoding task included asking participants if the odour was familiar/unfamiliar and if they liked it/felt indifferent/disliked it.
Engen & Ross (1973) [experiment 2]	Participants were presented with odours and asked to make a short-written description or specific label for each odour. Corrective feedback was then provided.
Engen & Ross (1973) [experiment 3]	Participants were asked to match odours to 20 odour labels in a list (either the correct label list or an associations list). Correct feedback was given.
Jehl et al. (1995)	In familiarisation sessions, participants were asked to remain silent, and were exposed to each odour in turn (with a 90 second interval between).
Jehl et al. (1997)	Participants were instructed to memorise an association between an odour and a name provided for it, they were later allowed to write this odour name down.
Larsson & Bäckman (1993)	Olfactory threshold test. Multi-choice synonym test. Health questionnaire. Participants were instructed to memorise the odour name/odour only in the name-only and odour-only conditions and completed familiarity ratings. In the odour-name condition, participants were presented with odour and told to memorise and rate these for familiarity, they were then told the veridical label for the odour.
Larsson & Bäckman (1997)	Olfactory-threshold test. 30-item synonym test. Health questionnaire. Presented with odours and asked to rate the familiarity of these.

Study	Encoding Task(s)
Lawless & Engen (1977)	Participants learned odour-picture pairs.
Lehrner (1993)	In the learning phase, participants were asked if the odour was familiar/unfamiliar, pleasant/unpleasant/neutral. They were then asked to generate a single-word label or association for each odour.
Lyman & McDaniel (1990)	Participants in the initial session rated the pleasantness of each odour (in the name-only group this was from the name of the odour provided). Exposure to the stimuli was repeated three times. For participants in an odour-picture or odour-name-picture or odour-name group the odour was initial presented followed by the matched stimuli.
Murphy et al. (1991)	Participants were not informed of the memory test. Familiarity ratings for each stimulus.
Olsson et al. (2009)	Participants had to answer if the first item (odour or word) in the pair (odour-odour or word-word) was edible or not, and if the second item in the pair was similar to the first item ("yes" / "no" similarity judgement.
Rabin & Cain (1984)	Participants rated familiarity of the odour on a 5-point scale and generated a label for the odour.
Saive et al. (2014)	3 encoding sessions, in which participants freely discovered an episode (three odours and three locations within a computer-controlled visual context).
Zucco (2003)	Participants smelled each odour and then performed the relevant encoding task. They had to either create an image of the source of the odour (visual imagery condition), think of a name and definition for the odour (label-plus-definition condition), remember a specific life-episode for the odour (life-episode condition), or engaged in no further encoding tasks (control group).

Retention Intervals

Seven studies investigated odour recognition memory using a single time point of testing only (Cain & Potts, 1996; Chrea et al., 2007; Davis, 1977; Jehl et al., 1995; Lyman & McDaniel, 1990; Saive et al., 2014; Zucco, 2003); whereas 10 studies utilised only multiple-time points in their procedure (Ayabe-Kanamura & Kikuchi, 1997; Cornell Kärnekull et al.,

2015; Jehl et al., 1997; Larsson & Bäckman, 1993, 1997; Lawless & Engen, 1977; Lehrner, 1993; Murphy et al., 1991; Olsson et al., 2009; Rabin & Cain., 1984). Engen and Ross (1973) used single and multiple time points of testing in different experiments.

Among those that used single time points and multiple time points of testing, procedures varied considerably on the length of retention interval between encoding and testing session, please see Table 8 below.

Table 8

Single and Mulitple Time-Point Retention Intervals

Study	Single Time Point	Multiple Time-Points
Ayabe-Kanamura & Kikuchi (1997)		15-minutes, 1 week, 2 weeks
Cain & Potts (1996)	2 days	
Chrea et al. (2007)	7 days	
Cornell Kärnekull et al. (2015)		Immediate, 4 days, 16 days, 64 days
Davis (1977)	7 days	
Engen & Ross (1973) [experiment 1]		Immediate, 1 day, 1 week, 1 month
Engen & Ross (1973) [experiment 2-3]	3 months	
Jehl et al. (1995)	1 day	
Jehl et al. (1997)		20 minutes, 1 day
Larsson & Bäckman (1993)		Immediate, 2 days
Larsson & Bäckman (1997)		Immediate, 2 days
Lawless & Engen (1977)		Immediate, 2 days, 2 weeks
Lehrner (1993)		30 minutes, 1 day, 7 days, 21 days
Lyman & McDaniel (1990)	7 days	
Murphy et al. (1991)		Immediate, 2 weeks, 6 months, 6 months ± a few days
Olsson et al. (2009)		15 minutes, 1 week
Rabin & Cain (1984)		10 minutes, 1 day, 7 days
Saive et al. (2014)	1 day	
Zucco (2003)	7 days	

Recognition Tasks

Fourteen studies employed a forced-choice recognition task, in which participants had to select from two options regarding if an odour had been shown before (Ayabe-Kanamura & Kikuchi, 1997; Cain & Potts, 1996; Chrea et al. 2007; Cornell Kärnekull et al., 2015; Davis, 1977; Jehl et al., 1997; Larsson & Bäckman, 1993, 1997; Lyman & McDaniel, 1990; Murphy et al., 1991; Olsson et al., 2009; Rabin & Cain, 1984; Saive et al., 2014; Zucco, 2003). Three of the 14 studies which employed a forced-choice recognition task also combined this with a confidence rating in their response (Cain & Potts, 1996; Olsson et al., 2009; Rabin & Cain, 1984).

Additionally, a further four studies utilised an alternative forced-choice task, in which participants had to select from a pair which odour was presented previously (Engen & Ross, 1973; Jehl et al., 1995; Lawless & Engen, 1977; Lehrner, 1993).

Outside of recognition tasks, several studies employed additional means of testing memory, such as identification tasks and recall tasks. Nine studies utilised an identification task in which participants were asked to identify the odour by providing a name for the odour (Cain & Potts, 1996; Cornell Kärnekull et al., 2015; Jehl et al., 1997; Larsson & Bäckman, 1993, 1997; Lehrner, 1993; Murphy et al., 1991; Olsson et al., 2009; Rabin & Cain, 1984). Four studies employed a paired-associates task in which participants had to match the odour to previously presented paired stimuli such as a picture, number, or written name (Davis 1977; Lawless & Engen, 1977; Lyman & McDaniel, 1990; Zucco, 2003), whilst another recorded recall for the episode in which the odour was learnt (Saive et al., 2014). One study also employed an olfactory threshold test within the recognition task (Murphy et al., 1991).

In regard to odour qualities, seven studies asked participants to provide an additional familiarity rating for the odours (Ayabe-Kanamura & Kikuchi, 1997; Davis, 1977; Larsson & Bäckman, 1993, 1997; Lehrner, 1993; Murphy et al., 1991; Saive et al., 2014). A further three

studies asked for a pleasantness rating for each odour (Ayabe-Kanamura & Kikuchi, 1997; Lehrner, 1993; Saive et al., 2014). Two studies asked for a similarity judgement of the odours, specifically Engen and Ross (1973) asked for a similarity rating, whilst Jehl et al. (1995) asked participants to judge if pairs of odours were similar for intensity (answers were 'identical'/ 'different'). One study asked for intensity ratings (Saive et al., 2014). One study asked participants to rate the meaningfulness of each odour (Davis, 1977).

Finally, some studies combined the odour recognition tasks with verbal memory tests (Jehl et al., 1997; Larsson & Bäckman, 1993, 1997).

Please see Table 9 below for the recognition and testing tasks of each study.

Table 9

Recognition and Testing Tasks

Study	Recognition/Testing Task(s)
Ayabe-Kanamura & Kikuchi (1997)	Forced choice ("learned"/ "unlearned" and later "old"/ "new"). Familiarity and pleasantness ratings.
Cain & Potts (1996)	Forced choice ("old"/ "new") recognition task. Confidence ratings. Identification task.
Chrea et al. (2007	Forced choice ("yes"/ "no") recognition task
Cornell Kärnekull et al. (2015)	Forced choice ("yes"/ "no") recognition task. Asked to identify the odour or face.
Davis (1977)	Forced choice ("old" / "new") recognition task. Identification of their number from the paired association. Familiarity and meaningfulness ratings.
Engen & Ross (1973) [experiment 1]	Alternative forced-choice recognition task, in which participants identified the "old" and "new" stimuli in each pair of odours presented.
Engen & Ross (1973) [experiment 2]	Alternative forced-choice recognition task, in which participants identified the "old" and "new" stimuli in each pair of odours presented. Similarity judgements regarding the pairs of odours.
Engen & Ross (1973) [experiment 3]	Alternative forced-choice recognition task, in which participants identified the "old" and "new" stimuli in each pair of odours presented.
Jehl et al. (1995)	Discrimination task - Participants were asked to make similarity judgements on pairs of odours. They were asked if the first odour in a pair was identical to the second odour. Participants were then asked which odour (if not both) was presented to them in the prior familiarisation sessions. Intensity similarity judgement of odours in each pair ("identical" or "different").
Jehl et al. (1997)	Three identification tasks – participants were asked if they could retrieve the odour's name. Corrective feedback was given. Forced choice ("yes" / "no") recognition test. Two verbal memory tests – free recall of written names of odours.

Study	Recognition/Testing Task(s)
Larsson & Bäckman (1993)	Recognition test – asked to select the odours presented in the inspection phase. Multiple choice antonym test. Identification task – asked to identify the odour by name.
Larsson & Bäckman (1997)	Forced choice ("old" / "new") recognition test (repeated for both the immediate session and delayed session). 70-item antonym test. In delayed recognition testing, participants were also asked to identify the odours Completed letter fluency and category fluency tests.
Lawless & Engen (1977)	Paired-associates task (immediate, 48 hours and at 2 weeks) in which participants matched odours and pictures. Feedback was given after the immediate testing session (only). In the last session (2 weeks) participants were also asked if they used any mnemonic scheme to remember odours or any other associations they made.
Lehrner (1993)	Alternative-forced choice recognition task ("old" / "new" in each pair). Participants also rated the odours as pleasant/unpleasant again Identification task - participants generated a label for each odour of the pair
Lyman & McDaniel (1990)	Half the participants engaged in free recall task for the written names of the odours and then a forced-choice ("old"/ "new") recognition test for 60 odours (30 targets, 30 distractors). The recall and recognition tasks were presented in a reverse order for the remaining half of the participants.
Murphy et al. (1991)	Forced choice ("yes" / "no") recognition task (at immediate, 2-3 weeks, 6 months). Olfactory threshold testing occurred at session 2 (at 2-3 weeks). At 6 months ± a few days, participants completed an identification task for the stimuli.
Olsson et al. (2009)	Forced choice ("yes" / "no") recognition task. Subsequently, they indicated if this answer was due to remembering (R), knowing (K), or a guess (G).Odour identification task.

Study	Recognition/Testing Task(s)
Rabin & Cain (1984)	Forced choice ("old" / "new") recognition test. Confidence rating of response. Identification task – participants then generated a label for the odours.
Saive et al. (2014)	Forced choice ("yes" / "no") recognition task for each odour. If participants recognised the odour ("yes" response) they were asked to retrieve the entire episode associated with and had to indicate it's visual context and location it (by pressing on the computer mouse when they recognised the odour's context). Participants performed intensity, familiarity, and pleasantness ratings for each odour. Response times and breathing rates were also recorded.
Zucco (2003)	Forced choice ("old" / "new") recognition test. Those in the experimental groups named the association (visual, label-definition, or life-episode) they had made in the learning phase.

Recognition Memory Across Time

Of the 11 studies that utilised multiple time points to measure recognition memory, eight studies suggested that odour recognition memory declined over time (Ayabe-Kanamura & Kikuchi, 1997; Cornell Kärnekull et al., 2015; Jehl et al., 1997; Larsson & Bäckman, 1993, 1997; Murphy et al., 1991; Olsson et al., 2009; Rabin & Cain, 1984).

This was largely due to a decrease in 'hits' (correctly recognised items; Ayabe-Kanamura & Kikuchi, 1997; Cornell Kärnekull et al., 2015; Jehl et al., 1997; Larsson & Bäckman, 1993, 1997) and an increase in false alarms (incorrectly recognised) over time (Cornell Kärnekull et al., 2015; Larsson & Bäckman, 1993, 1997; Murphy et al., 1991).

However, in contrast to the above findings, Engen and Ross (1973 [experiment 1]) suggested that odour recognition rates across retention intervals were stable (other than one significant difference between day 1 and day 30 testing, due to an increase in recognition scores on day 1) and above chance at 30 days testing. This aligns with the findings of Lehrner

(1993), who found odour hit rates and false alarm rates were stable over time for odours. Lawless and Engen (1977) even suggested odour recognition scores increased over time.

Of the studies that used a single time point of testing, only Jehl et al. (1995) and Saive et al. (2014) reported an overall level of odour recognition. Jehl et al. (1995) noted that hit scores did not significantly increase over increased numbers of familiarisation (learning) sessions, however, false alarms did significantly decrease, resulting in an overall significant increase in d' scores across familiarisation sessions. Saive et al. (2014) also noted that d' scores were high, specifically when hits and correct rejections were combined, this was significantly higher than misses and false alarms combined across participants.

However, the other six single time point studies failed to report an overall recognition score outside of their covariables of interest and are therefore discussed in the below co-variates section only (Cain & Potts, 1996; Chrea et al., 2007; Davis, 1977; Engen & Ross, 1973 [experiments 2 & 3]; Lyman & McDaniel, 1990; Zucco, 2003).

Covariates

Age

Larsson and Bäckman (1993, 1997) and Murphy et al. (1991) examined the effect of age on olfactory recognition memory.

Young participants had higher d' scores (specifically because of higher hit rates and lower false alarms) than older participants (Larsson & Bäckman, 1993, 1997; Murphy et al., 1991). Additionally, Murphy et al. reported that this discrepancy in age performance was associated with a quicker decline in hit rates in the elderly, an increased sensitivity to odour thresholds in young participants, and reduced familiarity judgements in the elderly.

Two of the studies, Larsson and Bäckman (1993, 1997) suggest this might be due to age-related differences in odour identification, although the latter study did not find any significant difference between young and old groups for olfactory threshold tests (unlike

Murphy et al., 1991). Specifically, Larsson and Bäckman (1997) identified that age-related differences were highly significantly interlinked with the odour naming-ability of participants (odour recognition score differences between groups dropped below significance when naming-ability was considered in the regressions); and that younger participants were more likely to generate veridical names and less likely to make name omissions than older participants.

Comparison to Recognition Memory for Other Stimuli

Three of the studies employed procedures that compared odour recognition memory to that of recognition memory for other stimuli, such as faces, symbols and visual forms (Cornell Kärnekull et al., 2015; Davis, 1977; Murphy et al., 1991).

Cornell Kärnekull et al. (2015) suggested that recognition memory for faces was greater (had higher d' scores) than that of odours. This may have been associated with the finding that other stimuli had lower false alarm rates compared to odours (Cornell Kärnekull et al., 2015; Davis, 1977; Murphy et al., 1991), but similar hit rates (Davis, 1977). Moreover, Murphy et al. also found younger participants had significantly better recognition memory for odours and symbols than older participants, but no significant difference between young and old groups for faces.

Effects of Multiple Encoding

Two studies (Lyman & McDaniel, 1990; Zucco, 2003) investigated olfactory recognition memory utilising multiple encoding methods.

Zucco (2003) found that odour recognition memory slightly varied depending on the encoding condition used, with participants from the life-episode group (in which they smelled the odour and had to remember a specific life episode related to the odour) producing

significantly higher d' scores than those from the control group, and the label-plus-definition group (in which participants generated a label and defined the odour).

Similarly, Lyman and McDaniel (1990) found that participants in the odour-picture-name group (in which odours were paired at encoding with an image and a name) had significantly higher d'scores than odour-only, odour-name (odours paired with a name), and name-only groups. Moreover, odour-name and odour-picture groups also had higher d' scores than odour-only and name-only groups (which had the lowest d' score).

Odour Identification and Naming Ability

Larsson and Bäckman (1993, 1997), Lehrner (1993), and Murphy et al. (1991) tested participants' ability to name the odours in identification tasks in addition to odour recognition tests. Overall, studies suggested that participants' ability to name odours was correlated to successful odour recognition.

Only one study, Chrea et al. (2007), investigated the influence of an odour's ability to be named. Chrea et al. suggested that odours that were more easily named and had a higher inter-rater agreement of the name between people of the same culture (which they termed codability), resulted in higher odour recognition rates at a delayed memory recognition test for French individuals (but not individuals from America or Vietnam).

Additionally, five studies utilised multiple time points for identification testing of odour labels and found that odours that were labelled more consistently were more likely to be recognised (Ayabe-Kanamura & Kikuchi, 1997; Cain & Potts, 1996; Cornell Kärnekull et al., 2015; Lehrner, 1993, Rabin & Cain, 1984).

However, Engen and Ross (1973), Olsson et al. (2009), and Rabin and Cain (1984) suggested the benefit of odour labelling on recognition is limited to accurate labels only, and Rabin and Cain (1984) suggested consistency in odour labelling reduces over time. Furthermore, Ayabe-Kanamura and Kikuchi (1997) found no overall benefit of verbal labels

for recognition of odours across time, with no significant differences in hits, false alarms and adjusted recognition scores (calculated as hits and correlations summated, divided by two) found between groups given a pleasant label, unpleasant label, or control.

Furthermore, variations in the quality of labels used influenced the odour recognition rates in three studies. When odours were paired with a name, three studies (Larsson & Bäckman, 1993; Lyman & McDaniel, 1990; Jehl et al., 1997) found that this increased odour d' scores, particularly when the odour was paired with a veridical name rather than a chemical name (Jehl et al., 1997).

Odour Qualities

Thirteen studies investigated the effects of odour qualities on recognition memory (Ayabe-Kanamura & Kikuchi, 1997; Cornell Kärnekull et al., 2015; Davis, 1977; Engen & Ross, 1973; Jehl et al., 1995; Larsson & Bäckman, 1993, 1997; Lehrner, 1993; Lyman & McDaniel, 1990; Murphy et al., 1991; Olsson et al., 2009; Rabin & Cain, 1984; Saive et al., 2014).

Familiarity. When rated for familiarity, odours were rated as more familiar than other stimuli, such as symbols, visual forms, and faces (but not words; Davis, 1977; Murphy et al., 1991). Odours that had increased familiarity scores were found to have higher recognition than odours with low familiarity scores in the majority of the studies (Cornell Kärnekull et al., 2015; Larsson & Bäckman, 1993, 1997; Rabin & Cain, 1984). However, Engen and Ross (1973) and Saive et al. (2014) found no significant effect of familiarity ratings on odour recognition rates, and Cornell Kärnekull et al. (2015) found that familiarity ratings were associated with an increased number of false alarms.

Furthermore, familiarity ratings were found to be stable over time by Davis (1977) and Ayabe-Kanamura and Kikuchi (1997) but decreased over time in the study by Olsson et al. (2009).

Intensity. Only two studies analysed intensity as a factor in odour recognition and across time (Jehl et al., 1995; Saive et al., 2014). It was found that intensity ratings did not significantly influence odour recognition rates (Saive et al., 2014), and that intensity ratings were stable across increased numbers of learning phases (Jehl et al., 1995).

Liked Odours. Only one study, Engen and Ross (1973) asked participants whether or not they liked the odours, and this was not significantly correlated with recognition scores.

Pleasantness. Quality ratings regarding odours' pleasantness were included in four studies (Ayabe-Kanamura & Kikuchi,1997; Lehrner, 1993; Lyman & McDaniel, 1990; Saive et al., 2014).

Ayabe-Kanamura and Kikuchi (1997) investigated odour recognition memory in three groups, each provided with odours with either a pleasant label, an unpleasant label, or no label (control group). Across the different groups, there were no significant differences in ratings of pleasantness, nor in the number of hits, false alarms, or d' scores. However, the pleasant-label group produced less unpleasant ratings than those in the unpleasant label group, and their d' scores significantly increased over time (all other groups had no significant effect of time).

Saive et al. (2014) however, investigated participants' odour recognition memory on the dependency of their odour ratings, in which odour ratings per participant were divided into pleasant, unpleasant, or neutral odour categories. Those odours rated as either pleasant or unpleasant had significantly higher recognition scores than those in a 'neutral' odour. In comparison to neutral odours, pleasant odours were rated as more intense and familiar, and unpleasant odours were rated as more intense and less familiar.

Neither Lehner (1993) nor Lyman and McDaniel (1990) analysed the results of the pleasantness judgements on recognition rates.

Sex

Studies appeared to vary in regard to findings on the influence of sex on olfactory recognition memory. Although Lehrner (1993) found females had better odour recognition than males (with a higher hit rate, but equal false alarm rate to males), Cornell Kärnekull et al. (2015) and Olsson et al. (2009) found no significant difference in the performance of male and female participants in their odour recognition memory.

Olfactory Threshold Tests

Only two of the studies reported analysis of olfactory threshold tests on overall odour recognition memory (Larsson & Bäckman, 1993; Murphy et al., 1991). Both studies found that participants' ability on olfactory threshold results produced no significant difference in recognition memory at different retention intervals, nor across all retention intervals.

Discussion

The aims of this systematic review were to explore if olfactory recognition memory is persistent over time, what experimental design methods were employed to investigate olfactory recognition memory, and what the influences of covariates on olfactory recognition memory were.

Overall, this review found that olfactory recognition memory significantly declined over time (Ayabe-Kanamura & Kikuchi, 1997; Cornell Kärnekull et al., 2015; Jehl et al., 1997; Larsson & Bäckman, 1993, 1997; Lehrner, 1993; Murphy et al., 1991; Olsson et al., 2009; Rabin & Cain, 1984). This goes against the finding of other studies in the literature, such as Lawless (1978). Unfortunately, due to the poor quality of reporting in the studies and the absence of key information, it was difficult for this review to establish if this decline in olfactory recognition memory signified a drop in olfactory recognition memory below chance. In turn, this made it difficult to compare studies that utilised multiple time points of testing to those that used single time points of testing. This result is perhaps unsurprising

however, given the concept that the olfactory system is slow to process information (Schab, 1991), hence the studies explored here may not be providing enough time to encode olfactory information, and it is therefore lost sooner than would be expected in optimal conditions for olfactory information processing. Moreover, the decline in olfactory recognition memory did not appear to be the result of forgetting, but an increased uncertainty as to previously exposed odours resulting in increased false alarms. This may therefore still suggest olfactory recognition memory is long-term in nature.

Regarding the experimental design methods employed by the studies, studies varied on the encoding tasks, retention intervals, and recognition tasks employed. Studies largely utilised quality judgements and/or identification tasks as their encoding tasks, varied considerably on their chosen length of retention interval (with almost no consistency in the literature observed), and largely utilised forced-choice or alternative forced-choice recognition tasks.

The choice of encoding tasks and recognition tasks utilised in the studies may too have influenced the decline in olfactory recognition memory retention observed in this review, as a singular method of encoding through odour quality judgements may have resulted in poor memory traces being made (Lyman & McDaniel, 1990). Odours, therefore, did not get the chance to benefit from multiple sources of encoding as they might otherwise in more ecologically valid environments, however when multiple encoding methods were used this did result in the expected increase in recognition memory (Lyman & McDaniel, 1990; Paivio, 1986; Zucco, 2003). This further adds support to a dual-coding theory for olfactory memory.

As for the covariates investigated within the studies reviewed, several covariates were found to influence olfactory recognition memory. Age appeared to negatively influence olfactory recognition memory, largely due to declining hit rates and reduced identification

ability (Larsson & Bäckman, 1993, 1997; Murphy et al., 1991). This supports other literature that suggests olfactory memory declines as humans age (Doty & Kamath, 2014; Schubert et al., 2012; Tzeng et al., 2021).

