CONTRASTING TOP-DOWN AND BOTTOM-UP RETRIEVAL METHODS FOR ASSESSING AUTOBIOGRAPHICAL MEMORY

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Autobiographical memory (AM) is a unique type of memory for storing personally relevant information. AM specificity has been linked to a variety of psychological functions and mental health outcomes. Researchers have relied on two approaches to measure AM specificity: *generative retrieval*, wherein individuals are cued to initiate a top-down search for a memory, and *direct retrieval*, wherein a highly specific cue induces bottom-up activation of a memory. AM has almost always been assessed via generative retrieval measures, which fail to fully measure AM access as they exclude instances of bottom-up AM retrieval. Consequently, generative retrieval measures may confound AM specificity with executive functioning because generative retrieval engages working memory to a greater extent than direct retrieval. This study compared direct retrieval (odor-elicited) and generative retrieval (sentence-completion) measures of AM access and contrasted working memory's association with both types of retrieval in 87 community-dwelling adult smokers. Analyses revealed no correlation between generative and direct retrieval measures. In addition, neither type of retrieval was significantly associated with working memory capacity. Concerns about measurement validity for the study sample limited the conclusions that could be drawn from the data, but highlighted the need for increased prudence when selecting memory measures. Future work using a broad and multimodal approach to AM assessment should continue to investigate the relationship between top-down and bottom-up approaches to measuring

AM access, as this holds promise for understanding AM structure and its relation to a host of psychologically meaningful constructs.

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1.0 INTRODUCTION

The study of memory is a core area of psychological research. Historically, research has dichotomized memory processes into short-term and long-term memory, with long-term memory being considered a more permanent memory store that contains information that can be accessed over the course of an individual's lifetime. (Baddeley & Warrington, 1970). An often-overlooked aspect of long-term memory research concerns autobiographical memory (AM). While there has been some debate about its definition (Marsh & Roediger, 2013), AM is considered to be a store of self-relevant or self-referential information (Tulving, 1972), or as Conway and Rubin (1993) more simply propose, AM is "memory of the events of one's own life" (p. 103).

Although it has received less experimental scrutiny than other types of memory, AM appears to be germane to nearly all major branches of psychology. Clinical psychological research, for example, documents that past and current depressive symptomatology, including suicide attempts, are associated with less detailed AM recall (Williams et al., 2007). Developmental psychologists have highlighted the importance of AM in both early (Kuyken, Howell, & Dalgleish, 2006; Wang, 2008) and late life (Addis & Tippett, 2004). Research spanning social psychology and cognitive neuroscience has demonstrated links between AM and social problem solving (Goddard, Dritschel, & Burton, 1996; Marx, Mark, & Claridge, 1992), as well as anticipating future situations and goals (Addis, Wong, & Schacter, 2007; Williams et al., 1996).

Despite its broad relevance to psychological research, much remains unknown about the mechanisms that underlie AM. The current study contrasted two distinct methods for assessing AM retrieval specificity as a way to investigate the understudied mechanisms subserving AM. The next section provides background for understanding AM within the context of long-term memory research, which is followed by a discussion of AM access and how understanding the two primary methods used to assess AM may allow for a more cohesive understanding of AM function.

1.1 RELATION OF AM TO LONG-TERM MEMORY

All long-term memories can be viewed as either non-declarative or declarative (Squire, 2004). Non-declarative memory is encoded outside of conscious awareness. Skills (e.g., riding a bike), well learned sequences of actions (e.g., starting your morning routine), and priming (e.g., recognizing the word bread faster after seeing butter) are examples of non-declarative memory. Declarative memory is intentionally encoded and can be further divided into episodic and semantic memories. This distinction is particularly important because AMs contain both episodic and semantic memories (Tulving, 1972). Episodic memory is memory for specific events and is rich in sensory detail and event-specific information (M. A. Conway, 2001). Semantic memory embodies information that is not tied to a specific event and represents general knowledge (Tulving, 1972). While episodic and semantic memory are distinct classifications of declarative memory, they often work in tandem when recalling information. For instance, when recalling information about last week one might include information that is semantic and episodic such as *my co-worker, who used to be a baker, brought in cookies on Wednesday.*

At issue is understanding just how AM relates to semantic and episodic memory. This can be a challenging endeavor because the content of AM is neither exclusively semantic nor episodic; instead AM contains elements of both (e.g., you can recall semantic information about yourself such as your cat's name or episodic information such as how you got lost driving to the humane society the day you adopted your cat) (Marsh & Roediger, 2013). The defining feature of AM is that the memories it contains must be highly self-relevant (Marsh & Roediger, 2013), while semantic and episodic memories can be for events or information with little self-relevance. This characteristic forms the basis for understanding AM in the context of other declarative memory systems because AM integrates self-relevant semantic and self-relevant episodic memories.

1.2 THE STRUCTURE AND ACCESS OF AM

Appreciating how AM differs from other types of declarative memory is a requisite first step in understanding AM. The next challenge, which research has begun to investigate, is to determine how AMs are accessed. The link between impaired AM access and psychopathology, and psychosocial functioning more generally, underscores the need to understand this process. AM access can occur through two complementary routes; direct retrieval and generative retrieval (M. A. Conway & Pleydell-Pearce, 2000). A comprehensive account of AM access requires assessment using both direct and generative retrieval measures. The current study examined how the approach to AM measurement affected the characteristics of the information being retrieved. To fully grasp how the method of AM access can alter the memory information being retrieved, a brief overview of the organization of AM is necessary.

1.2.1 Organization of AM

The most popular theory of AM organization is drawn from Conway's Self-Memory System (M. A. Conway, 2005; M. A. Conway & Pleydell-Pearce, 2000). This model proposes that AMs are reconstructed during retrieval by accessing a collection of self-relevant knowledge that is organized from very broad to very specific. The information that is retrieved when recalling an AM can fall into one of three levels of specificity.

The first and broadest level contains information that refers to lifetime periods, such as *my time in graduate school*. The next level encompasses general events, which are more specific than lifetime periods. In this level, individuals access both repeated and singular events, such as *nights at the pub* and *the time we went bungee jumping (Barsalou, 1988)*. In the last and most specific level of information, an individual retrieves event-specific knowledge. This level contains the vivid details of an event that can make one feel as if they have transported back in time to when their memory was first encoded, such as *the song my husband and I danced to on our first date*.

1.2.2 Generative Retrieval

According to M. A. Conway (1996), there are times when memory access is guided by a search term that cues the retrieval process. This method of memory access is also known as top-down or generative retrieval. Once the search begins, the level of lifetime periods is accessed, followed by general events, and finally event-specific knowledge. For instance, if trying to recall memories of one's grandmother, the term "grandmother" helps to cue an appropriate lifetime period during which memories of the grandmother exist, such as *when I was little*. From there, general event information encompassed within that period can be accessed, such as *evenings on the porch eating*

dessert with grandmother. In the final stage one retrieves event-specific knowledge nested within the general event. These are the vivid aspects of AM such as, *the evening we ate chocolate cake on the porch for my grandmother's 70th birthday*.

M. A. Conway (2001) argues that during generative retrieval AM searches typically start with broad information at the first two levels of specificity. This claim is supported by neuroimaging data revealing that specific AMs elicit brain activation that peaks more slowly than do general AMs (Addis, McIntosh, Moscovitch, Crawley, & McAndrews, 2004). The increase in retrieval time for more specific memories is thought to occur because the memory path is navigated linearly and event-specific knowledge takes longer to access because it is situated below the more general information (M. A. Conway, 2001, 2005).

1.2.3 Direct Retrieval

AM access can also occur through direct retrieval, which is a bottom-up process. Direct retrieval of AM is prompted when a cue is strongly associated with a singular piece of event-specific knowledge (Eade et al., 2006). Within the Self-Memory System framework, activation of the event-specific knowledge spreads, or extends, to broader levels (the corresponding general event and lifetime period). Returning to the prior example, this kind of retrieval might occur if one tasted the unmistakable flavor of the chocolate cake they had at their grandmother's 70th birthday and could instantly recall all the information from the general event and lifetime period associated with that taste.