Participants' ability to identify an odour also appeared to be associated with increased olfactory recognition memory (Larsson & Bäckman, 1993, 1997; Lehrner, 1993; Murphy et al., 1991). A particularly important skill appeared to be that of consistency of label use, with more consistent label use associated with better olfactory recognition memory, and use of veridical labels (Ayabe-Kanamura & Kikuchi, 1997; Cain & Potts, 1996; Cornell Kärnekull et al., 2015; Lehrner, 1993, Rabin & Cain, 1984). These findings suggest that olfactory recognition memory may be aided by semantic recall, in line with suggestions from Paivio (1986) regarding dual processing theory (Jönsson & Olsson, 2003).

In regard to odour qualities, familiarity, pleasantness/unpleasantness (more than hedonic neutrality) and difference in odours were associated with increased olfactory recognition memory, however the intensity and whether or not the odours were liked did not appear to have an effect on olfactory recognition memory (Jehl et al., 1995, 1997; Olsson et al., 2009). The familiarity and pleasantness findings are aligned with the research (Jönsson & Olsson, 2003). However, the lack of influence of intensity on olfactory recognition memory is more surprising, given the possible evolutionary advantages of avoiding intense odours (Kensinger, 2007; Larsson et al., 2009; Soussignan et al., 1997). This review's finding however was likely impacted by the very few studies (three) that incorporated intensity into their investigations and this, therefore, requires further exploration.

Sex and olfactory threshold detection rates were found not to influence olfactory recognition memory (Cornell Kärnekull et al., 2015; Olsson et al., 2009). This goes against previous literature that has suggested the prominence of sex differences in olfactory memory, and the influence of olfactory thresholds on olfactory memory (Öberg et al., 2002; Schubert

et al., 2012; Tzeng et al., 2021). It is however difficult to draw conclusions about the causes of this result due to the limited number of studies exploring these covariates in this review.

Lastly, compared to faces, odours had lower recognition memory, however, this effect was not observed in visual forms. This suggests that olfaction and visual forms, which are both more abstract in nature, might be using a different memory trace to that of faces (Cornell Kärnekull et al., 2015; Davis, 1977; Murphy et al., 1991).

Clinical Implications

This review suggests that olfactory recognition memory is subject to decline over time and that olfactory recognition memory can be influenced by a variety of factors such as age, multiple sources of encoding, and consistent use of labels.

These factors may be important when the strong link between olfaction and neurodegenerative diseases is considered (Devanand et al., 2015; Ponsen et al., 2009). This review would support other studies that suggest olfactory changes may be important to consider in screening for early detection of neurodegenerative diseases (Bhatia-Dey & Heinbockel, 2021). Perhaps, with further research, olfactory recognition skills could be enhanced through cognitive skills training programmes, such as olfactory training, incorporating skills like consistency of label use and multiple forms of encoding in aiding memory, in the hope of aiding a medium of memory in those who develop a neurodegenerative disease.

Directions for Future Research

Olfactory memory is still an under-researched area, historically because olfaction was associated with a source of disgust, and more recently impacted by the ability of the currently available methodology to accurately capture olfactory recall (Herz & Engen, 1996; Low, 2006; White et al., 2015). Further research into olfactory memory is therefore currently

required, with more high-quality reporting in the research papers, to ascertain the basic nature of olfactory memory traces.

Until such a time that olfactory recall can be accurately assessed with advancements in technology, future research should aim to utilise more consistent methodology and should explore differences between perceptual and semantic coding for olfactory memory (Wilson & Stevenson, 2006).

Possible directions for future research would be to further explore the persistence of long-term olfactory memory and the possible existence of a double dissociation between olfactory memory and that of other sensory memory modalities. One method by which future studies could investigate this would be to utilise studies focusing on participants with brain injury or unique amnesias.

Critique of the Current Review

Although this current review found a significant decline in olfactory memory over time, it is worth considering these findings in light of the potential limitations of this current review.

This review did not apply a limit to the timescale for publications, which resulted in the inclusion of material from 1973 to the present day. Although a broad scope of the literature is useful because of the limited amount of olfactory memory research currently available; neuropsychological knowledge has progressed considerably with technological advancements (such as brain imaging scans) and the introduction of memory models that have shaped more recent studies of memory using different methodologies (Baddeley, 2000; Boland et al., 2017; Herz et al., 2004). This may in part explain the variation in encoding and recognition tasks noted in this review. Hence, this may have meant that the older literature was not comparable to the more recent literature.

The literature included in this review were of mixed quality according to the critical appraisal tools, and often reported very little data and was heterogenous in many ways (such as the samples used). Because of this, the current review was unable to conduct a meta-analysis of the results, which would have been more powerful in understanding the first aim of the review than the narrative synthesis employed. This, therefore, limited the conclusions that could be drawn from the papers.

Future reviews may benefit from further exploring olfactory recognition memory by utilising more robust critical appraisal tools, narrower timescales of publication in searches, and the use of meta-analysis techniques.

Conclusion

In summary, this systematic review and narrative synthesis of the literature on olfactory recognition memory in a human population revealed the following: olfactory recognition memory does decline over time, largely due to increased false alarms; many methods are employed in studies to investigate olfactory recognition memory, the most common of which was forced-choice and alternative forced-choice; and several covariates may influence the recall of odours (such as participant's age, participant's ability to identify the odour and odour qualities of familiarity and pleasantness). Covariates of participants' sex and olfactory threshold detection ability and the intensity of odours were not found to influence olfactory recognition memory.

Several implications of these findings are suggested, focusing on the impact of olfaction and neurodegenerative disease, with an argument in favour of olfactory training with ageing populations.

However, the results of this literature review should be interpreted cautiously, due to the large time scale of included papers and the lack of meta-analysis.

Directions for future research are suggested, exploring olfactory memory with participants with brain injury or unique amnesias to further understand long-term olfactory memory and the nature of its encoding.

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Section B: Investigating Olfactory Memory in an Individual with Medically Unexplained Anterograde Amnesia.

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Abstract

Previous research has suggested that olfactory memory is more long-lasting than other sensory memory, due to its unique brain physiology and ties to emotionally salient episodic memories. One clinical participant, SI, is presented with medically unexplained anterograde amnesia following a shoulder injury in 2013, since which time he has maintained a memory-retention window of 1 waking day. This study aimed to explore olfactory memory with SI, in an observational case-control design. SI was compared to eight age and education-matched control participants on an olfactory memory recognition task, an implicit memory task (mirror maze), and a neuropsychological test battery (Short Parallel Assessments of Neuropsychology Status [SPANS]). Olfactory memory was tested immediately, after a 100-minute delay, and after a 24-hour delay. The implicit memory task and SPANS (recall and recognition components) were repeated on the second day of testing. Results indicated that SI's performance on the olfactory recognition memory task, implicit memory task, and SPANS were at a similar level to control participants on day 1 of testing; however, by day 2 of testing, unlike controls, SI did not demonstrate any retained learning. This finding was in spite of an incident of olfactory-cued episodic memory retrieval and occasional identification of odours. Despite previous research to the contrary, olfactory memory was unable to permeate SI's memory retention window and was quickly forgotten, raising questions about the consolidation of memory. Future research with larger samples is needed to confirm this finding and to continue exploring medically unexplained anterograde amnesia.

Keywords: anterograde amnesia, memory, olfaction, long-term.

Introduction

Amnesia, or memory loss, has been studied for centuries, and various causes and classifications are described in the literature (Langer, 2021). Amnesia can be categorised by its chronological pattern, with retrograde amnesia being the loss of previous memories inputted prior to onset, and anterograde amnesia being the inability to form new memories since onset (Langer, 2021; Sanders & Warrington, 1971). Anterograde amnesia in the absence of brain damage is rare and was historically referred to as psychogenic amnesia, however, this term attributed memory difficulties to psychological distress or feigning and was negatively associated with being intentional for secondary gains (Markowitsch, 2003). More recently these cases are referred to as functional amnesia (a term which acknowledges the uncertainty of the cause), or dissociative amnesia (a clinical diagnosis recognising amnesia typically resulting from psychological trauma; De Renzi et al., 1997; Markowitsch, 2003; Spiegel et al., 2011).

One such case of anterograde amnesia without any structural brain changes, classified clinically as dissociative amnesia, is WO (Burgess & Chadalavada, 2015). WO is a gentleman with reported anterograde amnesia following a root canal treatment in 2005. Since then, without reorientating himself throughout the day, WO has not made any new memories outside of a conscious memory-retention period of approximately 90-minutes; the only exceptions to this being an awareness of his father's death and the birth of a new baby recalled across a 24-hour period (before also being forgotten). Interestingly, despite deficits in new episodic and semantic memory, WO also demonstrates impaired implicit memory (which is otherwise typically intact in those with anterograde amnesia resulting from bilateral hippocampal damage; Spiers et al., 2001). Cases such as those presented by Burgess and Chadalavada (2015) provide a unique opportunity to learn more about human memory in otherwise apparently intact brain anatomy.

An area of memory requiring further research is olfactory memory (White, 1998; White et al., 2015). Olfaction, one's sense of smell, is considered one of the oldest senses and has been suggested to serve several functions such as food seeking, avoidance of hazards, and social communication (Sarafoleanu et al., 2009; Stevenson, 2010). Olfactory memory is the ability to recall odours (Herz & Engen, 1996; White et al., 2015). The detection, encoding, and recall of odour stimuli uses several cognitive skills, like executive functioning skills (Richardson & Zucco, 1989; Schlintl & Schienle, 2022; Solla et al., 2023).

It has been suggested that olfactory memory is more long-lasting than memories for other sensory modalities, or at least less subject to forgetting (Engen & Ross, 1973; Lawless & Engen, 1977; Lehrner, 1993; White et al., 2015). For example, Lawless (1978) compared recognition memory for olfactory stimuli to that of visual stimuli (scenic travel images) and free-form shapes over intervals of 20 minutes, 7 days, 4 weeks, or 4 months. Memory for olfactory stimuli was found to decline in the first 4 weeks, but remained stable above chance after this time, in a similar manner to the free-form shapes but dissimilar to visual stimuli which demonstrated strong memory retention at 4 weeks but a steeper memory decline thereafter. Because of this suggestion as to the longevity of odours, and other distinctive features (such as the lack of evidence of serial position effects), the structure of the olfactory memory model and the existence of an olfactory working memory system is currently debated (Baddeley & Hitch, 1974; Johnson & Miles, 2009; White, 1998).

This longevity of olfactory memory may be in part connected to the unique olfactory physiology and relationship between olfaction, the amygdala, and emotional memories. The olfactory memory pathway within the brain bypasses the thalamus (implicated in all other sensory modalities) and has a direct connection to the amygdala (Farbman, 1992; Herz & Engen, 1996). The amygdala has been associated with the emotional salience of memories, and emotional memories are more likely to be remembered (such as WO's demonstrated

recollection of his father's passing; Cahill & McGaugh, 1995; Kensinger, 2007). This may also explain the Proust phenomenon, the idea that olfaction has a strong cue to emotionally significant autobiographical (episodic) memories (Chu & Downes, 2000, 2002; Larsson et al., 2014; Proust, 1928). This connection between olfaction and episodic memory has been demonstrated in various studies (Chu & Downes, 2000; de Bruijn and Bender, 2017; Hackländer et al., 2018; Saive et al., 2014). Olfactory-evoked episodic memories are suggested to be older (from childhood before the age of 10) and more emotional than memories cued by verbal or visual information (Willander & Larsson, 2006, 2007). Anatomically, Herz et al. (2004) suggested that odour-cued personally significant memories resulted in increased amygdala and hippocampal activation compared to those visually-cued. Olfactory-cued memories have even been said to be helpful in those with neurodegenerative conditions such as Alzheimer's disease, resulting in more specific and emotional memories recalled than music or control conditions, and suggested as a potential therapeutic tool (El Haj et al., 2018).

Though odours have been shown to evoke episodic memories, this process does not require odour identification (Herz, 2004, 2005; Herz & Cupchick, 1992). Indeed, verbal identification is extremely difficult, bringing into question whether olfactory memory is encoded semantically (verbally) or perceptually (non-verbally; Cain, 1979; Conway & Pleydell-Pearce, 2000; Herz & Engen, 1996; Paivio, 1986). Support for a semantic olfactory memory pathway comes from studies that suggest identification of odours, consistent use of a label (even if incorrect), and more highly verbalisable odours are associated with greater recall (Cornell Kärnekull et al., 2015; Lyman & McDaniel, 1990; Moss et al., 2019). This semantic and verbal processing influence has been suggested as an explanation for sex differences found in olfactory memory tasks, whereby women often outperform men on olfactory identification and recognition (Brand & Millot, 2001; Lehrner, 1993; Öberg et al., 2002).

Furthermore, the semantic or perceptual processing debate may allude to reported differences between familiarity and recollection; the idea that one might come across a stimulus and have a feeling of knowing it with partial recall, versus fully recollecting when and where they have come across that stimulus before (Tulving, 1985; Yonelinas, 2002). This distinction has been referred to as the tip-of-the-nose phenomenon, akin to tip-of-the-tongue word-finding difficulties (Lawless & Engen, 1977). Studies suggest that odour familiarity aids recollection (Jönsson & Olsson, 2003; Larsson & Bäckman, 1993; Rabin & Cain, 1984).

Besides familiarity, other odour qualities have been found to influence the persistence of olfactory memories, such as intensity, pleasantness, and irritability. For example, Larsson et al. (2009) found participant performance on olfactory recognition tests was greater for odours rated unpleasant, irritable, and/or intense. Xiao et al. (2020) demonstrated that unpleasant odours produced greater responses on functional Magnetic Resonance Imaging (fMRI) scans in the amygdala, piriform cortex, and hippocampus than pleasant odours when participants were repeatedly exposed to the odours. This association between odour qualities and memory may provide an evolutionary advantage, enabling survival by avoiding aversive environments (Kensinger, 2007; Larsson et al., 2009).

To summarise, there are several unknowns still associated with olfactory memory; is olfactory memory truly long-term, what qualities aid long-term olfactory memory, and is olfactory memory affected by verbal identification?

Rationale and Aims

Recently, a new case of medically unexplained anterograde amnesia has come to light, that of SI (Burgess, 2017). SI presents with anterograde amnesia since a shoulder injury and unsuccessful corrective surgeries. Since this time in 2013, SI has failed to retain new memories outside of a memory-retention window of 1 waking day, with his memory failing after a night's

sleep. Like WO, SI has demonstrated one exception to this, a memory of an emotive Rugby World Cup game that lasted longer than 24 hours, before also being forgotten.

This current research aims to explore olfactory memory with a unique case of anterograde amnesia, SI, in the hope of developing a better understanding of the clinical participant's difficulties and contributing to the scientific understanding of olfactory memory, amnesia and related neurological difficulties (in line with NHS values of 'respect and dignity' and 'improving lives'; Department of Health and Social Care, 2015).

The above literature suggests that olfactory memory, with its strong persistence and unique physiology, would pose a potential means by which SI could remember information and a pathway which has not yet been explored with SI. However, SI does present with unique and very rare amnesia that has led to the following conservative hypotheses:

1) The clinical participant (SI) will not significantly differ to control participants in olfactory recognition memory at immediate (T0), or 100-minute delayed memory (T1) testing but will recognise significantly fewer odours than control participants at 24-hour delayed memory (T2) testing. Control participants will not demonstrate any significant difference in the number of odours correctly recognised across all time points.

2) There will be a correlation between odour quality ratings (intensity, pleasantness, recognisability, and familiarity) and olfactory recognition memory for control participants. SI will not differ from control participants in odour quality ratings.

3) There will be a qualitative difference in the description used by clinical and control participants when identifying each odour at each time point.

4) Control participants will demonstrate implicit learning on the mirror maze task across the two days of testing, however, the clinical participant will not demonstrate such implicit learning.

5) The clinical participant will score similarly to the control participants on the Short Parallel Assessments of Neuropsychology Status (SPANS) on day 1 of testing, however, will score differently to control participants in recall and recognition subtests on day 2.

Methods

Design

This study utilised a repeated-measures observational case-control design. The clinical participant was compared to eight matched controls for performance on an olfactory recognition memory task, which was performed immediately (T0), after a 100-minute delay (T1), and after a delay of 24 hours (T2). Participants also engaged in comparator tasks during the 100-minute delay, specifically the 'mirror maze task' (Burgess & Chadalavada, 2015; Milner et al., 1968) and the SPANS (Burgess, 2014).

The clinical participant's partner was consulted during the design process to ensure the suitability and appropriateness of the design to SI's abilities.

Across hypotheses 1, and 3-5, the independent variables (IV) of the study were the presence or absence of amnesia and time.

For hypothesis 1, the dependant variables (DV) were the number of hits (i.e., correctly recognised), false alarms (i.e., signalled recognition when the target was not present), misses (i.e., did not signal recognition in the presence of a target), and correct rejections (i.e., correctly dismissed the distractor odour as a foil).

For hypothesis 2, odour quality ratings for intensity, recognition, familiarity, and pleasantness and the target odour recognition scores (hits /misses) were the correlational variables included in the analysis.

For hypothesis 3, the DV was the description provided by participants when asked to identify the odour.

For hypotheses 4 and 5, the DVs were the scores obtained on the mirror maze task and the SPANS subtests.

Participants

Clinical Participant

SI is a 42-year-old white male, ex-smoker, who has demonstrated profound anterograde amnesia since a shoulder injury at work and two subsequent unsuccessful rotator-cuff surgeries in 2013 (Burgess, 2017). Since then, SI has not formed any new memories outside of a conscious memory retention window of approximately 1-waking day, with his memory failing after a night's sleep; the only known (reported by SI's partner) exception is that of an emotive Rugby World Cup game (the memory for which lasted 24-48 hours, before being forgotten).

SI grew up in a rural area of the UK and had poor attendance at school (due to family commitments) until he was 14 years old when he ceased formal education. Following school, SI trained as a Butcher and had various subsequent manual labour-based jobs, including within a factory warehouse where he sustained his shoulder injury. Since his injury and onset of memory difficulties, SI has not been able to maintain employment.

Throughout his early life and later adulthood, SI has engaged in various contact sports, including rugby, and has likely sustained head injuries related to these hobbies.

SI likely had undiagnosed epilepsy in his early life and was prescribed anti-epileptic medications (although he did not take these in his teenage years). SI's younger brother also has epilepsy.

SI has engaged in a range of neuropsychological assessments since the onset of reported difficulties, the results of which can be seen in Appendix C (Burgess, 2017). During assessments, SI reportedly appears to be applying excessive effort, and after any assessment session, SI reports headaches, in a similar manner to subjects post-ictal.

Overall, SI's premorbid IQ was estimated to be below the 25th percentile, with scores on various tasks such as digit span, fluency, and comprehension, around the 5th percentile (Burgess, 2017). This IQ is anticipated to be an underestimate, however, due to the reported observable decreased concentration and attention from previous levels when SI was tested, lack of historic schooling opportunities, and reliability and validity issues using a single neuropsychological assessment as an indicator of a larger multi-factorial construct (IQ). Therefore, SI's true IQ may be more represented in observed 'fluid' versus 'crystalised' skills. A low estimate of SI's IQ was between the 9th and 16th percentiles, with current data supporting an estimate closer to the latter, with 'fluid' and visuospatial skills seen as an area of relative strength.

Current brain scans (computerised tomography [CT], magnetic resonance imaging [MRI] and single-photon emission computed tomography [SPECT]) have not indicated any clinically significant brain damage. One scan did indicate reported evidence of a historic parafalcine subdural hematoma, but this was considered unrelated to reported difficulties and likely due to a premorbid head injury (Burgess, 2017; Cragun et al., 2020).

Occasionally, SI has been noted to experience periods of 'absence' and/or dissociation during the day, in which his memory reportedly lapses, and he presents as if he has awoken from sleep without memory for that day. Patterns and triggers to these periods are currently unknown. Several-hour and 24-hour electroencephalograms did not detect nocturnal or diurnal epileptic activity.

SI was recruited to this current study via an independent, professional relationship he and his partner have maintained with Dr Gerald Burgess since 2015. Following the Burgess and Chadalavada (2015) publication regarding the unique amnesia observed with WO, and a subsequent newspaper article (Robson, 2015), SI's partner contacted Dr Burgess directly and informed him of SI's memory difficulties and expressed interest in participating in research.

Since this time, SI has participated in two further research studies (Burgess, 2017; Yusuf-George et al., 2022). Regarding this current research, SI and his partner were introduced to the current author by Dr Burgess, and subsequent correspondence regarding recruitment to the present study occurred via email and later face-to-face discussions during the data collection process.

Control Participants

Eight control participants participated in this study. These participants were matched to the clinical participant on the following demographics: age (all control participants were between the ages of 40 and 55 years, $M = 42.5$), gender (male), and education level (further education equivalent or less). All control participants were white.

Control participants were eligible for the study on the basis that they had not knowingly experienced COVID-19 in the three months prior to participation (due to the reported impact of COVID-19 on anosmia; Klopfenstein et al., 2020) and were non- or ex-smokers (Dinc et al., 2020).

Additionally, control participants were excluded from the study if they were anosmic (self-reported or were unable to detect any of the smells in the study), had a diagnosed memory condition, had any current untreated illness resulting in nasal congestion, or had any known food or respiratory allergies.

Control participants were recruited via a purposive sampling method, including advertisement on social media (Appendix D) and word-of-mouth. All participants that volunteered were included in the study. Control participants were located in the South-East of England, and data were collected between January – February 2023. Participants did not receive payment for their participation.

No power calculation was conducted, due to the uniqueness of the clinical participant's presentation, the exploratory nature of this study, and the assumption that controls should

demonstrate near-perfect odour recognition, and therefore produce a large effect size. The decision to include eight control participants was based on the number of control participants used in a similar case-control design and literature that suggested the number of control participants should be three- or fourfold the number of clinical participants (which was initially going to be two, before WO was excluded due to contracting COVID19; Smith et al., 2010; Song & Chung, 2010; Ury, 1975).

Materials

Odours

Thirty-one original odours were sourced from fragrance suppliers, 29 from AromaPrime and two from Givaudan (Appendix E).

To this author's knowledge, these odours had not been previously utilised in research and their quality ratings were not normed. Although norms were available for other odours, such as in the study by Moss et al. (2016), it was considered prudent to undertake a small sample to rate the current odours used here, to provide norms to aid the allocation of odours to either 'targets' or 'foils'. In accordance with recommendations from Julious (2005) and due to the relatively small control sample size in the main study, the pilot aimed to recruit a minimum of 12 participants to provide such odour quality ratings.

Thirteen pilot participants were therefore recruited through convenience sampling methods. Pilot participants were not matched to the clinical participant for age (M = 30.23), sex (nine female, four male), or education level (all 13 had attended higher education), due to time limitations on data collection of the main study.

The 13 pilot participants (an additional 14th participant was excluded due to failure to complete the pilot testing) rated the odours for intensity, pleasantness, recognisability, and familiarity and were asked to name the odour and rate the accuracy of the assigned label (completed after all other qualities were rated and the assigned label was revealed). The pilot

data were then used to generate mean ratings for each odour on each quality, which was used to inform the distribution of odours into different, balanced groups used in the testing (Appendix F).

The six odours with the lowest mean rating for pleasantness were chosen as target odours (group A), to be remembered, on the basis that unpleasant odours are often better recalled than pleasant odours (Larsson et al., 2009). The aim of this decision was to maximise chances of recognition.

The 18 odours with the highest mean rating for pleasantness were then chosen as foils and assigned to the three groups to be used at the three time-points of memory testing. These three foil groups (groups B-D) were balanced for mean pleasantness ratings.

The remaining seven odours were excluded, one of which ('rotten egg') was excluded prior to the ranking of pleasantness, due to the observation that the smell dissipated within the timeframe of exposure and was therefore unsuitable for testing needs.