While less common than generative retrieval, this bottom-up retrieval nevertheless is thought to occur on a daily basis (D. Berntsen, 1996). Not only is direct retrieval critical to understand in order to have a comprehensive view of AM access, but this type of retrieval also has

clinical implications. In post-traumatic stress disorder, for example, this type of intrusive or spontaneous recall is a hallmark of the disorder wherein cues trigger vivid memory of past trauma (American Psychiatric Association, 2013). Post-traumatic stress disorder exemplifies the intense, and at times disruptive, nature of spontaneous recall, which occurs because direct retrieval activates specific details automatically (M. A. Conway & Pleydell-Pearce, 2000).

Because both generative retrieval and direct retrieval of AMs occur on a daily basis, there is a need to understand their underlying mechanisms. M. A. Conway's (2001) Self-Memory System provides a framework for testing both methods of AM access, but research has heavily emphasized the use of generative retrieval measures to the near exclusion of direct retrieval. As a result, there is an imbalance of knowledge between the methods of AM access that must be addressed.

1.3 AM RETRIEVAL SPECIFICITY

The current study investigated AM access by focusing on AM retrieval specificity. On one end of the continuum of retrieval specificity is what has been called overgeneral memory (OGM) (Raes, Hermans, Williams, & Eelen, 2007). In contrast to recalling specific self-relevant events (e.g., *my first day as a lifeguard*), OGM is the tendency to recall nonspecific memories of personal events (Williams & Broadbent, 1986). According to Raes et al. (2007), OGMs can contain events that have occurred repeatedly (e.g., *summer days at the pool*), or that involve personal semantic information (e.g., *my bathing suit is striped*), or both[1].

[1] While overgeneralizing a particular memory is not necessarily problematic or a sign of impaired AM (and may at times be adaptive), consistent access of only the two broader levels of self-relevant information (i.e., lifetime periods

Retrieval specificity can provide a way to test possible mechanisms thought to be involved in AM access. Other studies have sought to understand the cause of OGM by examining it alongside related processes. Ros, Latorre, and Serrano (2009) investigated whether reduced executive control is connected with OGM, while other research has investigated whether overgeneralizing autobiographical information correlates with overgeneralizing of other types of memory (Raes et al., 2006). Particular treatments for depression can also reduce OGM; such causal information may help to clarify the mechanisms involved in AM access (McBride, Segal, Kennedy, & Gemar, 2007).

1.4 AM RETRIEVAL AND WORKING MEMORY

Research suggests that OGM is the product of three interrelated processes: rumination, functional avoidance, and impaired executive control (Williams et al., 2007). Of particular interest to the current study is impaired executive control, defined by Williams as a reduced ability to maintain relevant task information while inhibiting irrelevant knowledge. Impaired executive control is thought to contribute to OGM because some memory retrieval involves maintaining a search term in mind while recalling an event. Maintaining a search term in mind while inhibiting irrelevant memories and details likely requires use of working memory (WM), a type of short-term memory that can store and manipulate limited amounts of information for short periods of time (Cowan, 2008). WM, which is a type of executive control, varies across both individuals and contexts

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and general events) is an indicator of disorder in AM access. It is this overreliance on general, self-relevant information that is linked it to a range of mood disorders in both adult (Williams et al., 2007) and child populations (Park, Goodyer, & Teasdale, 2002; Valentino, Toth, & Cicchetti, 2009), and is what is meant by OGM.

(Ilkowska & Engle, 2010). If WM is engaged when recalling a memory and an individual has a lower WM capacity (or is in a situation that lowers their WM capacity) it may be more likely that they terminate the search before accessing the detailed level of event-specific knowledge. Research linking reduced WM capacity and OGM is essential to test Williams et al.'s theory that executive control may partly underlie impaired AM retrieval.

While there is some research showing that individuals with lower WM tend to also have OGM (Raes et al., 2006; Ros et al., 2009), this research has been hampered by measurement challenges that call into question these findings. The current study evaluated the association between WM and AM specificity by using two distinct retrieval methods. In addition to the traditional generative retrieval measure, which may confound WM and AM specificity, this project also employed an underutilized approach to measuring AM access, direct retrieval, which is not thought to rely on WM (M. A. Conway & Pleydell-Pearce, 2000). Accordingly, the Self-Memory System model should predict that WM would be more correlated with a generative retrieval measure than it would with a direct retrieval measure. If WM performance were to be similarly correlated with both retrieval measures, this might mean that direct retrieval processes also require effortful executive control. By examining the correlations between WM and these two measures of AM retrieval, I sought to determine the extent to which prior findings linking OGM and reduced WM were impacted by the method of measurement.

1.5 MEASURING AM

AM specificity can be measured either with generative retrieval methods or with direct retrieval methods (Harris, O'Connor, & Sutton, 2015). Direct retrieval of AM has garnered far less

attention, with the possible exception of AM research that incorporates the chemical senses (Herz & Schooler, 2002; Rubin, Groth, & Goldsmith, 1984). Because AM can be accessed using either generative retrieval or direct retrieval, the reliance on generative retrieval measures limits the conclusions that can be drawn about AM access. Further research on the differences and similarities between these methods of access is crucial to better understand AM access and to evaluate the relevance of the executive control mechanism proposed by Williams et al. (2007), which is thought to be partially responsible for OGM.

1.5.1 Generative Retrieval Methods

For over 40 years research has utilized generative retrieval methods, which typically use cue-words, for measuring AM specificity (M. A. Conway & Pleydell-Pearce, 2000; Crovitz & Schiffman, 1974). While generative retrieval measures are optimally suited to assess the retrieval that occurs when a person engages in a top-down memory search, they do not offer a complete measure of AM access because AM can also be accessed through direct retrieval. In addition to neglecting direct retrieval, using only generative retrieval to measure AM access may impact the specificity of the memories being recalled due to their reliance on WM. When using a generative retrieval measure one necessarily forces the participant to keep a cue-word in mind while searching for an appropriate, specific memory, thus recruiting WM.

1.5.2 Direct Retrieval Methods

Inducing direct retrieval of AM requires using individually-tailored stimuli because the cues must maintain a connection to event-specific knowledge (Addis, Knapp, Roberts, & Schacter, 2012).

While generative retrieval cues are always presented semantically (e.g., cue-words, sentence completion stems, semi-structured interview questions), direct retrieval cues are often sensory in nature (El Haj, Postal, & Allain, 2012; Gilboa, Winocur, Grady, Hevenor, & Moscovitch, 2004; Herz, 2004). Perhaps the most well-known case of direct retrieval comes from Proust's 1922 volume *Swann's Way*, where the author is swept away in a flood of AMs upon tasting the familiar combination of petite madeleine and tea (Proust & Scott, 1922). The Proustian phenomenon refers specifically to taste, but other sensory modalities have been successfully used to induce and measure AM, including auditory and olfactory cues.

In a study with young adults, researchers found that segments of popular music induced an autobiographical association for almost one third of the presented music (Janata, Tomic, & Rakowski, 2007). In addition, self-selected music improved AM recall compared to silence or a predetermined music selection for a group of individuals with mild Alzheimer's disease, supporting the idea that music can aid AM recall even in a population that suffers particular difficulty with memory (El Haj et al., 2012). Neither of these studies, however, contrasted these direct retrieval cues with generative retrieval cue approaches.

With regard to direct retrieval, research has found that not all sensory cues are equally effective. Olfaction has demonstrated the most promise in reliably evoking powerful AMs (Herz & Schooler, 2002; Saive, Royet, & Plailly, 2014). In behavioral studies, olfactory cues induce AMs that are reported as being significantly more emotional than visual cues (Herz, 2004; Herz & Schooler, 2002). Olfactory cues also induce a stronger feeling of being drawn back in time (Herz & Schooler, 2002; Willander & Larsson, 2006) and evoke more specific details in AMs when compared to visual cues (Chu & Downes, 2002).

Neuroimaging data also support the claim that olfactory cues are better at initiating direct retrieval than other sensory modalities by showing an increase in activation in brain regions involved in emotion (Arshamian et al., 2013; Herz, Eliassen, Beland, & Souza, 2004) and in some cases, memory (Herz et al., 2004). Furthermore, odor memories are often from earlier life experiences and are less likely to be retrieved during day to day life, which could make them more likely to resist retroactive interference from subsequent associates (Lawless & Engen, 1977; Rubin et al., 1984). As a result of the privileged biological access to emotion and memory systems, and a resilience in maintaining primary memory associations, olfaction would appear to be ideally suited for examining the specificity of AM and was used as the direct retrieval measure of AM in the current study.