Odours were presented to participants in opaque, plastic test tubes, with a white screw top. Odours were transferred to test tubes by dipping 1cm of a 5cm x 0.5cm length fragrance test strip into the liquid odour sample from the suppliers and placing said strip into the test tubes. Odour strips were re-dipped into the sample pots and transferred back into the test tubes on each day of testing. Test tubes were contained within numbered, small, plastic, sealable bags. Odour samples and odour test tubes were kept in a stationary fridge at 4°C between testing trials and transferred for use in testing in a portable fridge to maintain consistent odour quality and strength.

During testing, participants were instructed to unscrew the test tube lid, hold the tube 2cm from the middle of the tip of their nose, and allowed to sniff the odour for an unlimited number of sniffs.

During the encoding task, and at the three time-points of testing, the presentation of target and foil odours was randomised (although the same randomised order was used across control and clinical participants, due to the small sample size).

Measures

Olfactory Recognition Memory Task

The olfactory recognition memory task was purpose-designed for this study, with questions adapted from previous research (Cornell Kärnekull et al., 2015; Engen & Ross, 1973; Larsson et al., 2009; Rabin & Cain, 1984). The main question of the memory task, "Did we show you this odour in the teaching block?", utilised an adapted old/new paradigm (Engen & Ross, 1973). The odour quality rating scales used in the recognition memory task were the same scales used in the pilot. Scales were presented to participants on laminated sheets of A4 for reference in testing (Appendix G). The participants were then asked to name the odour, in the hopes of encouraging recall through semantic and/or episodic cueing. Participants provided a verbal response to each question, which was recorded on the answer sheet (Appendix H) by the researcher. Responses to the naming question for each odour at each phase of the task (encoding – T2) were audio recorded and later transcribed.

Firstly, in an encoding phase, participants were shown the six target odours, one at a time. Participants answered the odour quality rating scales and naming question for each odour.

Participants then engaged in an immediate test of olfactory recognition memory (T0), in which they were presented with the six target odours and six new foil odours (each foil was only presented once to participants and did not repeat across the memory phases) and answered the task questions for each odour. This process was repeated after a 100-minute delay (T1) and after a 24-hour delay (T2).

The Short Parallel Assessments of Neuropsychological Status

Participants completed the SPANS Version A on both days of testing (Burgess, 2014). Specifically, on day 1, participants completed: the 24-hour recognition memory test, naming, sustained and divided listening (one and two), object recall, object recognition, figure copy, letter-number coding, figure recall, figure recognition, list learning, counting backwards, monetary calculations, list recall, list recognition, similarities, and the symbol-word paired associates tasks. On day 2, participants completed the recall and recognition components of the SPANS.

These comparator subtests were selected for the testing protocol as they utilise similar format and cognitive skills as needed in olfactory memory recognition tasks.

Mirror Maze

On days 1 and 2, clinical and control participants completed a pencil and paper maze task, in which they were asked to complete ten trials of a maze using only the reverse image available in a mirror, whilst their hands were covered using a clipboard to block their view (see Appendix I). Participants were instructed to complete the maze as quickly as possible, without touching or crossing the boundaries of the maze.

The 30cm x 30cm mirror was mounted on a wooden block, leaning at an approximate 95° angle. Participants' mirror maze completion was timed.

This implicit procedural memory task was selected for comparison to WO, and to examine SI's procedural memory skills which are often preserved in amnesia with observable hippocampal damage (Burgess & Chadalavada, 2015; Milner et al., 1968; Spiers et al., 2001).

Procedure

Once the prospective control participant contacted the lead researcher via their email address and indicated they met the inclusion criteria, they were sent a control participant information sheet (Appendix J). The consent form and demographics questionnaire were

completed on the first day of testing, with testing only proceeding if participant's consented and their demographics matched the study's requirements (Appendices K and L).

Testing occurred across two days, in participants' homes, in a quiet room that had been ventilated for 15 minutes before and during testing. Testing on day 1 lasted approximately 2 hours, and testing on day 2 lasted approximately 45 minutes. Throughout testing, participants only consumed water.

On day 1 of testing, participants first engaged in the encoding and immediate memory test of the olfactory recognition memory task. During a delay of 100 minutes post-T0 testing, participants completed the mirror maze and SPANS tasks, and a break was provided. Upon completion of the 100 minute delay, participants repeated the olfactory recognition memory task (T1).

On day 2, 24 hours after the encoding phase, participants engaged in a second test of delayed olfactory recognition memory (T2), followed by the repetition of the mirror maze task and recall and recognition components of the SPANS. Activities between T1 and T2 were uncontrolled.

Upon completion of the testing, participants were provided with a debrief (Appendix M).

Ethical Considerations

Ethical approval was acquired from the Salomons Institute of Applied Psychology Ethics Panel (Appendix N).

Written, informed consent was obtained from all participants on day 1 Control participants provided verbal consent on day 2, indicating that they wished to proceed with the second day of the study. As SI only had a memory-retention window of 1 waking day, the entire consent procedure was repeated on the second day of testing. SI was assumed to have the capacity to consent, with no evidence that indicated the contrary. SI's partner also provided

informed consent for the testing (Appendix O), and both SI and his partner had the right to withdraw SI from the study at any point up to 72 hours post-testing. No participant exercised their right to withdraw from the study.

The odours, with various degrees of pleasantness and intensity, had the potential to cause discomfort to participants, however, this did not exceed that which the participants would encounter in everyday life and was deemed a necessary risk for the importance of the study (Larsson et al., 2009). Although no participants expressed adverse reactions to the odours, had this occurred, their right to withdraw would have been reiterated and actioned accordingly.

Due to the duration of the study, there was potential for participants to experience fatigue and boredom. This was counteracted by including breaks within the 100-minute delay, before or after the comparator tasks were completed.

All control participant data were collected using a participant identification number, which was kept separate from consent forms. SI's data and details included in this study posed a risk to his anonymity, therefore insignificant details have been redacted to reduce the risk of identification, and SI was informed of and agreed to this risk.

Participants' responses to being asked to identify the odours were audio recorded on an encrypted device, and informed consent for this was obtained via the consent form. The audio recording was later transcribed, and the recording was deleted. The anonymised transcript was then transferred to a password-protected CD-ROM for storage, along with the other anonymised study data, in accordance with the Salomons Institute policy.

Data Analysis

IBM SPSS (version 29) was used to analyse the data. Data were subject initially to tests of parametric assumptions (Appendix P). Due to the small sample size and breach of parametric assumptions, nonparametric statistical analysis was used throughout this study.

As one of the groups consists of only SI (N = 1), nonparametric measures of independent group designs (such as the Kruskal-Wallis Test) were not able to be used.

Instead, control participants' repeated-measures variables were analysed using Friedman's tests, and, where appropriate, significant results were further explored using Wilcoxon signed-rank tests as post-hoc analysis, with a Bonferroni correction applied. SI's scores were then compared to control participants' scores both qualitatively and (where appropriate) using a Bayesian approach and SingleBayes.exe software as described in Crawford and Garthwaite (2007).

Correlational data for hypothesis 2 were analysed using two-tailed Kendall's tau coefficients, due to the small sample size (Field, 2009).

For hypothesis 3, in addition to the above, the audio-recorded data were transcribed and analysed using content analysis, based on the approach proposed by Elo and Kyngäs (2008). Specifically, a deductive content analysis was applied, using meaning as the unit of analysis, and manifest content. An unconstrained matrix was generated, using initial categories based on Cornell Kärnekull et al. (2015), until exhaustive codes were created.

Regarding hypothesis 5, SPANS results were explored qualitatively and compared to normative data generated by Burgess (2014, 2022).

Results

Hypothesis 1

The results of participants' olfactory recognition memory scores across T0 – T2 have been summarised in Table 1 below.

Table 1

Participants Olfactory Recognition Memory Scores Across Time (T0 –T2)

Participant(s)	Hits			Misses			False Alarms			Correct Rejections		
	T0	T1	T2	T0	T1	T2	T0	T1	T2	T0	T1	T2
Controls M (*SD*)	4.25 (*1.04*)	5.00 (*1.31*)	4.75 (*1.58*)	1.75 (*1.04*)	1.00 (*1.31*)	1.25 (*1.58*)	1.00 (*0.93*)	2.13 (*1.46*)	2.13 (*1.13*)	5.00 (*0.93*)	3.88 (*1.46*)	3.87 (*1.13*)
SI	3.00	3.00	0.00*	3.00	3.00	6.00*	2.00	3.00	0.00	4.00	3.00	6.00

*Significant Bayesian $p < .05$

As expected, controls participants did not significantly differ in the number of hits ($\chi^2(2) = 1.83$, $p > .05$), misses ($\chi^2(2) = 1.83$, $p > .05$), false alarms ($\chi^2(2) = 5.44$, $p > .05$), and correct rejections ($\chi^2(2) = 5.44$, $p > .05$), produced across T0, T1 and T2.

SI's scores were then compared to control participants for the number of hits, misses, false alarms and correct rejections using a Bayesian approach. Significant differences were found between SI's hit and miss scores compared to that of control participants' at T2, with no other significant difference identified. Specifically, SI's hit scores at T2 produced a Bayesian point estimate of 1.94% ($p < .05$, 95% credible interval of 0.00% - 12.69%), which suggests that only 1.94% of the control population would produce a hit score lower than SI's score. SI's miss scores at T2 produced a Bayesian point estimate of 98.72 % ($p < .05$, 95% credible interval of 90.37% - 99.99%). This suggests that 98.72% of control participants would produce a miss score lower than SI's score.

In considering the above finding, it is important to note that SI was observed to answer "No" to every odour (target or foil) on day 2 of testing, when asked "Did we show you this odour in the teaching block?"

Hypothesis 2

Target odour quality ratings were compared to olfactory memory recognition scores (hits/misses) obtained by control participants' using Kendall's tau. Control participants' pleasantness ratings ($\tau = 0.05$, $p > .05$), recognisability ratings ($\tau = .15$, $p > .05$), and familiarity ratings ($\tau = .15$, $p > .05$) were not significantly correlated to their recognition memory scores. Recognition memory task outcomes were however significantly correlated with control participants' intensity ratings, $\tau = -0.32$, $p < .001$.

SI target odour quality ratings were then compared to control participants' ratings using a Bayesian approach, see Table 2. SI's scores only significantly differed from control participants' scores for pleasantness at T0, with a Bayesian point estimate of 98.96 % ($p < .05$, 95% credible interval of 91.72% - 100.00%). This suggests that 98.96% of control participants would produce a lower pleasantness rating for the target odours than SI.

Table 2

Participant(s) Odour Quality Ratings Across Time (Encoding -T2)

Participant(s)	Quality Rating															
	Intensity				Pleasantness				Recognition				Familiarity			
	Encoding	T0	T1	T2	Encoding	T0	T1	T2	Encoding	T0	T1	T2	Encoding	T0	T1	T2
Controls M (*SD*)	4.00 (*0.85*)	3.98 (*1.10*)	4.06 (*1.00*)	4.17 (*1.08*)	-1.38 (*1.51*)	-1.88 (*0.91*)	-2.15 (*1.15*)	-2.27 (*1.14*)	0.50 (*0.62*)	0.73 (*0.68*)	0.88 (*0.79*)	0.83 (*0.78*)	0.54 (*0.62*)	0.75 (*0.67*)	0.88 (*0.79*)	0.83 (*0.78*)
SI	3.33	2.67	3.00	3.67	1.67	1.00*	0.33	0.17	0.67	0.33	0.17	0.5	0.83	0.33	0.17	0.33

*Significant Bayesian $p < .05$

Hypothesis 3

The content analysis of the participants' responses to being asked to name the odour were coded using four main categories based on Cornell Kärnekull et al. (2015) and generated from the data. The four main categories were: no association (no association was given), single association (a one-off association was made at T0, T1 or T2 without any prior associations made at encoding – T2), inconsistent association (subsequent association(s) made that are dissimilar to the prior association), or consistent association (subsequent associations made that are identical or similar to the prior association).

A second independent coder was utilised to code the data, and Fleiss' kappa indicated there was a very good inter-rater agreement, $K = .957$ (95% CI, .854 to 1.00), $p < .001$ (Altman, 1999; Table 3 below). Any disagreements in coding were resolved through discussion.

Table 3

Fleiss's Kappa Inter-Rater Agreement on Naming Categories

Category	*K*	95% CI
No association	1.00*	.846 – 1.00
Single association	1.00*	.846 – 1.00
Consistent association	.91*	.759 – 1.00
Inconsistent association	.87*	.716 – 1.00

* $p < .001$

The four association categories were then compared to the number of hits and misses made by control participants across T0 – T2 (Table 4). The category of no association was the most frequently used across all time points for control participants and SI.

Table 4

Naming Associations and Corresponding Olfaction Recognition Memory Scores for Targets

Participants	Category	T0			T1			T2			Data Extract Example
		Total frequency	Hits	Misses	Total frequency	Hits	Misses	Total frequency	Hits	Misses	
Controls M (*SD*)	No association	5.00 (*1.41*)	3.75 (1.75)	1.25 (*1.04*)	4.38 (*2.07*)	3.63 (*2.20*)	0.75 (*1.49*)	4.00 (*2.00*)	3.13 (*2.17*)	0.88 (*1.36*)	"No idea." (Participant 4, T0)
	Single association	0.13 (*0.35*)	0.00 (0.00)	0.13 (*0.35*)	0.50 (*0.76*)	0.38 (*0.52*)	0.13 (*0.35*)	0.50 (*0.76*)	0.38 (*0.74*)	0.13 (*0.35*)	"That is-. That is a-. That is a cheese." (Participant 9, T2 only)
	Consistent association	0.38 (*0.52*)	0.38 (0.52)	0.00 (*0.00*)	0.75 (*1.39*)	0.63 (*1.06*)	0.13 (*0.35*)	1.13 (*2.03*)	1.00 (*1.69*)	0.13 (*0.35*)	"It's the mud one I think." (Participant 5, T0) "It was the mud one I'm sure." (Participant 5, T1)
	Inconsistent association	0.50 (*1.07*)	0.25 (*0.46*)	0.25 (*0.71*)	0.38 (*0.52*)	0.25 (*0.46*)	0.13 (*0.35*)	0.38 (*0.52*)	0.25 (*0.46*)	0.13 (*0.35*)	"It smells like damp, like mould on a bathroom wall or something. Yeah, I reckon its mould." (Participant 8, encoding) "It smells like that dandelion. Or grass." (Participant 8, T1).
SI	No association	5	3	2	5	2	3	2	0	2	"Um… no, I haven't got a name, no sorry." (SI, T2)
	Single association	0	0	0	0	0	0	2	0	2*	"Uh- go flour, yeah, flour" (SI, T2 only)
	Consistent association	0	0	0	0	0	0	2	0	2*	"It reminds me of a can of petrol, when a can of petrol has not been filled for a long time, it smells like that. Stuck in the shed or something." (SI, encoding) "Petrol can." (SI, T2)
	Inconsistent association	1	1	0	1	1	0	0	0	0	"It reminds me of a lawn mower grass, that's been stuck in the lawn mower." (SI, encoding) "Cakes." (SI, T0)

*Significant Bayesian $p < .05$

The frequency of control participants' use of the four association categories was compared across time. A Friedman's test indicated that the control participants did not significantly differ in the frequency with which they used the categories of no association ($\chi^2(2) = 4.53$, $p > .05$), single association ($\chi^2(2) = 2.60$, $p > .05$), consistent association ($\chi^2(2) = 3.71$, $p > .05$), nor inconsistent association ($\chi^2(2) = 0.13$, $p > .05$) across time (T0 - T2).

When the mean scores for the number of hits, misses, false alarms and correct rejections and the frequency of association categories made by control participants were compared to SI's scores using a Bayesian approach, it was indicated that SI produced significantly more single associations and consistent associations with target odours he was unable to recognise (misses) than the control sample at T2 (Bayesian point estimate of 99.92%, $p < .05$, two-tailed, with a 95% credible interval of 99.42% – 100.00%), no other result was significantly different. This suggests that only 0.08% of the control participants would produce more single and consistent associations for target odours they were unable to recognise (misses) than SI at T2.

Hypothesis 4

The amount of time taken by control participants to complete the mirror maze trials significantly decreased across trials (T1 -T10) on day 1 ($\chi^2(9) = 53.78$, $p < .01$), and on day 2 ($\chi^2(9) = 36.03$, $p < .01$). Post-hoc Wilcoxon signed-rank tests with a Bonferroni correction of .0167 level of significance revealed that on day 1 trial times significantly decreased between trial 1 and trial 10 ($T = 0$, r = - 0.63) and between trial 1 and trial 5 ($T = 0$, $r = - 0.63$), but did not significantly decrease between trial 5 and trial 10 ($T = 8$, $r = - 0.35$). On day 2, trial times only significantly decreased between trial 1 and trial 10 ($T = 0$, $r = - 0.63$), but did not significantly decrease between trial 1 and trial 5 ($T = 4$, $r = - 0.49$), nor trial 5 and trial 10 ($T = 5$, $r = - 0. 46$).

When the data were collectively analysed, and day 2 results were treated essentially as trials 11 – 20, a Friedman's test indicated that the control participants significantly decreased

in the amount of time taken to complete trials across trial 1 to trial 20 ($\chi^2(19) = 110.13$, $p < .001$). Wilcoxon signed-rank tests used as post-hoc analysis with a Bonferroni correction of .0167, indicated that there was a significant medium decline in time taken to complete trials between trial 1 and trial 20 ($T = 0$, $r = -0.63$), between trial 10 and trial 20 ($T = 0$, $r = -0.63$), and between trial 1 and trial 15 ($T = 0$, $r = -0.63$).

Figure 1

Day 1 Mirror Maze Trials Completion Times for the Eight Control Participants and SI

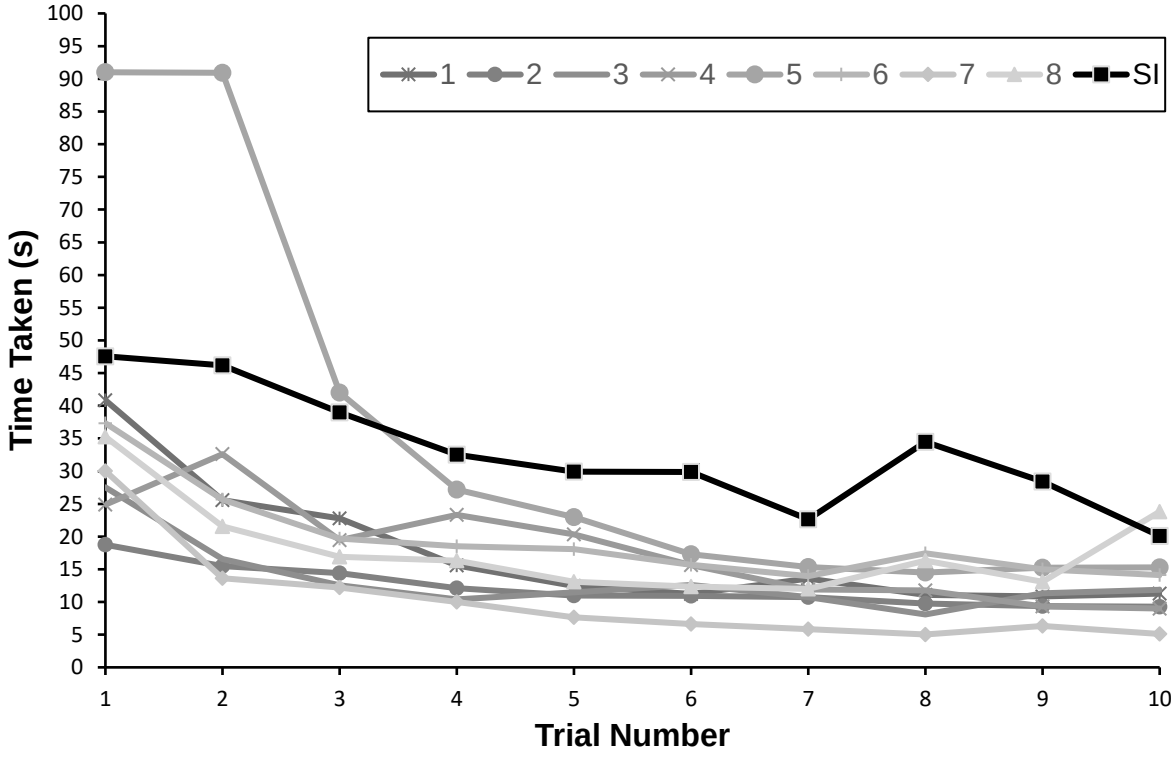
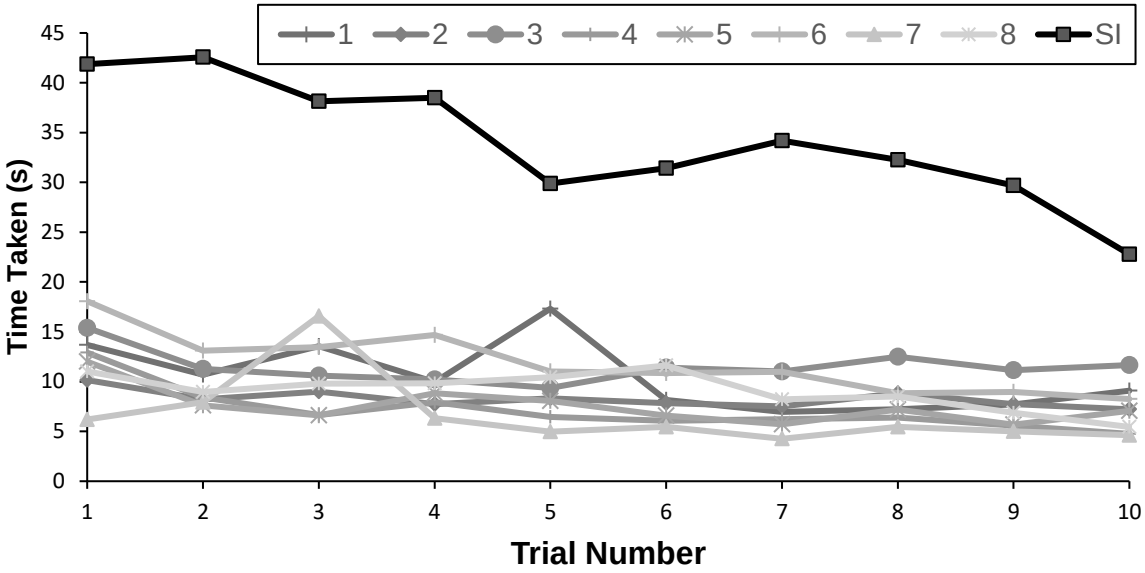


Figure 2

Day 2 Mirror Maze Trials Completion Times for the Eight Control Participants and SI



When SI's results were compared to the control participant's results (Table 5, Figures 1 and 2), a difference was apparent in the data. SI was significantly slower (when compared using a Bayesian approach) than control participants for completing the mirror maze from trial 4 to trial 9 on day 1 (Bayesian point estimates of 97.71 – 99.93% with 95% lower credible limits between 85.57% - 99.89% $p < .05$, one-tailed), and throughout all trials on day 2 (Bayesian point estimates of 99.94%, with 95% lower credible limits between 99.53 – 100.00 %). This suggests that where control participants had maintained their implicit learning on day 2, SI had not, and his time scores reverted to very similar times achieved on day 1 testing.

Table 5

Mirror Maze Trials Time Completion

Day	Participants	Trials									
		1	2	3	4	5	6	7	8	9	10
1	Controls M (*SD*)	38.21 (*22.49*)	30.25 (*25.31*)	20.01 (*9.65*)	16.69 (*6.14*)	14.64 (*5.26*)	12.79 (*3.40*)	11.76 (*2.89*)	11.75 (*4.21*)	11.32 (*3.05*)	12.47 (*5.58*)
	SI	47.57	46.16	38.97	32.50*	29.94*	29.87*	22.62*	34.47*	28.40*	20.09
2	Controls M (*SD*)	12.43 (*3.56*)	9.52 (*1.95*)	10.78 (*3.53*)	9.44 (*2.49*)	9.49 (3.73)	8.50 (*2.48*)	7.61 (*2.41*)	8.11 (*2.14*)	7.34 (*2.03*)	7.26 (*2.40*)
	SI	41.87*	42.56*	38.13*	38.50*	29.87*	31.43*	34.18*	32.25*	29.69*	22.78*

*Significant Bayesian $p < .05$

Hypothesis 5

On day 1 of testing (Table 6), SI performed as well as control participants on the SPANS subtests of naming and sustained and divided listening round 1. Two control participants performed at a lower level than SI on figure copy and writing sentences, and one control participant performed at the same low level as SI did on monetary calculation. SI however produced a lower score than all other control participants on sustained and divided listening round 2, object recall, object recognition, letter-number coding, figure recall, figure recognition, list learning, list recall, list recognition, similarities, and symbol-word paired associates.

In relation to the SPANS base rates and percentiles, generated from SPANS-X (Burgess, 2022) testing with a normative sample, SI's performance on day 1 for the figure copy, writing sentences, naming, and sustained and divided listening round 1 subtests were within the normal range expected for a typical age-matched population, all other scores fell below the expected level.

Table 6

Day 1 SPANS Tasks Base Rates and Percentiles Achieved by Each Participant

Day 1 Tasks	Control Participants																SI	
	1		2		3		4		5		6		7		8			
	BR	PCTL	BR	PCTL	BR	PCTL	BR	PCTL	BR	PCTL	BR	PCTL	BR	PCTL	BR	PCTL	BR	PCTL
Naming	94%	>6th	94%	>6th	94%	>6th	94%	>6th	94%	>6th	94%	>6th	94%	>6th	94%	>6th	94%	>6th
SDLR 1	96%	>4th	96%	>4th	96%	>4th	96%	>4th	96%	>4th	1%	1st	96%	>4th	96%	>4th	96%	>4th
SDLR 2	79%	>21st	79%	>21st	79%	>21st	79%	>21st	79%	>21st	3%	5th	16%	21st	16%	21st	0%	<1st
Object Recall	12%	14th	53%	>47th	33%	47th	33%	47th	33%	47th	12%	14th	53%	>47th	12%	14th	0%	<2nd
Object Recognition	9%	10th	90%	>10th	9%	10th	90%	>10th	90%	>10th	90%	>10th	90%	>10th	9%	10th	1%	1st
Figure Copy	27%	>74th	20%	47th	20%	47th	26%	74th	9%	12th	9%	12th	27%	>74th	27%	>74th	15%	27th
Letter-Number Coding	3%	5th	3%	5th	3%	5th	84%	>16th	4%	9th	2%	2nd	84%	>16th	84%	>16th	0%	<1st
Writing Sentences	32%	39th	6%	7th	6%	7th	32%	39th	32%	39th	6%	7th	32%	39th	32%	39th	32%	39th
Figure Recall	13%	23rd	17%	40th	5%	10th	34%	>66th	26%	66th	17%	40th	17%	40th	13%	23rd	1%	1st
Figure Recognition	86%	>14th	86%	>14th	86%	>14th	86%	>14th	86%	>14th	13%	14th	86%	>14th	13%	14th	0%	<1st
List Learning	1%	1st	14%	20th	3%	6th	14%	20th	38%	81st	14%	20th	14%	20th	14%	20th	0%	<1st
Counting Backwards	24%	37th	1%	1st	63%	>37th	24%	37th	24%	37th	24%	37th	63%	>37th	3%	4th	1%	1st
Monetary Calculations	66%	>34th	0%	<1st	11%	21st	11%	21st	66%	>34th	11%	21st	66%	>34th	66%	>34th	1%	1st
List Recall	68%	>32nd	7%	11th	68%	>32nd	68%	>32nd	68%	>32nd	21%	32nd	7%	11th	68%	>32nd	1%	1st
List Recognition	94%	6th	4%	6th	94%	6th	94%	6th	94%	6th	94%	6th	94%	6th	94%	6th	0%	<1st
Similarities	25%	44th	4%	6th	56%	>44th	25%	44th	56%	>44th	56%	>44th	13%	19th	56%	>44th	0%	<1st
SWPA	89%	>11th	89%	>11th	89%	>11th	89%	>11th	89%	>11th	3%	4th	89%	>11th	89%	>11th	0%	<1st

Note. The following abbreviations are used: base rates (BR), percentiles (PCTL), sustained and divided listening round (SDLR), and symbol-word paired associates (SWPA).

Table 7

Day 2 SPANS Recall and Recognition Tasks Base Rates and Percentiles Achieved by Each Participant

Day 2 Tasks	Control Participants																SI	
	1		2		3		4		5		6		7		8			
	BR	PCTL	BR	PCTL	BR	PCTL	BR	PCTL	BR	PCTL	BR	PCTL	BR	PCTL	BR	PCTL	BR	PCTL
24-hour Recognition	(3)	-	(3)	-	(3)	-	(3)	-	(3)	-	(2)	-	(3)	-	(3)	-	(2)	-
Object Recall	12%	14th	0%	<2nd	0%	<2nd	12%	14th	33%	47th	0%	<1st	2%	2nd	33%	47th	0%	<1st
Object Recognition	9%	10th	90%	>10th	9%	10th	90%	>10th	90%	>10th	90%	>10th	90%	>10th	9%	10th	0%	<1st
Figure Recall	17%	40th	5%	10th	13%	23rd	26%	66th	26%	66th	2%	5th	26%	66th	17%	40th	0%	<1st
Figure Recognition	86%	>14th	86%	>14th	86%	>14th	13%	14th	86%	>14th	13%	14th	13%	14th	13%	14th	0%	<1st
List Recall	0%	<4th	7%	11th	4%	4th	21%	32nd	21%	32nd	7%	11th	0%	<4th	7%	11th	0%	<1st
List Recognition	2%	2nd	94%	>6th	94%	>6th	94%	>6th	94%	>6th	94%	>6th	4%	6th	94%	>6th	0%	<1st
SWPA	89%	>11th	89%	>11th	89%	>11th	89%	>11th	89%	>11th	89%	>11th	89%	>11th	89%	>11th	0%	<1st

Note. The following abbreviations are used: base rates (BR), percentiles (PCTL), and symbol-word paired associates (SWPA). Brackets () within the table are used to convey raw scores, where no base rates and percentiles were available.

On day 2 of testing (Table 7), SI performed lower than all control participants on all tests of recall and recognition memory, with the exception of scoring at the same level as one participant on the 24-hour recognition memory test and object recall. Interestingly, despite reporting no memory of having completed the SPANS test, SI was able to identify two of the six objects from the 24-hour recognition memory test.

Across day 1 and 2, SI's performance declined in all tasks, apart from those in which he had already reached the floor level (figure recognition, list recognition and symbol-word paired associates). This was unlike control participants however, who largely maintained or improved their scores on the following tests: 24-hour recognition test, object recognition, figure recall (only three participants' scores declined), figure recognition (only two participants' scores declined), list recognition (only one participant's score declined), and symbol-word paired associates (in which no scores declined). Control participants' scores were observed to decline in object recall (five participants' scores declined, one by as much as SI), and list recall (seven participants' scores declined, one by as much as SI). Overall suggested however, is that the control participants benefitted from retention of memory between days 1 and 2, whereas SI did not demonstrate retention of memory across the same period.

Discussion

This case-control study aimed to explore olfactory recognition memory with a clinical participant with unique anterograde amnesia, SI, to develop a greater understanding of anterograde amnesia and olfactory memory.

Hypothesis 1

Control participants' olfactory recognition responses (hits, misses, false alarms and correct rejection) remained stable across time, in concordance with research regarding the longevity and limited decay of olfactory memory (Engen & Ross, 1973; Lawless, 1978; Lawless & Engen, 1977; Lehrner, 1993).

As expected, SI did not differ from control participants on the first day of testing (T0 and T1) but was significantly different to controls on day 2 (T2) for hits and misses. This is largely due to his response bias, responding "No" to every recognition question where statistically, by chance alone, he could have achieved three hit scores (correct response of "Yes" for three out of the six target odours).

Although WO (Burgess & Chadalavada, 2015) has not, to this author's knowledge, been tested for his olfactory memory, SI's results are comparable to WO's performance on explicit tests of memory, in that WO reportedly had intact recognition and recall when tested within his memory retention window of 90 minutes, but was unable to recall or recognise the learnt material when the test was administered after a 90-minute delay in which no rehearsal was permitted.

Therefore, despite previous research suggesting olfactory memory is better recognised and less likely to be forgotten than other sensory memory, due to its unique physiology and close anatomical link to the hippocampus and amygdala; in the case of SI, with clinically insignificant brain imaging and presumed intact brain anatomy, olfactory memory was unable to permeate his memory retention window and was quickly forgotten.

Hypothesis 2

Control participants' target odour quality ratings for pleasantness, familiarity and recognisability were not correlated with achieved outcomes (hits or misses). Only the intensity ratings were correlated with hits and misses of target odours, and this was a negative correlation suggesting that as intensity scores increased, hit scores decreased. SI's scores were also only found to differ to control participants for pleasantness at T0, the reason for this difference was unapparent. This finding was largely a deviation from the literature which suggests that odours rated unpleasant, intense, irritable, familiar, and recognisable were more likely to be recalled and recognised in testing (Larsson et al., 2009; Larsson & Bäckman, 1993; Lawless & Engen,

1977; Rabin & Cain, 1984). However, conclusions about the influence of quality ratings are likely limited by this present study's methodological choices, such as the small number of target odours in use and the small sample size of eight control participants. Moreover, the pleasantness ratings were likely influenced by using only unpleasant odours as target odours, therefore conclusions about the influences of odour pleasantness on recognition scores are very limited.

Hypothesis 3

Concerning the descriptions used by the control and clinical participants for the odours, the category of no association was the most frequently used by participants, who often did not provide a response, and these odours appeared to accumulate the highest number of hit responses. This may reflect the difficulty of identifying odours as previously described by Cain (1979) and further demonstrates that even unnamed odours can be correctly recognised (Herz & Cupchick, 1992).

Odours with consistent associations did not have many hits associated, nor did the frequency of use of consistent associations (or other categories) change over time, unlike the finding by Cornell Kärnekull et al. (2015) which suggested a decrease in the frequency of consistent associations. This finding however may have been impacted by the small number of odours named and also because of the difference in time delay used (24 hours versus 64 days at the largest interval) between this study and Cornell Kärnekull et al. (2015).

When SI's scores were compared to controls', he produced significantly more single and consistent associations with odours he was unable to recognise (misses) at T2. This could indicate that SI was unable to use the odours as cues to semantic information or episodic recall from the previous day's testing, although it is important to note SI's response bias ("No" to every recognition question).

Interestingly, SI, when asked to name one of the odours at T1 (subjectively) appeared to have an episodic memory triggered and became tearful. The incident of episodic memory retrieval appears in-keeping with previous research suggesting olfaction is a stronger cue to episodic retrieval than other senses (such as the Proust phenomenon), produces memories older in nature (childhood memories), and more emotionally charged (Chu & Downes, 2000, 2002; de Bruijn & Bender, 2017; Larsson et al., 2014; Proust, 1928; Saive et al., 2014; Willander & Larsson, 2006, 2007). However, according to previous research, this strong olfactory-episodic association should have aided recall, and should have experienced a slower forgetting rate, thus increasing the likelihood of a hit at T2 with SI (Hackländer et al., 2018); this was not the case. Upon inspection of the same odour at T2, SI did not explicitly allude to experiencing the same episodic recall that one might expect in complete anterograde amnesia.

Hypothesis 4

With the implicit memory task, the mirror maze, SI's timings across day 1 and day 2 were similar, and significantly much slower than control participants on day 2. SI, therefore, did not demonstrate evidence of implicit learning. This is clinically rare, given the reported sparing of implicit memory skills in anterograde amnesia in the presence of bilateral hippocampal lesions, and mimics the reported memory deficits of WO (Burgess & Chadalavada, 2015; Spiers et al., 2001).

Furthermore, SI was slower than control participants on the mirror maze by the second half of day 1 testing, which may imply difficulty with processing speed or the effects of fatigue. In considering his olfactory memory performance, this could explain SI's chance-level performance at T0 and T1 testing, as olfactory memory has been suggested to rely on cognitive skills such as processing speed (Schlintl & Schienle, 2022).

Hypothesis 5

On the SPANS, SI performed at a similar level or slightly below the normative sample and control participants on tasks of naming, sustained and divided listening round one, figure copy, writing sentences, and monetary calculations; but performed at a lower than anticipated level on all other tasks (sustained and divided listening round two, recall and recognition tests, letter-number coding, list learning, similarities, and symbol-word paired associates). These latter tasks are arguably considered to be more taxing on skills of executive functioning skills (such as inhibition, processing speed and cognitive flexibility) and general memory ability (Burgess, 2014). Notably, this was like the finding of Burgess and Chadalavada (2015) with WO, which suggested WO's intellect was largely intact post-onset of amnesia, however, his working memory and visuospatial skills had reportedly diminished over time.

In comparison to his performance on olfactory recognition memory tasks, this may have meant that SI struggled to compare and contrast odour objects, hence his near-chance scores of hits, misses, false alarms and correct rejections at T0 and T1 even theoretically before the onset of his lapse in memory-retention of 1 waking day. This would replicate the findings of research which suggest an association between a reduction in executive functioning, in older people and those with neurological conditions such as Parkinson's disease, and reduced olfactory memory (Schlintl & Schienle, 2022; Solla et al., 2023).

After the onset of memory lapse on day 2, SI was, unsurprisingly, worse than control participants on all SPANS recall and recognition tasks, with no apparent evidence of learning. The exception to this was the 24-hour memory recall task, where SI correctly selected two of the three items to remember (the "pint glass" and "cup of tea") out of six available items. Although this may suggest episodic recall beyond the memory retention period, this finding should be considered cautiously, as SI's decision may have been influenced by unintentional

episodic priming; with the two correctly identified objects likely closest in nature to his personal life than the other four objects.

Clinical Implications

The findings of this study challenge previous research which suggests the unique physiology of the olfactory memory pathway should allow for the retention of olfactory memories at a precedent above those of other sensory memory modalities (Farbman, 1992; Graziadei & Graziadei, 1979; Herz & Engen, 1996; Lawless, 1978). Despite the lack of any clinically significant brain anatomy changes, SI could not recall olfactory memories after a 24-hour delay. This, in turn, implies that olfactory memory is not as immediately long-term as research would suggest, but instead is a process involving consolidation over sleep.

In line with previous memory models such as Baddeley and Hitch (1974), olfactory memory may therefore contain a working memory store similar to the other senses, in which olfactory information is held and maintained before either consolidation into long-term memory or is forgotten. It may be this working memory which allowed SI to answer the questions about the odours on day 1, however, without consolidation into long-term memory, the olfactory memories were forgotten, and he was unable to answer questions about the odours on day 2.

Regarding anterograde amnesia in the absence of clinically significant brain abnormality, SI did not objectively demonstrate any retained memory over 24 hours across olfactory recognition memory tasks, implicit memory tasks, and other broader tasks of cognitive skills (SPANS). This is greatly similar to the case of WO previously reported (Burgess & Chadalavada, 2015). This suggests that the current scientific understanding of anterograde amnesia is limited by available technology and anatomical knowledge, and instead, the true causes exist beyond that on a metabolic level involved in the consolidation of memory.

Based on the findings of this study, clinical staff, particularly those conducting assessments with clinical populations, may benefit from training in the consolidation of memory. Such training should include information about olfactory memory difficulties and how these might present in those with amnesia versus populations with typical memory. It is hoped this training would allow for easier identification of other individuals with amnesia and would allow clinicians to draw on knowledge of olfactory difficulties in their formulations with clients presenting with a range of difficulties (such as dementia and post-traumatic stress disorder; Vermetten et al., 2007).

Future Research

The occurrence of anterograde amnesia in the absence of clinically significant brain injury is considered rare, however, the cases of SI and WO imply the existence of a clinical classification beyond current scientific understanding, and potentially centring on an issue at a metabolic, consolidation level. It would therefore be of utmost importance that future research investigates reported incidences of such cases to explore if they too exhibit similar memory deficits (such as impaired implicit memory), to determine if a distinct classification does indeed exist.

Those with anterograde amnesia and other neurological conditions provide unique opportunities to explore the current theories around olfactory memory, and future research should look to continue investigating olfactory long-term memory with these clinical populations. It would be especially interesting to explore such cases of anterograde amnesia if they were to present in a female, given women's reportedly enhanced olfactory memory (Brand & Millot, 2001 Lehrner, 1993; Öberg et al., 2002). This would hopefully provide more information about the unique anatomy, consolidation, and duration of olfactory long-term memory.

Limitations

The main limitation of this current study is the small sample size. Although for a case-control design, a large control participant sample was unnecessary, the findings are restricted by small effect sizes, reliance on nonparametric statistics, and lack of generalisability (for example with all male participants). Future studies into olfactory memory should aim to expand upon this research with a larger, more representative sample.

Another limitation of this study was methodological. The recognition memory task was purpose-designed, and, although based on previous research and using piloted questions, no normative data nor reliability statistics were available, the design relied heavily on verbal expression, and the naming question could have been utilised to better evoke the olfactory-episodic memory links (Herz, 2004, 2005; Herz & Cupchick, 1992). Future research should therefore aim to explore olfactory memory utilising less explicit methods (perhaps through exploring more implicit methods such as olfactory priming, or habituation), and should explore olfactory-episodic memory links by asking participants to name an episodic event associated with each odour in a manner like the Galton-Crovitz method (Crovitz & Schiffman, 1974; Hockländer et al., 2018).

Conclusion

Despite being anatomically intact, without clinically significant brain abnormalities, olfactory learning was unable to permeate SI's memory-retention window of 1 waking day. Control participants however demonstrated olfactory recognition memory that did not significantly differ over time. These findings challenge existing literature which suggests that olfactory memory is more long-lasting than other forms of sensory memory due to unique physiology and raises questions about the consolidation of olfactory memory.

This study found that odour quality ratings, other than intensity, were not correlated with the correct (hits) or incorrect (misses) identification of target odours in control participants.

This study replicated previous research in demonstrating the difficulty in naming odours, however, control participants were still able to recognise target odours above chance without attributing a name. With SI, naming (single, consistent, or inconsistent associations) did not appear to aid recall, and despite one odour triggering episodic recall, unlike previous suggestions, this did not aid his recollection of the odour in subsequent testing.

SI continued to demonstrate a lack of memory retention in other memory tasks, including implicit memory tasks (mirror maze) and tasks of other cognitive skills (SPANS). This is different to the pattern usually seen in anterograde amnesia resulting from observable brain injury, where implicit memory is reportedly more intact. This suggests that like WO, SI presents with unique anterograde amnesia, without brain structural changes, that may point towards a new classification with causes located on a metabolic level at the point of memory consolidation.

Several limitations of this study are suggested, such as its small sample size, reliance on verbally expressed methods of olfactory recognition, and limited investigation of olfactory-episodic memory links. Revised protocols are suggested to allow for the investigation of olfactory memory without such limitations.

Future research should aim to continue to explore olfactory memory with those with medically unexplained anterograde amnesia to answer the question, what does short-term olfactory memory comprise of and how is this consolidated into long-term memory?

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KARIANNE SNELL (BSc Hons)

Section C: Appendices of Supporting Material

A thesis submitted in partial fulfilment of the requirements of
Canterbury Christ Church University for the degree of
Doctor of Clinical Psychology

SEPTEMBER 2023

SALOMONS INSTITUTE
CANTERBURY CHRIST CHURCH UNIVERSITY

Appendix A: Studies and Experiments Included in Section A

Author (Year)	Experiment Number	Included/Excluded	Reason(s)
Ayabe-Kanamura & Kikuchi (1997)	-	-	-
Cain & Potts (1996)	1	Included	Meets criteria
	2	Included	Meets criteria
Chrea et al. (2007)	1	Excluded	No memory task
	2	Included	Meets criteria
Cornell Kärnekull et al. (2015)	-	-	-
Davis (1977)	-	-	-
Engen & Ross (1973)	1	Included	Meets criteria
	2	Included	Meets criteria
	3	Included	Meets criteria
Jehl et al. (1995)	-	-	-
Jehl et al. (1997)	-	-	-
Larsson & Bäckman (1993)	-	-	-
Larsson & Bäckman (1997)	-	-	-
Lawless & Engen (1977)	1	Included	Meets criteria
	2	Excluded	No recognition memory task, identification only
	3	Excluded	No recognition memory task, identification only
Lehrner (1993)	-	-	-
Lyman & McDaniel (1990)	1	Included	Meets criteria
	2	Excluded	Retention interval <24 hours
Murphy et al. (1991)	1	Excluded	Retention interval <24 hours
	2	Included	Meets criteria
	3	Excluded	Retention interval <24 hours
	4	Excluded	Retention interval <24 hours
Olsson et al. (2009)	1	Excluded	Retention interval <24 hours
	2	Included	Meets criteria
Rabin & Cain (1984)	-	-	-
Saive et al. (2014)	-	-	-
Zucco (2003)	1	Included	
	2	Excluded	Retention interval <24 hours

Note. - within table symbolises that the study was not divided into further experiments, and therefore no further information is provided regarding the study's inclusion in Section A of this project.

Appendix B: Section A Characteristics of Studies

Author (Year) [experiment number]	Country	Study Design	Participants
Ayabe-Kanamura & Kikuchi (1997)	Japan	3x3 Mixed Factorial Design	58 participants (31 men, 37 women). No age or ethnicity data provided.
Cain & Potts (1996) [experiment 1]	America	Within-Subjects Design	10 paid participants (4 men, 6 women). Recruited from the Yale community. No age or ethnicity data provided.
Cain & Potts (1996) [experiment 2]	America	Between-Subjects Design	20 participants (nine males and 11 females). No age or ethnicity data provided.
Chrea et al. (2007)	America, Vietnam & France	Quasi-experiment design	59 students, 20 from France (7 male, 13 female, M = 22.8, SD = 3.9), 20 from America (4 male, 16 female, M age = 23.1, SD = 5.0), and 19 from Vietnam (9 male, 10 female, M age = 22.4, SD = 1.2).

Author (Year) [experiment number]	Country	Study Design	Participants
Cornell Kärnekull et al. (2015)	Sweden	4x2x2 Mixed Factorial Design	83 participants (43 women, 40 men). The age ranged from 19 to 50 years for the women (M age = 26.3, SD = 5.8) and from 19 to 44 years for the men (M age = 26.1, SD = 5.8). No ethnicity data
Davis (1977)	America	2 x 3 Mixed Factorial Design	No participant data provided regarding number of participants, age, sex, or ethnicity. 13-16 participants were assigned to each condition.
Engen & Ross (1973) [experiment 1]	America	Mixed Design	37 participants. No age, sex, or ethnicity data provided.
Engen & Ross (1973) [experiment 2]	America	Between-Subjects Design	68 participants. No age, sex, or ethnicity data provided. Participants were not informed of the delayed recognition test.
Engen & Ross (1973) [experiment 3]	America	Between-Subjects Design	74 participants. No age, sex, or ethnicity data provided.
Jehl et al. (1995)	France	4X3 Between-Subjects Factorial Design	110 adults between 19 and 30 years of age (M = 23.63 + 2.78). No sex or ethnicity data was provided.