Because direct retrieval measures require little, if any, WM capacity they should provide a cleaner test than generative retrieval measures of Williams et al.'s (2007) proposition that executive processes play an important role in AM access. Moreover, just as generative retrieval measures are not suited to measure bottom-up direct retrieval, direct retrieval measures cannot be used to measure top-down generative retrieval. In order to advance knowledge regarding AM access, researchers must use complementary methods of measurement that comprehensively assess the construct, while being aware of how outside processes may impact these measures, as noted by Williams et al. (2007):

> "Because the impact of executive capacity deficits on specificity of recollection is likely to be, in part, a function of the balance of generative versus direct retrieval, future studies examining the effects of capacity impairments on retrieval will need to take account of the method of retrieval participants are likely to be using when interpreting their findings." (p. 138-139)

The current study aimed to address this limitation by utilizing both generative and direct retrieval methods to measure AM.

1.6 THE CURRENT STUDY

While both generative and (to a lesser extent) direct retrieval procedures have been used to measure AM in past studies, to my knowledge only one study has compared the two directly. Addis et al. (2012) found that direct retrieval cues resulted in stronger activation in the AM network (hippocampus, medial prefrontal, parietal cortices) than did generative retrieval. In that study, however, the direct retrieval cues were personalized word-cues. While the authors argue that this type of direct retrieval does not tax WM as heavily as does using a generic cue-word, it nevertheless still relies on a semantic cue, which a person must hold in mind and therefore may not be as "direct" of a direct retrieval measure. Consequently, there is still a need to explore how direct retrieval based on olfaction compares to traditional generative retrieval.

The current study aimed to examine the connection between direct and generative retrieval through two distinct aims. The first aim was to comprehensively measure AM access by contrasting measures of AM specificity relying on both generative (a sentence completion task) and direct (response to olfactory cues) retrieval methods with the expectation that specificity on the generative retrieval measure would be moderately correlated with specificity on the direct retrieval measure. The second aim was to investigate how WM capacity is related to performance on these two retrieval measures with the expectation that performance a WM task would more strongly correlate with specificity on the generative retrieval measure than on the direct retrieval measure.

2.0 METHODS

2.1 PARTICIPANTS

Eighty-seven individuals (38 female) completed the study (*M* = 41.84 years, *SD* = 10.34 years); this group is a subsample of participants from an ongoing parent study being conducted in the Alcohol and Smoking Research Laboratory. All participants were current smokers recruited from the greater Pittsburgh area using a combination of community newspapers, fliers, and Craigslist. Participants were between 18 and 55 years of age, had smoked between 10-30 cigarettes a day for at least 12 months, were not actively trying to quit smoking, did not use any other form of nicotine, and were fluent English speakers. Participants provided informed consent and were compensated for their time.

2.2 EXPERIMENTAL MEASURES

2.2.1 Individual difference measures

Age and gender information were collected using a standard demographic form used previously in our laboratory (Sayette, Loewenstein, Griffin, & Black, 2008; Sayette & Parrott, 1999). Both were used as control variables during analyses, as prior research has demonstrated that age (Ros et al., 2009) and gender (Ros et al., 2014) influenced AM specificity when using generative retrieval methods.

Participants' sense of smell, as indexed by the Sniffin Sticks threshold test, was also used as a control variable because smell acuity differences could alter how individuals react to the odor-induced AM retrieval procedure. The Sniffin Sticks test is a widely used measure that assesses several dimensions of olfaction (Hummel, Sekinger, Wolf, Pauli, & Kobal, 1997) and has been found to have a test-retest reliability of 0.92 (Haehner et al., 2009). To measure an individual's ability to detect an odor they smell three felt-tip pens and select which one contains the odorant, *n*-butanol. The concentration of the odorant is increased or decreased depending on the performance on the prior two presentations and the final score on the olfactory threshold test reflects when a participant can no longer detect the odorant.