Author (Year) [experiment number]	Country	Study Design	Participants
Jehl et al. (1997)	France	5x2 Between-Subjects Factorial Design	100 subjects (50 women, 50 men, 18-32 years of age, M = 25.3). College graduate students. No ethnicity data was provided.
Larsson & Bäckman (1993)	Sweden	3x3x2 Quasi-Mixed Factorial Design	108 healthy women volunteered. Participants were divided into three groups dependant on their age, young (18-30 years old), young-old (60-69 years old), and old (70-79 years old). No ethnicity data provided. 36 participants were in each age group. 12 participants of each age group were randomly assigned to each encoding condition.
Larsson & Bäckman (1997)	Sweden	3x2 Quasi-Mixed Factorial Design	72 women participants, who were divided into three groups of 24 participants based on age: young (aged 19±34 years), young-old (aged 60±69 years), and old adults (aged 70±79 years). No ethnicity data provided.
Lawless & Engen (1977)	America	Mixed Design	15 Brown University students volunteered for a practice study (8 participants' data was included in the practice group and 7 participants' in the control group). Another 74 subjects were paid participants. 30 subjects were male; 59 were female. No age or ethnicity data provided. Three participants were excluded for failing to perfume above chance levels (total participants therefore 86).
Lehrner (1993)	Austria	2x4 Quasi-Mixed Factorial Design	27 men and 29 women participants, between 18 and 27 years of age. No further age information or ethnicity data provided.
Lyman & McDaniel (1990)	America	5x2 Between-Subjects Factorial Design	120 participants, recruited from universities, 70 male and 50 female participants. No age or ethnicity data provided.

Author (Year) [experiment number]	Country	Study Design	Participants
Murphy et al. (1991)	America	2x3x4 Quasi-Mixed Factorial Design	32 participants (16 students, (M, SD = 21.4, 2.6; and 16 elderly, M, SD = 72.1, 6.6). 16 were female, and 16 were male. No ethnicity data was provided. No control group.
Olsson et al. (2009)	Sweden	2x2 Within-Subjects Factorial Design	16 men and 16 women with the mean age of 23.7 (SD=4.2). No ethnicity information was provided.
Rabin & Cain (1984)	America	Mixed Design	45 Yale undergraduates (24 females, 21 males) participated. No information provided on ages or ethnicities of participants.
Saive et al. (2014)	France	2x3 Mixed Factorial Design	25 healthy participants (13 women; age: M = 21.4 SD = ± 2.1).
Zucco (2003)	Italy	Between-Subjects Design	48 university students ranging in age from 20 to 30 years (M = 24.7 years). 28 males and 20 females.

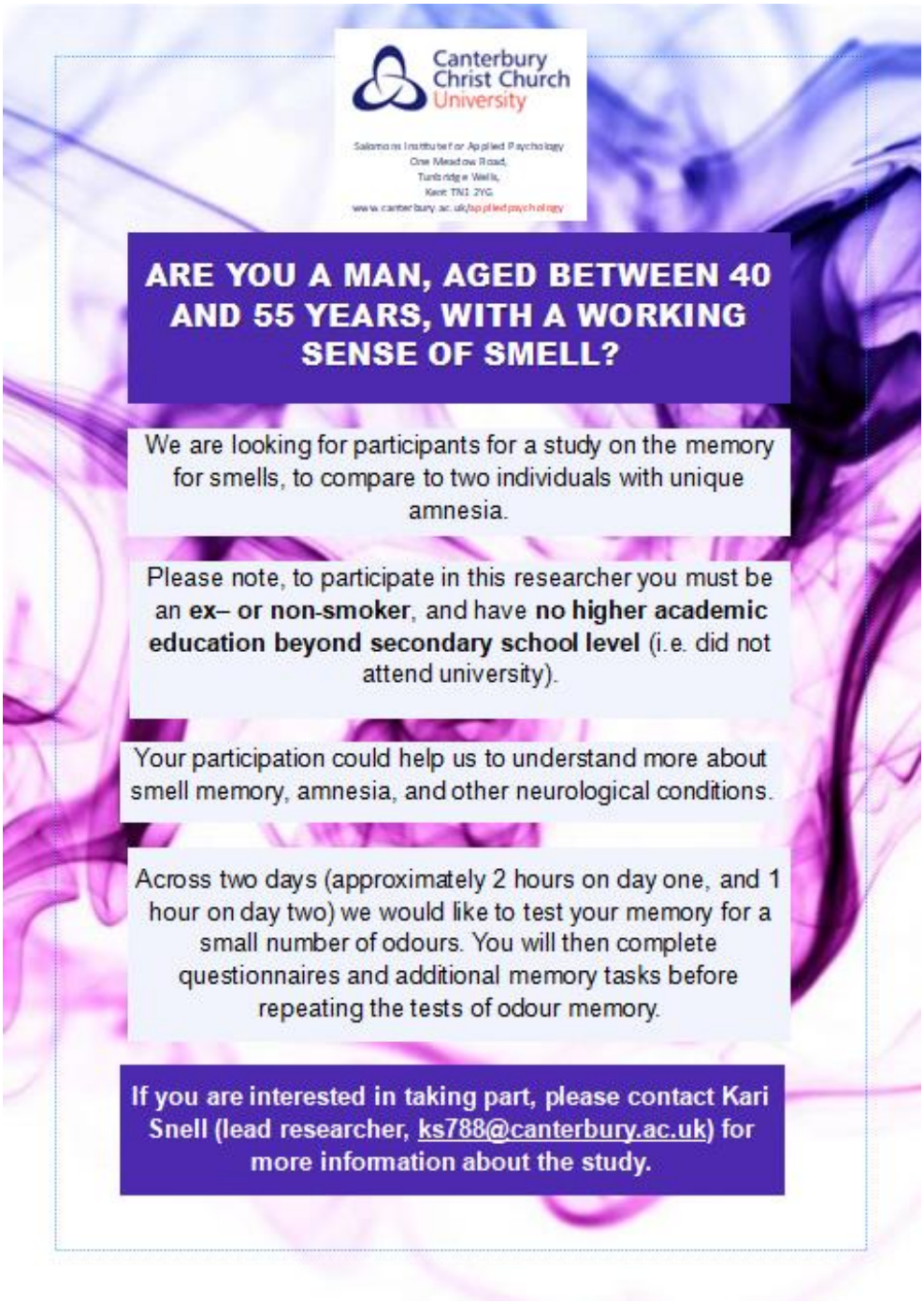
Appendix C: SI Previous Neuropsychological Assessment

SI completed a previous neuropsychological assessment with Dr Gerald Burgess in 2017, the results of which are being prepared for publication.

Of note, SI completed a Weschler Adult Intelligence Scale – IV (WAIS-IV), and achieved the following results:

WAIS-IV Subtest	Standard Score
Block Design	6
Digit Span	5
Matrix Reasoning	7
Vocabulary	7
Information	7
Letter-Number Sequencing	8

Appendix D: Advertisement



Appendix E: Odour Groups for Testing

Supplier	Odour Number	Odour Name	Included/Excluded	Group
AromaPrime	1	Basil	Included	B
AromaPrime	2	Hospital modern day	Included	D
AromaPrime	3	Skunk	Excluded	-
AromaPrime	4	Racing car	Excluded	-
AromaPrime	5	Fressia Meadow	Included	C
AromaPrime	6	Brewery	Included	D
AromaPrime	7	Candy Floss	Included	B
AromaPrime	8	Lavender	Included	B
AromaPrime	9	Cigarette ash	Included	D
AromaPrime	10	Rotten egg	Excluded	-
AromaPrime	11	Sweaty feet	Included	A
AromaPrime	12	Buttered popcorn	Included	B
Givaudan	13	Lemon	Included	D
AromaPrime	14	Flatulence	Included	A
AromaPrime	15	Coffee blend	Included	C
AromaPrime	16	Fish market	Excluded	-
AromaPrime	17	Sports changing room	Included	C
AromaPrime	18	Washday	Included	D
AromaPrime	19	Rotten flesh	Excluded	-
AromaPrime	20	Dentist	Included	C
AromaPrime	21	Sewer	Included	A
AromaPrime	22	Methane	Included	A
AromaPrime	23	Garden shed	Included	B
AromaPrime	24	Vomit	Included	A
AromaPrime	25	Peppermint	Included	D
AromaPrime	26	Pine forest	Included	C
AromaPrime	27	Gun smoke	Excluded	-
AromaPrime	28	Crusty bread	Included	B
AromaPrime	29	Acrid rubbish	Included	A
AromaPrime	30	Urine	Excluded	-
Givaudan	31	Cantaloup melon	Included	C

Appendix F: Odour Quality Ratings from the Pilot Study

Smell Number	Score	How would you rate the smell **intensity**?	How would you rate the smell **pleasantness**?	How well do you **recognise** the smell?	How **confident** are you of this name?	How **familiar** is the smell?	How **accurately** does the smell match the name?
1	*M*	3.85	1.38	1.08	28.33	1.31	0.31
	SD	0.80	2.10	0.64	28.87	0.75	0.48
2	*M*	3.79	-0.07	1.14	41.43	1.14	0.93
	SD	0.97	1.69	0.77	28.78	0.77	0.83
3	*M*	4.29	-1.93	0.43	21.79	0.71	0.57
	SD	1.27	2.02	0.51	24.78	0.73	0.79
4	*M*	4.14	-1.07	0.79	24.64	0.86	0.33
	SD	1.17	2.02	0.58	23.08	0.66	0.65
5	*M*	3.50	1.71	1.21	36.43	1.36	1.31
	SD	0.94	1.27	0.58	27.06	0.50	0.75
6	*M*	3.21	1.43	1.21	42.86	1.29	0.71
	SD	1.05	1.65	0.70	24.63	0.73	0.73
7	*M*	3.50	2.36	1.29	43.21	1.36	1.07
	SD	1.02	1.28	0.47	28.93	0.50	0.73
8	*M*	3.64	2.14	1.43	62.86	1.71	1.71
	SD	0.93	1.29	0.65	27.01	0.47	0.61
9	*M*	4.21	-1.00	1.14	43.57	1.21	1.15
	SD	0.80	2.25	0.66	29.25	0.70	0.80
10	*M*	1.38	-1.00	0.29	16.15	0.21	0.31
	SD	1.04	1.75	0.47	22.93	0.43	0.63
11	*M*	3.86	-2.71	0.79	26.15	0.86	1.08
	SD	1.41	1.20	0.89	28.73	0.86	0.76

Smell Number	Score	How would you rate the smell **intensity**?	How would you rate the smell **pleasantness**?	How well do you **recognise** the smell?	How **confident** are you of this name?	How **familiar** is the smell?	How **accurately** does the smell match the name?
12	*M*	4.36	-0.64	0.79	28.85	1.00	0.92
	SD	1.15	2.34	0.70	25.51	0.88	0.76
13	*M*	3.43	2.29	1.29	57.14	1.50	1.79
	SD	1.22	1.07	0.73	34.07	0.65	0.43
14	*M*	5.21	-3.64	0.14	4.23	0.14	0.29
	SD	0.97	0.50	0.36	10.77	0.36	0.73
15	*M*	3.29	0.86	0.86	35.00	0.93	1.00
	SD	1.33	1.75	0.77	23.12	0.73	0.88
16	*M*	3.85	-2.62	1.15	35.38	1.23	1.08
	SD	1.07	1.12	0.69	34.79	0.60	0.76
17	*M*	4.00	1.92	1.54	58.46	1.54	0.31
	SD	0.91	0.76	0.52	27.64	0.52	0.75
18	*M*	3.85	1.00	1.15	31.92	1.31	0.77
	SD	0.80	1.47	0.38	25.13	0.48	0.83
19	*M*	4.77	-2.31	0.69	19.23	0.62	0.50
	SD	0.83	2.39	0.63	25.32	0.65	0.76
20	*M*	4.31	-0.85	0.38	11.67	0.69	0.54
	SD	0.85	2.15	0.65	18.01	0.63	0.66
21	*M*	4.85	-3.38	0.31	13.33	0.31	0.67
	SD	1.14	0.87	0.48	19.69	0.48	0.49
22	*M*	4.62	-2.77	0.46	12.31	0.54	0.30
	SD	1.04	1.42	0.52	15.36	0.52	0.48
23	*M*	3.62	1.00	1.31	39.23	1.15	0.23
	SD	0.77	1.78	0.48	25.32	0.38	0.60

Smell Number	Score	How would you rate the smell **intensity**?	How would you rate the smell **pleasantness**?	How well do you **recognise** the smell?	How **confident** are you of this name?	How **familiar** is the smell?	How **accurately** does the smell match the name?
24	*M*	4.38	-3.31	1.08	50.00	1.31	1.08
	SD	1.19	0.95	0.64	30.00	0.75	0.64
25	*M*	3.77	1.77	1.46	52.31	1.46	1.69
	SD	1.01	1.01	0.52	23.86	0.52	0.48
26	*M*	3.38	1.62	1.15	34.62	1.38	1.08
	SD	1.19	1.04	0.69	26.02	0.65	0.64
27	*M*	4.77	-2.46	0.38	13.85	0.62	0.10
	SD	0.93	2.03	0.51	18.95	0.51	0.32
28	*M*	3.46	1.23	0.69	37.50	0.92	0.23
	SD	0.66	1.79	0.63	31.94	0.76	0.44
29	*M*	4.69	-3.31	0.15	11.67	0.31	0.67
	SD	0.95	1.03	0.38	13.37	0.48	0.89
30	*M*	3.92	-2.31	0.62	10.77	0.54	0.54
	SD	1.04	2.02	0.51	17.06	0.78	0.66
31	*M*	3.77	2.31	1.62	63.85	1.69	1.77
	SD	0.83	1.32	0.51	28.73	0.48	0.44

Appendix G: Stimuli Scales from the Olfactory Recognition Memory Test

Teaching Block

1. How would you rate the smell intensity?

6	Intolerable
5	Very strong
4	Strong
3	Easily perceptible
2	Weak
1	Very weak
0	Not perceptible

2. How would you rate the smell pleasantness?

-4	Extremely unpleasant
-3	Moderately unpleasant
-2	Unpleasant
-1	Slightly unpleasant
1	Slightly pleasant
2	Pleasant
3	Moderately pleasant
4	Extremely pleasant

3. How well do you recognise the smell?

0	Unknown
1	Vague recognition
2	Full recognition

4. How familiar is the smell?

0	Unfamiliar
1	Vague familiarity
2	Full familiarity

5. What is the name of the smell?
(this question has an open response that will be audio recorded)

6. How confident are you of this name?

0	**No confidence**
20	
40	
60	
80	
100	**Very high confidence**

Memory Phases

1. Did we show you this odour in the teaching block?

Yes
No

2. How confident are you of your response?

0	**No confidence**
20	
40	
60	
80	
100	**Very high confidence**

3. How would you rate the smell intensity?

6	Intolerable
5	Very strong
4	Strong
3	Easily perceptible
2	Weak
1	Very weak
0	Not perceptible

4. How would you rate the smell pleasantness?

-4	Extremely unpleasant
-3	Moderately unpleasant
-2	Unpleasant
-1	Slightly unpleasant
1	Slightly pleasant
2	Pleasant
3	Moderately pleasant
4	Extremely pleasant

5. How well do you recognise the smell?

0	Unknown
1	Vague recognition
2	Full recognition

6. How familiar is the smell?

0	Unfamiliar
1	Vague familiarity
2	Full familiarity

7. What is the name of the smell?
(this question has an open response that will be audio recorded)

8. How confident are you of this name?

0	**No confidence**
20	
40	
60	
80	
100	**Very high confidence**

Appendix H : Olfactory Memory Recognition Task Researcher Answer Sheet

6	Intolerable
5	Very strong
4	Strong
3	Easily perceptible
2	Weak
1	Very weak
0	Not perceptible

-4	Extremely unpleasant
-3	Moderately unpleasant
-2	Unpleasant
-1	Slightly unpleasant
1	Slightly pleasant
2	Pleasant
3	Moderately pleasant
4	Extremely pleasant

0	Unknown
1	Vague recognition
2	Full recognition

0	Unfamiliar
1	Vague familiarity
2	Full familiarity

0	No confidence
20	
40	
60	
80	
100	Very high confidence

Encoding Phase End Time:

Start Time:

Smell Number	How would you rate the smell intensity?	How would you rate the smell pleasantness?	How well do you recognise the smell?	How familiar is the smell?	What is the name of the smell?	How confident are you of this name?
29						
11						
14						
22						
24						
21						

6	Intolerable
5	Very strong
4	Strong
3	Easily perceptible
2	Weak
1	Very weak
0	Not perceptible

-4	Extremely unpleasant
-3	Moderately unpleasant
-2	Unpleasant
-1	Slightly unpleasant
1	Slightly pleasant
2	Pleasant
3	Moderately pleasant
4	Extremely pleasant

0	Unknown
1	Vague recognition
2	Full recognition

0	Unfamiliar
1	Vague familiarity
2	Full familiarity

0	No confidence
20	
40	
60	
80	
100	Very high confidence

T0 Start Time: End Time:

Smell Number	Did we show you this odour in the teaching block?	How confident are you of your response?	How would you rate the smell intensity?	How would you rate the smell pleasantness?	How well do you recognise the smell?	How familiar is the smell?	What is the name of the smell?	How confident are you of this name?
7								
28								
24								
8								
14								
1								
22								
12								
29								
21								
23								
11								

6	Intolerable
5	Very strong
4	Strong
3	Easily perceptible
2	Weak
1	Very weak
0	Not perceptible

-4	Extremely unpleasant
-3	Moderately unpleasant
-2	Unpleasant
-1	Slightly unpleasant
1	Slightly pleasant
2	Pleasant
3	Moderately pleasant
4	Extremely pleasant

0	Unknown
1	Vague recognition
2	Full recognition

0	Unfamiliar
1	Vague familiarity
2	Full familiarity

0	No confidence
20	
40	
60	
80	
100	Very high confidence

T1 Start Time: End Time:

Smell Number	Did we show you this odour in the teaching block?	How confident are you of your response?	How would you rate the smell intensity?	How would you rate the smell pleasantness?	How well do you recognise the smell?	How familiar is the smell?	What is the name of the smell?	How confident are you of this name?
24								
11								
29								
17								
21								
5								
14								
15								
22								
26								
31								
20								

6	Intolerable
5	Very strong
4	Strong
3	Easily perceptible
2	Weak
1	Very weak
0	Not perceptible

-4	Extremely unpleasant
-3	Moderately unpleasant
-2	Unpleasant
-1	Slightly unpleasant
1	Slightly pleasant
2	Pleasant
3	Moderately pleasant
4	Extremely pleasant

0	Unknown
1	Vague recognition
2	Full recognition

0	Unfamiliar
1	Vague familiarity
2	Full familiarity

0	No confidence
20	
40	
60	
80	
100	Very high confidence

T2 Start Time: End Time:

Smell Number	Did we show you this odour in the teaching block?	How confident are you of your response?	How would you rate the smell intensity?	How would you rate the smell pleasantness?	How well do you recognise the smell?	How familiar is the smell?	What is the name of the smell?	How confident are you of this name?
18								
13								
29								
25								
9								
21								
14								
2								
22								
11								
6								
24								

Appendix I: Mirror Maze Diagram

Appendix J: Participant Information Sheets

Salomons Institute for Applied Psychology
One Meadow Road
Tunbridge Wells
Kent TN1 2YG
www.canterbury.ac.uk/appliedpsychology

Control Participant - Information about the research

Investigating smell memory in individuals with medically unexplained amnesia

Hello. My name is Kari Snell and I am a trainee clinical psychologist at Canterbury Christ Church University. Along with my colleagues, Dr Jerry Burgess (Senior Lecturer and Neuropsychological Lead at the Salomons Institute, jerry.burgess@canterbury.ac.uk) and Dr Philip Ulrich (Lecturer in Psychology, Canterbury Christ Church University, philip.ulrich@canterbury.ac.uk), we would like to invite you to take part in a research study. Before you decide whether to take part, it is important that you understand why the research is being done and what it would involve for you.

Talk to others about the study if you wish.
(Part 1 tells you the purpose of this study and what will happen to you if you take part. Part 2 gives you more detailed information about the conduct of the study).

Part 1 of the Information Sheet

What is the purpose of the study?
Previous research has suggested that memory for smells is unique, often more closely tied to our emotional memories and less likely to be forgotten than the memory for other senses.

The aim of this study is to explore memory for smells in individuals with amnesia, and to compare them to individuals without amnesia.

Why have I been invited?
You have been invited to take part in this research because you meet the matching criteria, this is when individuals in one group are matched to another group based on certain characteristics. In this case these characteristics are sex, age, education level, and smoking status. Your results will be compared to this other group, who are individuals experiencing amnesia.

Do I have to take part?
It is up to you to decide whether to join the study. If you agree to take part, I will then ask you to sign a consent form. You are free to withdraw from the study at any time up until the data analysis has begun, without giving a reason.

What will happen to me if I take part?

If you agree to take part, you will be asked to smell some odours presented to you. You will be asked to name the odour, and to rate its pleasantness and intensity, and to remember the odours for a later time. Your memory for the odours will be tested immediately after they are shown to you, after a short delay, and then on the next day (one day after the first session). These sessions will take place in a suitable venue nearby. Each session should last approximately 1-2 hours.

Please note that your responses when asked to name the odour at each time point of testing will be audio recorded. This audio recording will be carried out by using an encrypted device. The audio recording will be transcribed anonymously (it will not involve identifiable data such as your name) for data analysis.

Expenses and payments
There will be no payment offered for taking part in the research.

What will I be asked to do?
You will be asked to remember, and name 6 odours presented to you. You will be asked to rate each odour for its pleasantness and intensity on questionnaires. You will then be immediately shown some more odours, some will be familiar to you and some will not, and you will be asked if you recognise each odour from the first session and how confident you feel in your response. You will again be asked to name each odour and rate each odour for its pleasantness and intensity on a questionnaire. This process will be repeated after a short delay of approximately 100 minutes, in which time you will complete some other tasks of verbal, visual and procedural memory. On the next day, you will again repeat this process for the final time.

Please note that your responses throughout testing will be audio recorded. This is to enable the researchers to compare your responses over time and to ensure all the researchers are administering the testing consistently across time. This audio recording will be carried out by using an encrypted device. The audio recording will be transcribed anonymously (it will not involve identifiable data such as your name) for data analysis.

What are the possible disadvantages and risks of taking part?
Some of the smells shown to you may be unpleasant and intense and could cause some discomfort.

Some elements of the tasks asked of you could be considered repetitive, and you may find yourself becoming bored or fatigued. Specifically, testing will last around 2 hours on day 1, and approximately 1 hour on day 2. However, breaks will be possible during testing to try to reduce the effects of boredom and fatigue.

What are the possible benefits of taking part?
The information we get from this study may help us to improve the understanding of amnesia and similar difficulties and could help to improve the care of those experiencing these difficulties. This study will not involve any treatment.

What if there is a problem?
Should you have any complaint or concern about the way you have been treated during this study or any possible harm you might suffer will be addressed. Please feel free to raise any such concern with the researcher at any time during the study, or alternatively please speak to the Salomons Research Director; the detailed information on this is given in Part 2.

Will information from or about me from taking part in the study be kept confidential?
Yes. We will follow ethical and legal practice and all information about you will be handled in confidence.

There are some rare situations in which information would have to be shared with others. The details are included in Part 2.

This completes part 1.

If the information in Part 1 has interested you and you are considering participation, please read the additional information in Part 2 before making any decision.

Part 2 of the Information Sheet

What will happen if I don't want to carry on with the study?
You can withdraw from the study up until the data has started to be analysed. After this point, 72 hours after your participation, the data will no longer be able to be identified on an individual level and so it will no longer be possible to withdraw your data. If you choose to withdraw from the study at any point prior to 72 hours after you have participated in the study, all the data you have provided will be removed from the research without any consequence to you. If you would like to withdraw your data from the study, please contact any of the researchers using their contact information below.

What if there is a problem?
Should there be any problems encountered, we encourage you to make a complaint to the lead researcher and/or the Salomons Research Director. Your complaints will be taken very seriously and will be investigated further.

Concerns and Complaints
If you have a concern about any aspect of this study, you should ask to speak to me, and I will do my best to address your concerns. You can contact me by emailing me at: ks788@canterbury.ac.uk and I will get back to you as soon as possible.

If you remain dissatisfied and wish to complain formally, you can do this by contacting Dr Fergal Jones, Clinical Psychology Programme Research Director, Salomons Institute for Applied Psychology – fergal.jones@canterbury.ac.uk

Will information from me or about me taking part in the study be kept confidential?
We will follow ethical and legal practice regarding information about you. The following measures will be taken regarding confidentiality:

- Your data from the study will be collected on a password-protected laptop and encrypted audio recorder.
- Your results will be anonymised and coded using a unique two-letter system. The only document to contain the link between these codes and the true identities of participants will be kept on an encrypted device and only available to the lead researcher.
- Your anonymised data will be stored on a password protected CD-ROM at Salomons Institute for Applied Psychology for 10 years and it will then be destroyed. Only the research team will have access to this anonymised data, however the data from the study may be made available to future research (at which point further ethical approval would be sought from The Salomons Ethics Panel).
- As a research participant, you have the right to check the accuracy of data held about you and to correct any errors.

- Please be aware, should you disclose information that concerns me about your safety or the safety of others around you, I am obliged to break confidentiality to speak to a third party to ensure your/their safety.

What will happen to the results of the research study?
The results of the research study will be written up into a case study and may be published in a scientific journal and on Canterbury Christ Church University's website.

As a participant of the study, you can receive a copy of the results once the write-up is completed. Should you wish to receive a copy of the results, please send me your email address by contacting me at ks788@canterbury.ac.uk You will be informed of when the results have been written up and will be sent a copy of the publication.

The data collected in this study may be used again in other studies at a later time.

Who is sponsoring and funding the research?
This research is being sponsored by Canterbury Christ Church University.

Who has reviewed the study?
This study has been reviewed and given favourable opinion by The Salomons Ethics Panel, Salomons Institute for Applied Psychology, Canterbury Christ Church University. For your references should you wish to enquire further about the approval for this study, the protocol number for this piece of research is ETH2021-0388.

You will be provided with a copy of this information sheet and the consent form, should you agree to participate in the study.

Further information and contact details
If you would like to speak to me and find out more about the study or have questions about it, you can contact me by emailing ks788@canterbury.ac.uk and I will get back to you as soon as possible.

Salomons Institute for Applied Psychology
One Meadow Road,
Tunbridge Wells,
Kent TN1 2YG
www.canterbury.ac.uk/appliedpsychology

Clinical Participant - Information about the research

Investigating smell memory in individuals with medically unexplained amnesia

Hello. My name is Kari Snell and I am a trainee clinical psychologist at Canterbury Christ Church University. Along with my colleagues, Dr Jerry Burgess (Senior Lecturer and Neuropsychological Lead at the Salomons Institute, jerry.burgess@canterbury.ac.uk) and Dr Philip Ulrich (Lecturer in Psychology, Canterbury Christ Church University, philip.ulrich@canterbury.ac.uk), we would like to invite you to take part in a research study. Before you decide whether to take part, it is important that you understand why the research is being done and what it would involve for you.

Talk to others about the study if you wish.
(Part 1 tells you the purpose of this study and what will happen to you if you take part.
Part 2 gives you more detailed information about the conduct of the study).

Part 1 of the Information Sheet

What is the purpose of the study?
Previous research has suggested that memory for smells is unique, often more closely tied to our emotional memories and less likely to be forgotten than the memory for other senses.

The aim of this study is to explore memory for smells in individuals with amnesia, and to compare them to individuals without amnesia.

Why have I been invited?
You have been invited to take part in this research because you have memory difficulties which we wish to investigate further. You are one of two individuals with memory difficulties we wish to explore in this study, and your results will be compared to a group of individuals similar to yourself, but without such difficulties.

Do I have to take part?
It is up to you to decide whether to join the study. If you agree to take part, I will then ask you to sign a consent form. You are free to withdraw from the study at any time up until the data analysis has begun, without giving a reason.

What will happen to me if I take part?
If you agree to take part, you will be asked to smell some odours presented to you. You will be asked to name the odour, and to rate its pleasantness and intensity, and to remember the odours for a later time. Your memory for the odours will be tested immediately after they are shown to you, after a short delay, and then on the next day (one day after the first session). These sessions will take place in your home, or another suitable venue nearby. Each session should last approximately 1-2 hours.

Expenses and payments

There will be no payment offered for taking part in the research.

What will I be asked to do?
You will be asked to remember and name 6 odours presented to you. You will be asked to rate each odour for its pleasantness and intensity on questionnaires. You will then be immediately shown some more odours, some will be familiar to you and some will not, and you will be asked if you recognise each odour from the first session and how confident you feel in your response. You will again be asked to name each odour and rate each odour for its pleasantness and intensity on a questionnaire. This process will be repeated after a short delay of approximately 100 minutes, in which time you will complete some other tasks of verbal, visual and procedural memory. On the next day, you will again repeat this process for the final time.

Please note that your responses throughout testing will be audio recorded. This is to enable the researchers to compare your responses over time and to ensure all the researchers are administering the testing consistently across time. This audio recording will be carried out by using an encrypted device. The audio recording will be transcribed anonymously (it will not involve identifiable data such as your name) for data analysis.

What are the possible disadvantages and risks of taking part?
Some of the smells shown to you may be unpleasant and intense and could cause some discomfort.

Some elements of the tasks asked of you could be considered repetitive, and you may find yourself becoming bored or fatigued. Specifically, testing will last around 2 hours on day 1, and approximately 1 hour on day 2. However, breaks will be possible during testing to try to reduce the effects of boredom and fatigue.

Your results will be written up and likely published in a scientific journal. Although we will take measures to hide your identifiable features (such as removing your name and only using an anonymised code to refer to you), because your difficulties are so unique it may mean that the information published in the journal could still be linked to you.

What are the possible benefits of taking part?
We cannot promise the study will help you, but the information we get from this study may help us to improve the understanding of difficulties similar to yours and may help to improve the care of others experiencing these difficulties. This study will not involve any treatment.

What if there is a problem?
Should you have any complaint or concern about the way you have been treated during this study or any possible harm you might suffer will be addressed. Please feel free to raise any such concern with the researcher at any time during the study, or alternatively please speak to the Salomons Research Director; the detailed information on this is given in Part 2. Your carer/family member will also be involved in the study, supporting the process, and may be able to act on your behalf (as an advocate of any of your concerns) should you so wish.

Will information from or about me from taking part in the study be kept confidential?
Yes. We will follow ethical and legal practice and all information about you will be handled in confidence. The exception to this is that although we will take every effort to disguise your identity, we will be writing about you in some depth, and you may therefore still be recognisable from the information written.

There are some rare situations in which information would have to be shared with others. The details are included in Part 2.

This completes part 1.

If the information in Part 1 has interested you and you are considering participation, please read the additional information in Part 2 before making any decision.

Part 2 of the Information Sheet

What will happen if I don't want to carry on with the study?
You can withdraw from the study up until the data has started to be analysed. After this point, 72 hours after your participation, the data will no longer be able to be identified on an individual level and so it will no longer be possible to withdraw your data. If you choose to withdraw from the study at any point prior to 72 hours after you have participated in the study, all the data you have provided will be removed from the research without any consequence to you. If you would like to withdraw your data from the study, please contact any of the researchers using their contact information below.

What if there is a problem?
Should there be any problems encountered, we encourage you to make a complaint to the lead researcher and/or the Salomons Research Director. Your complaints will be taken very seriously and will be investigated further.

Concerns and Complaints
If you have a concern about any aspect of this study, you should ask to speak to me and I will do my best to address your concerns. You can contact me by emailing me at: ks788@canterbury.ac.uk and I will get back to you as soon as possible.

You can also contact the supervisor of the study, Jerry Burgess (with whom you have a prior relationship) by emailing him at: jerry.burgess@canterbury.ac.uk and he will get back to you as soon as possible.

If you remain dissatisfied and wish to complain formally, you can do this by contacting Dr Fergal Jones, Clinical Psychology Programme Research Director, Salomons Institute for Applied Psychology – fergal.jones@canterbury.ac.uk

Will information from me or about me taking part in the study be kept confidential?
We will follow ethical and legal practice regarding information about you. The following measures will be taken regarding confidentiality:

- Your data from the study will be collected on a password-protected laptop and encrypted audio recorder.
- Your results will be anonymised and coded using a unique two-letter system. The only document to contain the link between these codes and the true identities of participants will be kept on an encrypted device and only available to the lead researcher.
- The exception to the above is that although we will take every effort to disguise your identity, we will be writing about you in some depth, and you may therefore still be recognisable from the information written.
- Your anonymised data will be stored on a password protected CD-ROM at Salomons Institute for Applied Psychology for 10 years and it will then be destroyed. Only the research team will have access to this anonymised data, however the data from the study may be made available to future research (at which point further ethical approval would be sought from The Salomons Ethics Panel).
- As a research participant, you have the right to check the accuracy of data held about you and to correct any errors.

- Please be aware, should you disclose information that concerns me about your safety or the safety of others around you, I am obliged to break confidentiality to speak to a third party to ensure your/their safety.

What will happen to the results of the research study?
The results of the research study will be written up into a case study and may be published in a scientific journal and on Canterbury Christ Church University's website.

As a participant of the study, you can receive a copy of the results once the write-up is completed. Should you wish to receive a copy of the results, please send me your email address by contacting me at ks788@canterbury.ac.uk You will be informed of when the results have been written up and will be sent a copy of the publication.

The data collected in this study may be used again in other studies at a later time.

Who is sponsoring and funding the research?
This research is being sponsored by Canterbury Christ Church University.

Who has reviewed the study?
This study has been reviewed and given favourable opinion by The Salomons Ethics Panel, Salomons Institute for Applied Psychology, Canterbury Christ Church University. For your references should you wish to enquire further about the approval for this study, the protocol number for this piece of research is ETH2021-0388.

You will be provided with a copy of this information sheet and the consent form, should you agree to participate in the study.

Further information and contact details
If you would like to speak to me and find out more about the study or have questions about it, you can contact me by emailing ks788@canterbury.ac.uk and I will get back to you as soon as possible.

Appendix K: Participant Consent Form

Salomons Institute for Applied Psychology

One Meadow Road, Tunbridge Wells, Kent TN1 2YG

Ethics approval number: ETH2021-0388.

Version number: 1
Participant Identification number for this study:

CONSENT FORM

Title of Project: Investigating smell memory in two individuals with medically unexplained amnesia
Name of Researcher: Kari Snell

Please initial in the box

1. I confirm that I have read and understand the information sheet dated..... (version.....) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.	☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time prior to the start of data analysis (72 hours after participation), without giving any reason.	☐
3. I understand that my responses to questions included in the study will be audio recorded on an encrypted device and later transcribed (written-up). I give permission for this audio recording to occur.	☐
4. I understand that relevant sections of my medical notes, as specified in the information sheet, and data collected during the study may be looked at by the lead supervisor, Jerry Burgess. I give permission for these individuals to have access to my data.	☐
5. I agree that anonymous quotes from my interview and other anonymous data may be used in published reports of the study findings.	☐
6. I agree for my anonymous data to be used in further research studies.	☐
7. I agree to take part in the above study.	☐

Name of Participant_____ Date_____

Signature _____

Name of Person taking consent _____ Date_____

Signature _____

Appendix L: Participant Demographics Questionnaire

Canterbury Christ Church University

Salomons Institute for Applied Psychology
One Meadow Road, Tunbridge Wells, Kent TN1 2YG

www.canterbury.ac.uk/appliedpsychology

Investigating smell memory in individuals with medically unexplained amnesia

Demographic Questionnaire

Please complete the below information, which will be used to ensure your characteristics match those of the participants in the clinical group with amnesia, to allow us to compare your data. We will not use this information to identify you the study write up, this information will be anonymised.

Your date of birth:	
Your gender (please circle):	Male Female Non-Binary Other (please specify): ……
What is the highest level of education that you have achieved? (please circle)	No Formal Education Secondary School College / Sixth Form / Work-Based Apprenticeship University Undergraduate University Postgraduate

Employment status (please circle):	Employed Full-Time Employed Part-Time Unemployed Student Retired Other (please state) ……...
What is your current occupation?	…… ……
What is your smoking status? (please circle)	Non-Smoker Ex-Smoker Smoker
Do you have a sense of smell? (please circle)	Yes / No
Have you had COVID-19 within the past 3 months? (please circle)	Yes / No
Do you have any untreated illnesses currently resulting in a congested nose? (please circle)	Yes / No **Please provide more details if you answered 'Yes' to having an untreated illness resulting in a congested nose**: …… ……

Do you have a diagnosed memory condition? (please circle)	Yes / No **If you answered 'yes' to having a diagnosed memory condition, please name the memory condition here:** …… ……
Do you have any known allergies? (please circle)	Yes / No **If you answered 'Yes' to having allergies, please provide more details about what you are allergic to:** …… ……

Appendix M: Participant Debrief Sheet

Salomons Institute for Applied Psychology
1 Meadow Road
Tunbridge Wells
Kent
TN1 2YG
www.canterbury.ac.uk/appliedpsychology

Debrief Sheet

Investigating smell memory in individuals with medically unexplained amnesia

Thank you for taking the time to participate in this study.

Previous research has suggested that memory for smells is unique, often more closely tied to our emotional memories and less likely to be forgotten than the memory for other senses.

The aim of this study was to explore memory for smells in individuals with amnesia, and to compare them to individuals without amnesia.

What should I do now?

You are not required to do anything further as part of this study. We would like to thank you for your involvement. Your input in this study will hopefully further the scientific understanding of amnesia and olfactory (smell) memory.

What if I would like a copy of the results?

If you would like to receive a copy of the study's collective results please contact the lead researcher, Kari Snell (ks788@canterbury.ac.uk), and provide your email address.

What will happen if I don't want to carry on with the study?

You can withdraw from the study up until the data has started to be analysed. After this point, 72 hours after your participation, the data will no longer be able to be identified on an individual level and so it will no longer be possible to withdraw your data. If you choose to withdraw from the study at any point prior to 72 hours after you have participated in the study, all the data you have provided will be removed from the research without any consequence to you. If you would like to withdraw your data from the study, please contact any of the researchers using their contact information below.

Queries or concerns

If you have any queries or concern about any aspect of this study, please contact the lead researcher (Kari Snell) or any other member of the research team using the contact details at the bottom of the debrief sheet. We will get back to you as soon as possible.

Although we hope that participating in this study has not resulted in any negative effects for you, should you think or feel you have experienced any negative outcomes and wish to discuss those further please contact any of the study's researchers using the contact information below or utilise the sources of further support detailed below.

Further support available to you

- Your GP, who will be able to offer you a range of support including possible referral or signposting for self-referral to your local Improving Access to Psychological Therapies (IAPT) service (who provide therapies for people experiencing difficulties with mental health conditions such as low mood or anxiety).
- British Association for Behavioural and Cognitive Psychotherapies (BABCP), where you can find information about accessing a private Psychotherapist: www.babcp.com
- British Association for Counselling and Psychotherapy (BACP), where you can find information about accessing a private Counsellor: www.bacp.co.uk/search/Therapists
- Mind, a mental health charity providing various forms of support for anyone experiencing mental health difficulties, visit: www.mind.org.uk or call the Mind Infoline (available Monday-Friday, 09:00 – 18:00): 0300 123 3393

Contacts

Miss Kari Snell (Trainee Clinical Psychologist at the Salomons Institute and lead researcher) ks788@canterbury.ac.uk

Dr Jerry Burgess (Senior Lecturer and Neuropsychology Lead at the Salomons Institute) jerry.burgess@canterbury.ac.uk

Dr Philip Ulrich (Lecturer in Psychology, Canterbury Christ Church University) philip.ulrich@canterbury.ac.uk

Thank you again for your participation

Appendix N: Ethical Approval

This has been removed from the electronic copy.

Appendix O: Family Member Information Sheet

Salomons Institute for Applied Psychology
One Meadow Road
Tunbridge Wells
Kent TN1 2YG
www.canterbury.ac.uk/appliedpsychology

Family Member - Information about the research

Investigating smell memory in individuals with medically unexplained amnesia

Hello. My name is Kari Snell and I am a trainee clinical psychologist at Canterbury Christ Church University. Along with my colleagues, Dr Jerry Burgess (Senior Lecturer and Neuropsychological Lead at the Salomons Institute, jerry.burgess@canterbury.ac.uk) and Dr Philip Ulrich (Lecturer in Psychology, Canterbury Christ Church University, philip.ulrich@canterbury.ac.uk), we would like to invite you to take part in a research study. Before you decide whether to take part, it is important that you understand why the research is being done and what it would involve for you.

Talk to others about the study if you wish.
(Part 1 tells you the purpose of this study and what will happen to you if you take part. Part 2 gives you more detailed information about the conduct of the study).

Part 1 of the Information Sheet

What is the purpose of the study?
Previous research has suggested that memory for smells is unique, often more closely tied to our emotional memories and less likely to be forgotten than the memory for other senses.

The aim of this study is to explore memory for smells in individuals with amnesia, and to compare them to individuals without amnesia.

Why have I been invited?
As a carer/family member of someone with amnesia (a clinical participant) who may participate in this research, we would like to invite you to consult with us on the research to ensure its appropriateness and comfortableness for your significant other.

Do I have to take part?
It is up to you to decide whether to join the study. If you agree to take part, I will then ask you to sign a consent form. You are free to withdraw from the study at any time up until the data analysis has begun, without giving a reason.

What will happen to me if I take part?

If you agree to take part, you will be asked to comment on the appropriateness and feasibility of the research. You will be asked to support the clinical participant in their participation of the research.

Expenses and payments
There will be no payment offered for taking part in the research.

What will I be asked to do?
You will be asked to comment on the appropriateness and feasibility of the research. You will be asked to support the clinical participant in their participation of the research. You will be asked some informal questions about your significant other, relevant to the testing and their presentation.

Your significant other's responses throughout testing will be audio recorded. If you are in the room during testing, please be aware that anything you say during that time will also be recorded on the encrypted device. Your significant other's responses are being audio recorded to enable researchers to document exactly what words they select to describe the odour, to compare their responses over time. The audio recording will be transcribed anonymously (it will not involve identifiable data such as your or your significant other's name) for data analysis.

What are the possible disadvantages and risks of taking part?
Some of the smells shown in the testing may cause some discomfort to your significant other and you.

You may find some of the elements of the tasks repetitive and may become bored or fatigued. Specifically, testing will last around 2 hours on day 1, and approximately 1 hour on day 2. However, breaks will be possible during testing to try to reduce the effects of boredom and fatigue on both your significant other and you.

What are the possible benefits of taking part?
The information we get from this study may help us to improve the understanding of amnesia and similar difficulties and could help to improve the care of those experiencing these difficulties. This study will not involve any treatment.

What if there is a problem?
Should you have any complaint or concern about the way you or your significant other have been treated during this study or any possible harm you or they might suffer will be addressed. You will be asked to advocate on the behalf of your significant other, supporting them through testing and raising their concerns if they are unable to themselves. Please feel free to raise any such concern with the researcher at any time during the study, or alternatively please speak to the Salomons Research Director; the detailed information on this is given in Part 2.

Will information from or about me from taking part in the study be kept confidential?
Yes. We will follow ethical and legal practice and all information about you will be handled in confidence.

There are some rare situations in which information would have to be shared with others. The details are included in Part 2.

This completes part 1.
If the information in Part 1 has interested you and you are considering participation, please read the additional information in Part 2 before making any decision.

Part 2 of the Information Sheet

What will happen if I don't want to carry on with the study?
You can withdraw from the study up until the data has started to be analysed. After this point, 72 hours after your participation, the data will no longer be able to be identified on an individual level and so it will no longer be possible to withdraw your data. If you choose to withdraw from the study at any point prior to 72 hours after you have participated in the study, all the data you have provided will be removed from the research without any consequence to you. If you would like to withdraw your data from the study, please contact any of the researchers using their contact information below.

What if there is a problem?
Should there be any problems encountered, we encourage you to make a complaint to the lead researcher and/or the Salomons Research Director. Your complaints will be taken very seriously and will be investigated further.

Concerns and Complaints
If you have a concern about any aspect of this study, you should ask to speak to me, and I will do my best to address your concerns. You can contact me by emailing me at: ks788@canterbury.ac.uk and I will get back to you as soon as possible.

You can also contact the supervisor of the study, Jerry Burgess (with whom you have a prior relationship) by emailing him at: jerry.burgess@canterbury.ac.uk and he will get back to you as soon as possible.

If you remain dissatisfied and wish to complain formally, you can do this by contacting Dr Fergal Jones, Clinical Psychology Programme Research Director, Salomons Institute for Applied Psychology – fergal.jones@canterbury.ac.uk

Will information from me or about me taking part in the study be kept confidential?
We will follow ethical and legal practice regarding information about you. The following measures will be taken regarding confidentiality:

- Study data will be collected on a password-protected laptop and encrypted audio recorder.
- Your contributions to the study will be anonymised and coded. The only document to contain the link between these codes and the true identities of participants/family members will be kept on an encrypted device and only available to the lead researcher.
- Your anonymised data will be stored on a password protected CD-ROM at Salomons Institute for Applied Psychology for 10 years and it will then be destroyed. Only the research team will have access to this anonymised data, however the data from the study may be made available to future research (at which point further ethical approval would be sought from The Salomons Ethics Panel).
- As a family member supporting this study you are considered to be a research participant, and as such you have the right to check the accuracy of data held about you and to correct any errors.
- Please be aware, should you disclose information that concerns me about your safety or the safety of others around you, I am obliged to break confidentiality to speak to a third party to ensure your/their safety.

What will happen to the results of the research study?
The results of the research study will be written up into a case study and may be published in a scientific journal and on Canterbury Christ Church University's website.

As a participant of the study, you can receive a copy of the results once the write-up is completed. Should you wish to receive a copy of the results, please send me your email address by contacting me at ks788@canterbury.ac.uk You will be informed of when the results have been written up and will be sent a copy of the publication.

The data collected in this study may be used again in other studies at a later time.

Who is sponsoring and funding the research?
This research is being sponsored by Canterbury Christ Church University.

Who has reviewed the study?
This study has been reviewed and given favourable opinion by The Salomons Ethics Panel, Salomons Institute for Applied Psychology, Canterbury Christ Church University. For your references should you wish to enquire further about the approval for this study, the protocol number for this piece of research is ETH2021-0388.

You will be provided with a copy of this information sheet and the consent form, should you agree to participate in the study.

Further information and contact details
If you would like to speak to me and find out more about the study or have questions about it, you can contact me by emailing ks788@canterbury.ac.uk and I will get back to you as soon as possible.

Appendix P: Tests of Parametric Assumptions in SPSS

Hypothesis 1: Olfactory Recognition Memory Scores

Descriptives

			Statistic	Std. Error
Hits	Mean		4.25	.366
	95% Confidence Interval for Mean	Lower Bound	3.38	
		Upper Bound	5.12	
	5% Trimmed Mean		4.22	
	Median		4.00	
	Variance		1.071	
	Std. Deviation		1.035	
	Minimum		3	
	Maximum		6	
	Range		3	
	Interquartile Range		2	
	Skewness		.386	.752
	Kurtosis		-.448	1.481
T1_Hits	Mean		5.00	.463
	95% Confidence Interval for Mean	Lower Bound	3.91	
		Upper Bound	6.09	
	5% Trimmed Mean		5.06	
	Median		5.50	
	Variance		1.714	
	Std. Deviation		1.309	
	Minimum		3	
	Maximum		6	
	Range		3	
	Interquartile Range		3	
	Skewness		-1.018	.752
	Kurtosis		-.700	1.481
T2_Hits	Mean		4.75	.559
	95% Confidence Interval for Mean	Lower Bound	3.43	

	Upper Bound	6.07	
	5% Trimmed Mean	4.83	
	Median	5.50	
	Variance	2.500	
	Std. Deviation	1.581	
	Minimum	2	
	Maximum	6	
	Range	4	
	Interquartile Range	3	
	Skewness	-.904	.752
	Kurtosis	-.695	1.481

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Hits	.220	8	.200*	.917	8	.408
T1_Hits	.277	8	.070	.748	8	.008
T2_Hits	.285	8	.054	.815	8	.041

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Descriptives

			Statistic	Std. Error
False Alarms	Mean		1.00	.327
	95% Confidence Interval for Mean	Lower Bound	.23	
		Upper Bound	1.77	
	5% Trimmed Mean		1.00	
	Median		1.00	
	Variance		.857	
	Std. Deviation		.926	
	Minimum		0	
	Maximum		2	
	Range		2	
	Interquartile Range		2	
	Skewness		.000	.752
	Kurtosis		-2.100	1.481

T1_False_Alarms	Mean		2.13	.515
	95% Confidence Interval for Mean	Lower Bound	.91	
		Upper Bound	3.34	
	5% Trimmed Mean		2.08	
	Median		2.00	
	Variance		2.125	
	Std. Deviation		1.458	
	Minimum		0	
	Maximum		5	
	Range		5	
	Interquartile Range		2	
	Skewness		.824	.752
	Kurtosis		2.002	1.481
T2_False_Alarms	Mean		2.13	.398
	95% Confidence Interval for Mean	Lower Bound	1.18	
		Upper Bound	3.07	
	5% Trimmed Mean		2.08	
	Median		2.00	
	Variance		1.268	
	Std. Deviation		1.126	
	Minimum		1	
	Maximum		4	
	Range		3	
	Interquartile Range		2	
	Skewness		.488	.752
	Kurtosis		-.989	1.481

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
False Alarms	.235	8	.200*	.802	8	.030
T1_False_Alarms	.284	8	.056	.900	8	.286
T2_False_Alarms	.216	8	.200*	.882	8	.197

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Descriptives

			Statistic	Std. Error
Misses	Mean		1.75	.366
	95% Confidence Interval for Mean	Lower Bound	.88	
		Upper Bound	2.62	
	5% Trimmed Mean		1.78	
	Median		2.00	
	Variance		1.071	
	Std. Deviation		1.035	
	Minimum		0	
	Maximum		3	
	Range		3	
	Interquartile Range		2	
	Skewness		-.386	.752
	Kurtosis		-.448	1.481
T1_Misses	Mean		1.00	.463
	95% Confidence Interval for Mean	Lower Bound	-.09	
		Upper Bound	2.09	
	5% Trimmed Mean		.94	
	Median		.50	
	Variance		1.714	
	Std. Deviation		1.309	
	Minimum		0	
	Maximum		3	
	Range		3	
	Interquartile Range		3	
	Skewness		1.018	.752
	Kurtosis		-.700	1.481
T2_Misses	Mean		1.25	.559
	95% Confidence Interval for Mean	Lower Bound	-.07	
		Upper Bound	2.57	
	5% Trimmed Mean		1.17	

	Median	.50	
	Variance	2.500	
	Std. Deviation	1.581	
	Minimum	0	
	Maximum	4	
	Range	4	
	Interquartile Range	3	
	Skewness	.904	.752
	Kurtosis	-.695	1.481

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Misses	.220	8	.200*	.917	8	.408
T1_Misses	.277	8	.070	.748	8	.008
T2_Misses	.285	8	.054	.815	8	.041

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Descriptives

			Statistic	Std. Error
Correct Rejections	Mean		5.00	.327
	95% Confidence Interval for Mean	Lower Bound	4.23	
		Upper Bound	5.77	
	5% Trimmed Mean		5.00	
	Median		5.00	
	Variance		.857	
	Std. Deviation		.926	
	Minimum		4	
	Maximum		6	
	Range		2	
	Interquartile Range		2	
	Skewness		.000	.752
	Kurtosis		-2.100	1.481
T1_Correct_Rejections	Mean		3.88	.515
	95% Confidence Interval for Mean	Lower Bound	2.66	

		Upper Bound	5.09	
	5% Trimmed Mean		3.92	
	Median		4.00	
	Variance		2.125	
	Std. Deviation		1.458	
	Minimum		1	
	Maximum		6	
	Range		5	
	Interquartile Range		2	
	Skewness		-.824	.752
	Kurtosis		2.002	1.481
T2_Correct_Rejections	Mean		3.88	.398
	95% Confidence Interval for Mean	Lower Bound	2.93	
		Upper Bound	4.82	
	5% Trimmed Mean		3.92	
	Median		4.00	
	Variance		1.268	
	Std. Deviation		1.126	
	Minimum		2	
	Maximum		5	
	Range		3	
	Interquartile Range		2	
	Skewness		-.488	.752
	Kurtosis		-.989	1.481

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Correct Rejections	.235	8	.200*	.802	8	.030
T1_Correct_Rejections	.284	8	.056	.900	8	.286
T2_Correct_Rejections	.216	8	.200*	.882	8	.197

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Hypothesis 2: Odour Quality Ratings

Descriptives

	Intensity_Rating			Statistic	Std. Error
Hit_M_FA_CR	Very Weak	Mean		.2500	.25000
		95% Confidence Interval for Mean	Lower Bound	-.5456	
			Upper Bound	1.0456	
		5% Trimmed Mean		.2222	
		Median		.0000	
		Variance		.250	
		Std. Deviation		.50000	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		.75	
		Skewness		2.000	1.014
		Kurtosis		4.000	2.619
	Weak	Mean		.6667	.14213
		95% Confidence Interval for Mean	Lower Bound	.3538	
			Upper Bound	.9795	
		5% Trimmed Mean		.6852	
		Median		1.0000	
		Variance		.242	
		Std. Deviation		.49237	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		1.00	
		Skewness		-.812	.637
		Kurtosis		-1.650	1.232
	Easily Perceptible	Mean		.9167	.08333
		95% Confidence Interval for Mean	Lower Bound	.7333	
			Upper Bound	1.1001	
		5% Trimmed Mean		.9630	

		Median		1.0000	
		Variance		.083	
		Std. Deviation		.28868	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		.00	
		Skewness		-3.464	.637
		Kurtosis		12.000	1.232
	Strong	Mean		.8507	.04386
		95% Confidence Interval for Mean	Lower Bound	.7632	
			Upper Bound	.9383	
		5% Trimmed Mean		.8897	
		Median		1.0000	
		Variance		.129	
		Std. Deviation		.35903	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		.00	
		Skewness		-2.014	.293
		Kurtosis		2.119	.578
	Very Strong	Mean		.7143	.07055
		95% Confidence Interval for Mean	Lower Bound	.5718	
			Upper Bound	.8568	
		5% Trimmed Mean		.7381	
		Median		1.0000	
		Variance		.209	
		Std. Deviation		.45723	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		1.00	
		Skewness		-.984	.365
		Kurtosis		-1.085	.717
	Intolerable	Mean		.7143	.18443

	95% Confidence Interval for Mean	Lower Bound	.2630	
		Upper Bound	1.1656	
	5% Trimmed Mean		.7381	
	Median		1.0000	
	Variance		.238	
	Std. Deviation		.48795	
	Minimum		.00	
	Maximum		1.00	
	Range		1.00	
	Interquartile Range		1.00	
	Skewness		-1.230	.794
	Kurtosis		-.840	1.587

Tests of Normality

	Intensity_Rating	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Hit_M_FA_CR	Very Weak	.441	4	.	.630	4	.001
	Weak	.417	12	<.001	.608	12	<.001
	Easily Perceptible	.530	12	<.001	.327	12	<.001
	Strong	.512	67	<.001	.426	67	<.001
	Very Strong	.448	42	<.001	.567	42	<.001
	Intolerable	.435	7	<.001	.600	7	<.001

a. Lilliefors Significance Correction

Descriptives

	Pleasantness_Recoded			Statistic	Std. Error
Hit_M_FA_CR	Extremely Unpleasant	Mean		.7778	.10083
		95% Confidence Interval for Mean	Lower Bound	.5650	
			Upper Bound	.9905	
		5% Trimmed Mean		.8086	
		Median		1.0000	
		Variance		.183	

		Std. Deviation		.42779	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		.25	
		Skewness		-1.461	.536
		Kurtosis		.137	1.038
	Moderately Unpleasant	Mean		.6552	.08983
		95% Confidence Interval for Mean	Lower Bound	.4712	
			Upper Bound	.8392	
		5% Trimmed Mean		.6724	
		Median		1.0000	
		Variance		.234	
		Std. Deviation		.48373	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		1.00	
		Skewness		-.689	.434
		Kurtosis		-1.644	.845
	Unpleasant	Mean		.8519	.04880
		95% Confidence Interval for Mean	Lower Bound	.7540	
			Upper Bound	.9497	
		5% Trimmed Mean		.8909	
		Median		1.0000	
		Variance		.129	
		Std. Deviation		.35858	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		.00	
		Skewness		-2.038	.325
		Kurtosis		2.235	.639
	Slightly Unpleasant	Mean		.7750	.06687
		95% Confidence Interval for Mean	Lower Bound	.6397	

			Upper Bound	.9103	
		5% Trimmed Mean		.8056	
		Median		1.0000	
		Variance		.179	
		Std. Deviation		.42290	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		.00	
		Skewness		-1.369	.374
		Kurtosis		-.135	.733
	Slightly Pleasant	Mean		.6667	.33333
		95% Confidence Interval for Mean	Lower Bound	-.7676	
			Upper Bound	2.1009	
		5% Trimmed Mean		.	
		Median		1.0000	
		Variance		.333	
		Std. Deviation		.57735	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		.	
		Skewness		-1.732	1.225
		Kurtosis		.	.

Tests of Normality

	Pleasantness_Recoded	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Hit_M_FA_CR	Extremely Unpleasant	.476	18	<.001	.520	18	<.001
	Moderately Unpleasant	.417	29	<.001	.602	29	<.001
	Unpleasant	.512	54	<.001	.424	54	<.001
	Slightly Unpleasant	.478	40	<.001	.517	40	<.001
	Slightly Pleasant	.385	3	.	.750	3	<.001

a. Lilliefors Significance Correction

Descriptives

	Recognition_Rating			Statistic	Std. Error
Hit_M_FA_CR	No recognition	Mean		.7143	.06091
		95% Confidence Interval for Mean	Lower Bound	.5922	
			Upper Bound	.8364	
		5% Trimmed Mean		.7381	
		Median		1.0000	
		Variance		.208	
		Std. Deviation		.45584	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		1.00	
		Skewness		-.975	.319
		Kurtosis		-1.090	.628
	Vague Recognition	Mean		.7797	.05442
		95% Confidence Interval for Mean	Lower Bound	.6707	
			Upper Bound	.8886	
		5% Trimmed Mean		.8107	
		Median		1.0000	
		Variance		.175	
		Std. Deviation		.41803	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		.00	
		Skewness		-1.385	.311
		Kurtosis		-.086	.613
	Full Recognition	Mean		.8966	.05755
		95% Confidence Interval for Mean	Lower Bound	.7787	
			Upper Bound	1.0144	
		5% Trimmed Mean		.9406	
		Median		1.0000	
		Variance		.096	

		Std. Deviation	.30993	
		Minimum	.00	
		Maximum	1.00	
		Range	1.00	
		Interquartile Range	.00	
		Skewness	-2.748	.434
		Kurtosis	5.961	.845

Tests of Normality

	Recognition_Rating	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Hit_M_FA_CR	No recognition	.449	56	<.001	.566	56	<.001
	Vague Recognition	.481	59	<.001	.511	59	<.001
	Full Recognition	.527	29	<.001	.354	29	<.001

a. Lilliefors Significance Correction

Descriptives

	Fam_Rating			Statistic	Std. Error
Hit_M_FA_CR	No familiarity	Mean		.7091	.06181
		95% Confidence Interval for Mean	Lower Bound	.5852	
			Upper Bound	.8330	
		5% Trimmed Mean		.7323	
		Median		1.0000	
		Variance		.210	
		Std. Deviation		.45837	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		1.00	
		Skewness		-.947	.322
		Kurtosis		-1.147	.634
	Vague familiarity	Mean		.7833	.05363
		95% Confidence Interval for Mean	Lower Bound	.6760	

			Upper Bound	.8907	
		5% Trimmed Mean		.8148	
		Median		1.0000	
		Variance		.173	
		Std. Deviation		.41545	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		.00	
		Skewness		-1.411	.309
		Kurtosis		-.011	.608
	Full familiarity	Mean		.8966	.05755
		95% Confidence Interval for Mean	Lower Bound	.7787	
			Upper Bound	1.0144	
		5% Trimmed Mean		.9406	
		Median		1.0000	
		Variance		.096	
		Std. Deviation		.30993	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		.00	
		Skewness		-2.748	.434
		Kurtosis		5.961	.845

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Fam_Rating	Statistic	df	Sig.	Statistic	df	Sig.
Hit_M_FA_CR	No familiarity	.446	55	<.001	.570	55	<.001
	Vague familiarity	.482	60	<.001	.508	60	<.001
	Full familiarity	.527	29	<.001	.354	29	<.001

a. Lilliefors Significance Correction

Hypothesis 3: Naming Associations

Descriptives

	Association			Statistic	Std. Error
T0_hits	No Association	Mean		3.7500	.61962
		95% Confidence Interval for Mean	Lower Bound	2.2848	
			Upper Bound	5.2152	
		5% Trimmed Mean		3.7778	
		Median		4.0000	
		Variance		3.071	
		Std. Deviation		1.75255	
		Minimum		1.00	
		Maximum		6.00	
		Range		5.00	
		Interquartile Range		2.75	
		Skewness		-.345	.752
		Kurtosis		-1.260	1.481
	Single Association	Mean		.0000	.00000
		95% Confidence Interval for Mean	Lower Bound	.0000	
			Upper Bound	.0000	
		5% Trimmed Mean		.0000	
		Median		.0000	
		Variance		.000	
		Std. Deviation		.00000	
		Minimum		.00	
		Maximum		.00	
		Range		.00	
		Interquartile Range		.00	
		Skewness		.	.
		Kurtosis		.	.
	Consistent Association	Mean		.3750	.18298
		95% Confidence Interval for Mean	Lower Bound	-.0577	
			Upper Bound	.8077	
		5% Trimmed Mean		.3611	

		Median		.0000	
		Variance		.268	
		Std. Deviation		.51755	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		1.00	
		Skewness		.644	.752
		Kurtosis		-2.240	1.481
	Inconsistent Association	Mean		.2500	.16366
		95% Confidence Interval for Mean	Lower Bound	-.1370	
			Upper Bound	.6370	
		5% Trimmed Mean		.2222	
		Median		.0000	
		Variance		.214	
		Std. Deviation		.46291	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		.75	
		Skewness		1.440	.752
		Kurtosis		.000	1.481
T0_misses	No Association	Mean		1.2500	.36596
		95% Confidence Interval for Mean	Lower Bound	.3846	
			Upper Bound	2.1154	
		5% Trimmed Mean		1.2222	
		Median		1.0000	
		Variance		1.071	
		Std. Deviation		1.03510	
		Minimum		.00	
		Maximum		3.00	
		Range		3.00	
		Interquartile Range		1.75	
		Skewness		.386	.752
		Kurtosis		-.448	1.481
	Single Association	Mean		.1250	.12500

		95% Confidence Interval for Mean	Lower Bound	-.1706	
			Upper Bound	.4206	
		5% Trimmed Mean		.0833	
		Median		.0000	
		Variance		.125	
		Std. Deviation		.35355	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		.00	
		Skewness		2.828	.752
		Kurtosis		8.000	1.481
	Consistent Association	Mean		.0000	.00000
		95% Confidence Interval for Mean	Lower Bound	.0000	
			Upper Bound	.0000	
		5% Trimmed Mean		.0000	
		Median		.0000	
		Variance		.000	
		Std. Deviation		.00000	
		Minimum		.00	
		Maximum		.00	
		Range		.00	
		Interquartile Range		.00	
		Skewness		.	.
		Kurtosis		.	.
	Inconsistent Association	Mean		.2500	.25000
		95% Confidence Interval for Mean	Lower Bound	-.3412	
			Upper Bound	.8412	
		5% Trimmed Mean		.1667	
		Median		.0000	
		Variance		.500	
		Std. Deviation		.70711	
		Minimum		.00	
		Maximum		2.00	
		Range		2.00	

		Interquartile Range		.00	
		Skewness		2.828	.752
		Kurtosis		8.000	1.481
T0_total	No Association	Mean		5.0000	.50000
		95% Confidence Interval for Mean	Lower Bound	3.8177	
			Upper Bound	6.1823	
		5% Trimmed Mean		5.1111	
		Median		5.5000	
		Variance		2.000	
		Std. Deviation		1.41421	
		Minimum		2.00	
		Maximum		6.00	
		Range		4.00	
		Interquartile Range		1.75	
		Skewness		-1.616	.752
		Kurtosis		2.471	1.481
	Single Association	Mean		.1250	.12500
		95% Confidence Interval for Mean	Lower Bound	-.1706	
			Upper Bound	.4206	
		5% Trimmed Mean		.0833	
		Median		.0000	
		Variance		.125	
		Std. Deviation		.35355	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		.00	
		Skewness		2.828	.752
		Kurtosis		8.000	1.481
	Consistent Association	Mean		.3750	.18298
		95% Confidence Interval for Mean	Lower Bound	-.0577	
			Upper Bound	.8077	
		5% Trimmed Mean		.3611	
		Median		.0000	
		Variance		.268	

		Std. Deviation		.51755	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		1.00	
		Skewness		.644	.752
		Kurtosis		-2.240	1.481
	Inconsistent Association	Mean		.5000	.37796
		95% Confidence Interval for Mean	Lower Bound	-.3937	
			Upper Bound	1.3937	
		5% Trimmed Mean		.3889	
		Median		.0000	
		Variance		1.143	
		Std. Deviation		1.06904	
		Minimum		.00	
		Maximum		3.00	
		Range		3.00	
		Interquartile Range		.75	
		Skewness		2.339	.752
		Kurtosis		5.469	1.481
T1_hits	No Association	Mean		3.6250	.77776
		95% Confidence Interval for Mean	Lower Bound	1.7859	
			Upper Bound	5.4641	
		5% Trimmed Mean		3.6944	
		Median		4.0000	
		Variance		4.839	
		Std. Deviation		2.19984	
		Minimum		.00	
		Maximum		6.00	
		Range		6.00	
		Interquartile Range		3.75	
		Skewness		-.438	.752
		Kurtosis		-1.129	1.481
	Single Association	Mean		.3750	.18298
		95% Confidence Interval for Mean	Lower Bound	-.0577	

			Upper Bound	.8077	
		5% Trimmed Mean		.3611	
		Median		.0000	
		Variance		.268	
		Std. Deviation		.51755	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		1.00	
		Skewness		.644	.752
		Kurtosis		-2.240	1.481
	Consistent Association	Mean		.6250	.37500
		95% Confidence Interval for Mean	Lower Bound	-.2617	
			Upper Bound	1.5117	
		5% Trimmed Mean		.5278	
		Median		.0000	
		Variance		1.125	
		Std. Deviation		1.06066	
		Minimum		.00	
		Maximum		3.00	
		Range		3.00	
		Interquartile Range		1.00	
		Skewness		1.960	.752
		Kurtosis		3.937	1.481
	Inconsistent Association	Mean		.2500	.16366
		95% Confidence Interval for Mean	Lower Bound	-.1370	
			Upper Bound	.6370	
		5% Trimmed Mean		.2222	
		Median		.0000	
		Variance		.214	
		Std. Deviation		.46291	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		.75	
		Skewness		1.440	.752

		Kurtosis		.000	1.481
T1_misses	No Association	Mean		.7500	.52610
		95% Confidence Interval for Mean	Lower Bound	-.4940	
			Upper Bound	1.9940	
		5% Trimmed Mean		.6111	
		Median		.0000	
		Variance		2.214	
		Std. Deviation		1.48805	
		Minimum		.00	
		Maximum		4.00	
		Range		4.00	
		Interquartile Range		1.50	
		Skewness		1.951	.752
		Kurtosis		3.205	1.481
	Single Association	Mean		.1250	.12500
		95% Confidence Interval for Mean	Lower Bound	-.1706	
			Upper Bound	.4206	
		5% Trimmed Mean		.0833	
		Median		.0000	
		Variance		.125	
		Std. Deviation		.35355	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		.00	
		Skewness		2.828	.752
		Kurtosis		8.000	1.481
	Consistent Association	Mean		.1250	.12500
		95% Confidence Interval for Mean	Lower Bound	-.1706	
			Upper Bound	.4206	
		5% Trimmed Mean		.0833	
		Median		.0000	
		Variance		.125	
		Std. Deviation		.35355	
		Minimum		.00	

		Maximum		1.00	
		Range		1.00	
		Interquartile Range		.00	
		Skewness		2.828	.752
		Kurtosis		8.000	1.481
	Inconsistent Association	Mean		.1250	.12500
		95% Confidence Interval for Mean	Lower Bound	-.1706	
			Upper Bound	.4206	
		5% Trimmed Mean		.0833	
		Median		.0000	
		Variance		.125	
		Std. Deviation		.35355	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		.00	
		Skewness		2.828	.752
		Kurtosis		8.000	1.481
T1_total	No Association	Mean		4.3750	.73040
		95% Confidence Interval for Mean	Lower Bound	2.6479	
			Upper Bound	6.1021	
		5% Trimmed Mean		4.5278	
		Median		5.0000	
		Variance		4.268	
		Std. Deviation		2.06588	
		Minimum		.00	
		Maximum		6.00	
		Range		6.00	
		Interquartile Range		2.75	
		Skewness		-1.578	.752
		Kurtosis		2.463	1.481
	Single Association	Mean		.5000	.26726
		95% Confidence Interval for Mean	Lower Bound	-.1320	
			Upper Bound	1.1320	
		5% Trimmed Mean		.4444	

		Median		.0000	
		Variance		.571	
		Std. Deviation		.75593	
		Minimum		.00	
		Maximum		2.00	
		Range		2.00	
		Interquartile Range		1.00	
		Skewness		1.323	.752
		Kurtosis		.875	1.481
	Consistent Association	Mean		.7500	.49099
		95% Confidence Interval for Mean	Lower Bound	-.4110	
			Upper Bound	1.9110	
		5% Trimmed Mean		.6111	
		Median		.0000	
		Variance		1.929	
		Std. Deviation		1.38873	
		Minimum		.00	
		Maximum		4.00	
		Range		4.00	
		Interquartile Range		1.00	
		Skewness		2.294	.752
		Kurtosis		5.531	1.481
	Inconsistent Association	Mean		.3750	.18298
		95% Confidence Interval for Mean	Lower Bound	-.0577	
			Upper Bound	.8077	
		5% Trimmed Mean		.3611	
		Median		.0000	
		Variance		.268	
		Std. Deviation		.51755	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		1.00	
		Skewness		.644	.752
		Kurtosis		-2.240	1.481
T2_hits	No Association	Mean		3.1250	.76619

		95% Confidence Interval for Mean	Lower Bound	1.3132	
			Upper Bound	4.9368	
		5% Trimmed Mean		3.1389	
		Median		3.5000	
		Variance		4.696	
		Std. Deviation		2.16712	
		Minimum		.00	
		Maximum		6.00	
		Range		6.00	
		Interquartile Range		4.00	
		Skewness		-.549	.752
		Kurtosis		-.663	1.481
	Single Association	Mean		.3750	.26305
		95% Confidence Interval for Mean	Lower Bound	-.2470	
			Upper Bound	.9970	
		5% Trimmed Mean		.3056	
		Median		.0000	
		Variance		.554	
		Std. Deviation		.74402	
		Minimum		.00	
		Maximum		2.00	
		Range		2.00	
		Interquartile Range		.75	
		Skewness		1.951	.752
		Kurtosis		3.205	1.481
	Consistent Association	Mean		1.0000	.59761
		95% Confidence Interval for Mean	Lower Bound	-.4131	
			Upper Bound	2.4131	
		5% Trimmed Mean		.8333	
		Median		.5000	
		Variance		2.857	
		Std. Deviation		1.69031	
		Minimum		.00	
		Maximum		5.00	
		Range		5.00	

		Interquartile Range		1.00	
		Skewness		2.366	.752
		Kurtosis		6.020	1.481
	Inconsistent Association	Mean		.2500	.16366
		95% Confidence Interval for Mean	Lower Bound	-.1370	
			Upper Bound	.6370	
		5% Trimmed Mean		.2222	
		Median		.0000	
		Variance		.214	
		Std. Deviation		.46291	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		.75	
		Skewness		1.440	.752
		Kurtosis		.000	1.481
T2_misses	No Association	Mean		.8750	.47949
		95% Confidence Interval for Mean	Lower Bound	-.2588	
			Upper Bound	2.0088	
		5% Trimmed Mean		.8056	
		Median		.0000	
		Variance		1.839	
		Std. Deviation		1.35620	
		Minimum		.00	
		Maximum		3.00	
		Range		3.00	
		Interquartile Range		2.50	
		Skewness		1.210	.752
		Kurtosis		-.470	1.481
	Single Association	Mean		.1250	.12500
		95% Confidence Interval for Mean	Lower Bound	-.1706	
			Upper Bound	.4206	
		5% Trimmed Mean		.0833	
		Median		.0000	
		Variance		.125	

		Std. Deviation		.35355	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		.00	
		Skewness		2.828	.752
		Kurtosis		8.000	1.481
	Consistent Association	Mean		.1250	.12500
		95% Confidence Interval for Mean	Lower Bound	-.1706	
			Upper Bound	.4206	
		5% Trimmed Mean		.0833	
		Median		.0000	
		Variance		.125	
		Std. Deviation		.35355	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		.00	
		Skewness		2.828	.752
		Kurtosis		8.000	1.481
	Inconsistent Association	Mean		.1250	.12500
		95% Confidence Interval for Mean	Lower Bound	-.1706	
			Upper Bound	.4206	
		5% Trimmed Mean		.0833	
		Median		.0000	
		Variance		.125	
		Std. Deviation		.35355	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		.00	
		Skewness		2.828	.752
		Kurtosis		8.000	1.481
T2_total	No Association	Mean		4.0000	.70711
		95% Confidence Interval for Mean	Lower Bound	2.3280	

			Upper Bound	5.6720	
		5% Trimmed Mean		4.1111	
		Median		4.5000	
		Variance		4.000	
		Std. Deviation		2.00000	
		Minimum		.00	
		Maximum		6.00	
		Range		6.00	
		Interquartile Range		2.75	
		Skewness		-1.143	.752
		Kurtosis		1.357	1.481
	Single Association	Mean		.5000	.26726
		95% Confidence Interval for Mean	Lower Bound	-.1320	
			Upper Bound	1.1320	
		5% Trimmed Mean		.4444	
		Median		.0000	
		Variance		.571	
		Std. Deviation		.75593	
		Minimum		.00	
		Maximum		2.00	
		Range		2.00	
		Interquartile Range		1.00	
		Skewness		1.323	.752
		Kurtosis		.875	1.481
	Consistent Association	Mean		1.1250	.71807
		95% Confidence Interval for Mean	Lower Bound	-.5730	
			Upper Bound	2.8230	
		5% Trimmed Mean		.9167	
		Median		.5000	
		Variance		4.125	
		Std. Deviation		2.03101	
		Minimum		.00	
		Maximum		6.00	
		Range		6.00	
		Interquartile Range		1.00	
		Skewness		2.504	.752

		Kurtosis		6.610	1.481
	Inconsistent Association	Mean		.3750	.18298
		95% Confidence Interval for Mean	Lower Bound	-.0577	
			Upper Bound	.8077	
		5% Trimmed Mean		.3611	
		Median		.0000	
		Variance		.268	
		Std. Deviation		.51755	
		Minimum		.00	
		Maximum		1.00	
		Range		1.00	
		Interquartile Range		1.00	
		Skewness		.644	.752
		Kurtosis		-2.240	1.481
Total_Hits	No Association	Mean		10.5000	1.83225
		95% Confidence Interval for Mean	Lower Bound	6.1674	
			Upper Bound	14.8326	
		5% Trimmed Mean		10.6111	
		Median		10.5000	
		Variance		26.857	
		Std. Deviation		5.18239	
		Minimum		1.00	
		Maximum		18.00	
		Range		17.00	
		Interquartile Range		7.00	
		Skewness		-.513	.752
		Kurtosis		.763	1.481
	Single Association	Mean		.7500	.31339
		95% Confidence Interval for Mean	Lower Bound	.0089	
			Upper Bound	1.4911	
		5% Trimmed Mean		.7222	
		Median		.5000	
		Variance		.786	
		Std. Deviation		.88641	
		Minimum		.00	

		Maximum		2.00	
		Range		2.00	
		Interquartile Range		1.75	
		Skewness		.615	.752
		Kurtosis		-1.481	1.481
	Consistent Association	Mean		2.0000	1.10195
		95% Confidence Interval for Mean	Lower Bound	-.6057	
			Upper Bound	4.6057	
		5% Trimmed Mean		1.7222	
		Median		.5000	
		Variance		9.714	
		Std. Deviation		3.11677	
		Minimum		.00	
		Maximum		9.00	
		Range		9.00	
		Interquartile Range		3.00	
		Skewness		1.963	.752
		Kurtosis		4.067	1.481
	Inconsistent Association	Mean		.7500	.31339
		95% Confidence Interval for Mean	Lower Bound	.0089	
			Upper Bound	1.4911	
		5% Trimmed Mean		.7222	
		Median		.5000	
		Variance		.786	
		Std. Deviation		.88641	
		Minimum		.00	
		Maximum		2.00	
		Range		2.00	
		Interquartile Range		1.75	
		Skewness		.615	.752
		Kurtosis		-1.481	1.481
Total_Misses	No Association	Mean		2.8750	.91491
		95% Confidence Interval for Mean	Lower Bound	.7116	
			Upper Bound	5.0384	
		5% Trimmed Mean		2.7500	

		Median		2.5000	
		Variance		6.696	
		Std. Deviation		2.58775	
		Minimum		.00	
		Maximum		8.00	
		Range		8.00	
		Interquartile Range		3.50	
		Skewness		1.172	.752
		Kurtosis		1.247	1.481
	Single Association	Mean		.3750	.26305
		95% Confidence Interval for Mean	Lower Bound	-.2470	
			Upper Bound	.9970	
		5% Trimmed Mean		.3056	
		Median		.0000	
		Variance		.554	
		Std. Deviation		.74402	
		Minimum		.00	
		Maximum		2.00	
		Range		2.00	
		Interquartile Range		.75	
		Skewness		1.951	.752
		Kurtosis		3.205	1.481
	Consistent Association	Mean		.2500	.25000
		95% Confidence Interval for Mean	Lower Bound	-.3412	
			Upper Bound	.8412	
		5% Trimmed Mean		.1667	
		Median		.0000	
		Variance		.500	
		Std. Deviation		.70711	
		Minimum		.00	
		Maximum		2.00	
		Range		2.00	
		Interquartile Range		.00	
		Skewness		2.828	.752
		Kurtosis		8.000	1.481
		Mean		.5000	.32733

	Inconsistent Association	95% Confidence Interval for Mean	Lower Bound	-.2740	
			Upper Bound	1.2740	
		5% Trimmed Mean		.4444	
		Median		.0000	
		Variance		.857	
		Std. Deviation		.92582	
		Minimum		.00	
		Maximum		2.00	
		Range		2.00	
		Interquartile Range		1.50	
		Skewness		1.440	.752
		Kurtosis		.000	1.481

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Association	Statistic	df	Sig.	Statistic	df	Sig.
T0_hits	No Association	.262	8	.112	.916	8	.397
	Single Association	.	8	.	.	8	.
	Consistent Association	.391	8	<.001	.641	8	<.001
	Inconsistent Association	.455	8	<.001	.566	8	<.001
T0_misses	No Association	.220	8	.200*	.917	8	.408
	Single Association	.513	8	<.001	.418	8	<.001
	Consistent Association	.	8	.	.	8	.
	Inconsistent Association	.513	8	<.001	.418	8	<.001
T0_total	No Association	.260	8	.118	.771	8	.014
	Single Association	.513	8	<.001	.418	8	<.001
	Consistent Association	.391	8	<.001	.641	8	<.001
	Inconsistent Association	.430	8	<.001	.568	8	<.001
T1_hits	No Association	.234	8	.200*	.904	8	.314

	Single Association	.391	8	<.001	.641	8	<.001
	Consistent Association	.347	8	.005	.676	8	.001
	Inconsistent Association	.455	8	<.001	.566	8	<.001
T1_misses	No Association	.443	8	<.001	.601	8	<.001
	Single Association	.513	8	<.001	.418	8	<.001
	Consistent Association	.513	8	<.001	.418	8	<.001
	Inconsistent Association	.513	8	<.001	.418	8	<.001
T1_total	No Association	.244	8	.178	.813	8	.040
	Single Association	.371	8	.002	.724	8	.004
	Consistent Association	.330	8	.010	.628	8	<.001
	Inconsistent Association	.391	8	<.001	.641	8	<.001
T2_hits	No Association	.227	8	.200*	.901	8	.297
	Single Association	.443	8	<.001	.601	8	<.001
	Consistent Association	.375	8	.001	.638	8	<.001
	Inconsistent Association	.455	8	<.001	.566	8	<.001
T2_misses	No Association	.366	8	.002	.671	8	.001
	Single Association	.513	8	<.001	.418	8	<.001
	Consistent Association	.513	8	<.001	.418	8	<.001
	Inconsistent Association	.513	8	<.001	.418	8	<.001
T2_total	No Association	.191	8	.200*	.888	8	.223
	Single Association	.371	8	.002	.724	8	.004
	Consistent Association	.400	8	<.001	.605	8	<.001
	Inconsistent Association	.391	8	<.001	.641	8	<.001
Total_Hits	No Association	.136	8	.200*	.980	8	.963
	Single Association	.301	8	.031	.782	8	.018
	Consistent Association	.261	8	.117	.716	8	.003
	Inconsistent Association	.301	8	.031	.782	8	.018

Total_Misses	No Association	.231	8	.200*	.905	8	.319
	Single Association	.443	8	<.001	.601	8	<.001
	Consistent Association	.513	8	<.001	.418	8	<.001
	Inconsistent Association	.455	8	<.001	.566	8	<.001

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Hypothesis 4: Mirror Maze

Descriptives

			Statistic	Std. Error
T1	Mean		38.2063	7.95073
	95% Confidence Interval for Mean	Lower Bound	19.4058	
		Upper Bound	57.0067	
	5% Trimmed Mean		36.3542	
	Median		32.6350	
	Variance		505.713	
	Std. Deviation		22.48807	
	Minimum		18.75	
	Maximum		91.00	
	Range		72.25	
	Interquartile Range		14.41	
	Skewness		2.272	.752
	Kurtosis		5.772	1.481
T2	Mean		30.2500	8.94798
	95% Confidence Interval for Mean	Lower Bound	9.0914	
		Upper Bound	51.4086	
	5% Trimmed Mean		27.8039	
	Median		23.5700	
	Variance		640.531	
	Std. Deviation		25.30872	
	Minimum		13.63	
	Maximum		90.90	
	Range		77.27	
	Interquartile Range		15.13	
	Skewness		2.490	.752
	Kurtosis		6.546	1.481
T3	Mean		20.0050	3.40887
	95% Confidence Interval for Mean	Lower Bound	11.9443	
		Upper Bound	28.0657	
	5% Trimmed Mean		19.2133	
	Median		18.1800	
	Variance		92.963	

	Std. Deviation		9.64175	
	Minimum		12.23	
	Maximum		42.03	
	Range		29.80	
	Interquartile Range		9.03	
	Skewness		2.043	.752
	Kurtosis		4.750	1.481
T4	Mean		16.6850	2.17211
	95% Confidence Interval for Mean	Lower Bound	11.5488	
		Upper Bound	21.8212	
	5% Trimmed Mean		16.4722	
	Median		15.9550	
	Variance		37.745	
	Std. Deviation		6.14366	
	Minimum		10.00	
	Maximum		27.20	
	Range		17.20	
	Interquartile Range		11.29	
	Skewness		.672	.752
	Kurtosis		-.529	1.481
T5	Mean		14.6363	1.85945
	95% Confidence Interval for Mean	Lower Bound	10.2394	
		Upper Bound	19.0331	
	5% Trimmed Mean		14.5603	
	Median		12.7800	
	Variance		27.660	
	Std. Deviation		5.25932	
	Minimum		7.64	
	Maximum		23.00	
	Range		15.36	
	Interquartile Range		8.66	
	Skewness		.491	.752
	Kurtosis		-.960	1.481
T6	Mean		12.7850	1.20312
	95% Confidence Interval for Mean	Lower Bound	9.9401	

		Upper Bound	15.6299	
	5% Trimmed Mean		12.8778	
	Median		12.4650	
	Variance		11.580	
	Std. Deviation		3.40293	
	Minimum		6.61	
	Maximum		17.29	
	Range		10.68	
	Interquartile Range		4.67	
	Skewness		-.518	.752
	Kurtosis		.264	1.481
T7	Mean		11.7625	1.02055
	95% Confidence Interval for Mean	Lower Bound	9.3493	
		Upper Bound	14.1757	
	5% Trimmed Mean		11.8917	
	Median		11.9450	
	Variance		8.332	
	Std. Deviation		2.88656	
	Minimum		5.84	
	Maximum		15.36	
	Range		9.52	
	Interquartile Range		3.13	
	Skewness		-1.162	.752
	Kurtosis		2.182	1.481
T8	Mean		11.7538	1.48822
	95% Confidence Interval for Mean	Lower Bound	8.2347	
		Upper Bound	15.2728	
	5% Trimmed Mean		11.8103	
	Median		11.4400	
	Variance		17.718	
	Std. Deviation		4.20932	
	Minimum		5.03	
	Maximum		17.46	
	Range		12.43	
	Interquartile Range		7.36	
	Skewness		-.153	.752

	Kurtosis		-.759	1.481
T9	Mean		11.3163	1.07724
	95% Confidence Interval for Mean	Lower Bound	8.7690	
		Upper Bound	13.8635	
	5% Trimmed Mean		11.3758	
	Median		11.0800	
	Variance		9.284	
	Std. Deviation		3.04690	
	Minimum		6.32	
	Maximum		15.24	
	Range		8.92	
	Interquartile Range		5.18	
	Skewness		-.158	.752
	Kurtosis		-.582	1.481
T10	Mean		12.4700	1.97200
	95% Confidence Interval for Mean	Lower Bound	7.8070	
		Upper Bound	17.1330	
	5% Trimmed Mean		12.2500	
	Median		11.5800	
	Variance		31.110	
	Std. Deviation		5.57767	
	Minimum		5.09	
	Maximum		23.81	
	Range		18.72	
	Interquartile Range		5.94	
	Skewness		1.106	.752
	Kurtosis		2.123	1.481
T11	Mean		12.4313	1.25787
	95% Confidence Interval for Mean	Lower Bound	9.4569	
		Upper Bound	15.4056	
	5% Trimmed Mean		12.4642	
	Median		12.4550	
	Variance		12.658	
	Std. Deviation		3.55778	
	Minimum		6.20	

	Maximum		18.07	
	Range		11.87	
	Interquartile Range		4.60	
	Skewness		-.208	.752
	Kurtosis		.728	1.481
T12	Mean		9.5188	.68850
	95% Confidence Interval for Mean	Lower Bound	7.8907	
		Upper Bound	11.1468	
	5% Trimmed Mean		9.4258	
	Median		8.6800	
	Variance		3.792	
	Std. Deviation		1.94738	
	Minimum		7.62	
	Maximum		13.09	
	Range		5.47	
	Interquartile Range		3.12	
	Skewness		.972	.752
	Kurtosis		-.187	1.481
T13	Mean		10.7838	1.24697
	95% Confidence Interval for Mean	Lower Bound	7.8351	
		Upper Bound	13.7324	
	5% Trimmed Mean		10.6947	
	Median		10.2050	
	Variance		12.440	
	Std. Deviation		3.52698	
	Minimum		6.60	
	Maximum		16.57	
	Range		9.97	
	Interquartile Range		6.29	
	Skewness		.367	.752
	Kurtosis		-.825	1.481
T14	Mean		9.4425	.88173
	95% Confidence Interval for Mean	Lower Bound	7.3575	
		Upper Bound	11.5275	
	5% Trimmed Mean		9.3250	

	Median		9.3350	
	Variance		6.220	
	Std. Deviation		2.49391	
	Minimum		6.33	
	Maximum		14.67	
	Range		8.34	
	Interquartile Range		2.35	
	Skewness		1.288	.752
	Kurtosis		2.674	1.481
T15	Mean		9.4912	1.31993
	95% Confidence Interval for Mean	Lower Bound	6.3701	
		Upper Bound	12.6124	
	5% Trimmed Mean		9.3081	
	Median		8.8400	
	Variance		13.938	
	Std. Deviation		3.73332	
	Minimum		4.97	
	Maximum		17.31	
	Range		12.34	
	Interquartile Range		4.03	
	Skewness		1.307	.752
	Kurtosis		2.608	1.481
T16	Mean		8.4988	.87715
	95% Confidence Interval for Mean	Lower Bound	6.4246	
		Upper Bound	10.5729	
	5% Trimmed Mean		8.4936	
	Median		8.0000	
	Variance		6.155	
	Std. Deviation		2.48096	
	Minimum		5.47	
	Maximum		11.62	
	Range		6.15	
	Interquartile Range		5.08	
	Skewness		.228	.752
	Kurtosis		-1.912	1.481
T17	Mean		7.6088	.85048

	95% Confidence Interval for Mean	Lower Bound	5.5977	
		Upper Bound	9.6198	
	5% Trimmed Mean		7.6058	
	Median		7.2300	
	Variance		5.787	
	Std. Deviation		2.40552	
	Minimum		4.26	
	Maximum		11.01	
	Range		6.75	
	Interquartile Range		4.45	
	Skewness		.424	.752
	Kurtosis		-.732	1.481
T18	Mean		8.1125	.75613
	95% Confidence Interval for Mean	Lower Bound	6.3245	
		Upper Bound	9.9005	
	5% Trimmed Mean		8.0172	
	Median		7.8700	
	Variance		4.574	
	Std. Deviation		2.13867	
	Minimum		5.45	
	Maximum		12.49	
	Range		7.04	
	Interquartile Range		2.22	
	Skewness		1.154	.752
	Kurtosis		2.114	1.481
T19	Mean		7.3413	.71660
	95% Confidence Interval for Mean	Lower Bound	5.6468	
		Upper Bound	9.0357	
	5% Trimmed Mean		7.2592	
	Median		7.3000	
	Variance		4.108	
	Std. Deviation		2.02684	
	Minimum		5.02	
	Maximum		11.14	
	Range		6.12	

	Interquartile Range		3.04	
	Skewness		.836	.752
	Kurtosis		.404	1.481
T20	Mean		7.2613	.84811
	95% Confidence Interval for Mean	Lower Bound	5.2558	
		Upper Bound	9.2667	
	5% Trimmed Mean		7.1636	
	Median		7.1350	
	Variance		5.754	
	Std. Deviation		2.39882	
	Minimum		4.62	
	Maximum		11.66	
	Range		7.04	
	Interquartile Range		3.95	
	Skewness		.717	.752
	Kurtosis		.129	1.481

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
T1	.328	8	.011	.728	8	.005
T2	.338	8	.008	.650	8	<.001
T3	.263	8	.109	.768	8	.013
T4	.149	8	.200*	.927	8	.492
T5	.241	8	.193	.933	8	.544
T6	.173	8	.200*	.945	8	.665
T7	.234	8	.200*	.910	8	.352
T8	.123	8	.200*	.975	8	.931
T9	.137	8	.200*	.952	8	.729
T10	.181	8	.200*	.926	8	.481
T11	.136	8	.200*	.989	8	.993
T12	.238	8	.200*	.878	8	.181
T13	.152	8	.200*	.939	8	.601
T14	.254	8	.137	.893	8	.252
T15	.215	8	.200*	.904	8	.314
T16	.204	8	.200*	.886	8	.214
T17	.170	8	.200*	.928	8	.495
T18	.245	8	.171	.906	8	.326

T19	.170	8	.200*	.932	8	.530
T20	.150	8	.200*	.934	8	.549

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Appendix Q: Naming Categories Transcript

This has been removed from the electronic copy.

Appendix R: Author Submission Notes for the Journal of Experimental Psychology: Learning, Memory, and Cognition

Journal of Experimental Psychology: Learning, Memory, and Cognition

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- Editorial by Aaron S. Benjamin, PhD
  February 2019

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SUBMIT MANUSCRIPT

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Appendix S: End of Study Summary and Feedback Letter to the Salomons Ethics Panel

Dear Salomons Institute for Applied Psychology Ethics Panel,

This letter is to summarise the research completed for the Major Research Project approved by the Ethics Panel in November 2021 (ethics application number ETH2021-0388).

Since approval by the Ethics Panel, this project has been successfully carried out with one of the clinical participants with medically unexplained amnesia, SI, and eight age and education-matched control participants.

Unfortunately, due to circumstances outside of the control of the research team, the second clinical participant, WO, was not available for testing. This was because WO contracted COVID-19 two days before he was scheduled to participate in testing and lost his sense of smell and taste (which are currently yet to return). The ethics panel will be contacted further about this, with the scope to seek approval to continue the project to test WO (should he still be willing to undergo testing), to support the project for publication.

In regards to the work that was undertaken as part of this project, please see the summary below.

Background:

Previous research has suggested that olfactory memory is more long-lasting than other sensory memory, due to its unique brain physiology and ties to emotionally salient episodic memories.

One clinical participant, SI, was presented with medically unexplained anterograde amnesia following a shoulder injury in 2013, since which time he has maintained a memory-retention window of 1 waking day. This study aimed to explore olfactory memory with SI, in an observational case-control design.

Methods:

SI was compared to eight age and education-matched control participants on an olfactory memory recognition task, an implicit memory task (mirror maze), and a neuropsychological test battery (Short Parallel Assessments of Neuropsychology Status [SPANS]). Olfactory memory was tested immediately, after a 100-minute delay, and after a 24-hour delay. The implicit memory task and SPANS (recall and recognition components) were repeated on the second day of testing.

Results

Results indicated that SI's performance on the olfactory recognition memory task, implicit memory task, and SPANS were at a similar level to control participants on day 1 of testing; however, by day 2 of testing, unlike controls, SI did not demonstrate any retained learning. This finding was in spite of an incident of olfactory-cued episodic memory retrieval and occasional identification of odours.

Discussion

Despite previous research to the contrary, olfactory memory was unable to permeate SI's memory retention window and was quickly forgotten. Due to SI's apparent intact brain anatomy, this raises questions about the consolidation of olfactory memory from short-term to long-term memory.

Clinical Implications

SI's inability to recall olfactory memory after a 24-hour delay implies that olfactory memory is not as immediately long-term as research would suggest. This reignites questions regarding the nature of olfactory memory encoding and consolidation.

SI's performance was qualitatively similar to WO's previous performance (Burgess & Chadalavada, 2015). This raises further questions about the consolidation of all memory on a metabolic level.

Future Research

Future research with larger samples is needed to confirm the finding of this project and to continue exploring medically unexplained anterograde amnesia.

Thank you for your approval for this project. I hope this project has been completed to your satisfaction. Should you require any further information, please contact me on the below information.

Yours sincerely,

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