2.2.2 Working Memory

An abbreviated version of the automated OSpan was used to assess WM capacity (Foster et al., 2015). The automated version of the OSpan correlates well with other measures of WM, including the original OSpan and the Raven Progressive Matrices measure, and has good test-retest reliability (0.83) (Unsworth, Heitz, Schrock, & Engle, 2005). The abbreviated version of the OSpan can include one, two, or three blocks of the task as each of the three blocks contributes equally to the measure of WM (Foster et al., 2015); in the current study participants completed two blocks of the OSpan. Participants' partial score on the automated OSpan was used in the analyses. The partial score better captures individual differences compared to the absolute score, which only awards points if 100% of the items in a trial are recalled and thus may cause floor effects (A. R. A. Conway et al., 2005).

2.2.3 Generative Retrieval of AM

The Sentence Completion for Events of the Past Test (SCEPT) was used to measure generative retrieval (Raes et al., 2007). The SCEPT instructs participants to complete 11 sentence stems in any way they would like as long as the response makes sense with the stem and that each sentence is about a different topic (sentence stem examples: Last year… I will never forget…). Unlike other generative retrieval measures, such as the Autobiographical Memory Test (Williams & Broadbent, 1986), the SCEPT does not use single cue-words and never explicitly directs participants to recall a memory. It has been found that not explicitly instructing an individual to recall a specific memory accounts for the SCEPT's increased sensitivity to detect AM specificity variability in non-clinical samples relative to the Autobiographical Memory Test (Debeer, Hermans, & Raes, 2009; Raes et al., 2007).

Consistent with the scoring procedures used in other AM research (Raes et al., 2007), responses to the sentence stems were coded as specific (i.e., events that refer to a single event that is less than a day in length) or non-specific (i.e., repeated events, events that are longer than a single day, or personally relevant information that is not tied to a specific memory).

2.2.4 Direct Retrieval of AM

Direct retrieval was measured using the Aroma Questionnaire, which participants completed while they sampled the 12 odors (see appendix A for questionnaire). The 12 odors were pilot tested and fell into one of four categories for most participants: pleasant (7)[2]; neutral (1); unpleasant (1); or

[2] The parent study is most interested in exploring how pleasant odors impact cigarette craving, which is why the sample consists of primarily pleasant odors. The current study focused on pleasant odors in part due to the

related to tobacco (3). The Aroma Questionnaire is based on similar questionnaires used by Herz and colleagues for studies of olfactory induced memory retrieval (Herz & Cupchik, 1992; Herz & Schooler, 2002). Participants rated each odor on several dimensions using a Likert-type scale ranging from 1 *extremely weak* to 9 *extremely strong* and indicated if the odor bought back any memories. If a memory was cued they were asked to briefly describe the memory and rate the memory on emotional intensity, specificity, and pleasantness using scales ranging from 1 to 9. A direct retrieval specificity score was calculated by summing the specificity score given to any memory retrieved while smelling the 7 pleasant odors.

2.3 STUDY OVERVIEW

Participants completed three laboratory sessions (1 questionnaire session and two experimental sessions) on three separate days. Measures relevant to the current study were administered across the three sessions (for a list of all the measures used in the parent study please refer to appendix B).

2.3.1 Session 1

Following a telephone screen, eligible participants attended the first session, which did not require smoking abstinence. Informed consent was obtained and a carbon monoxide (CO) level reading

imbalance between the number of pleasant and non-pleasant odors. Furthermore, pilot data showed that AMs cued by pleasant odors were rated as significantly more specific than AMs for unpleasant or tobacco odors. While this is an interesting finding, the current study was not powered to examine this difference and instead focused on the specificity of AMs cued by pleasant odors.

was collected. To ensure participants smoked an average of 10 to 30 cigarettes per day, CO levels had to fall between 10 and 50 parts per million (ppm). Participants then completed a forced choice odor task to ensure they had an adequate sense of smell to participate in the study (to date only one participant has been excluded based on their performance). Participants completed a packet of questionnaires including demographic characteristics and measures related to the parent study. Following the first packet of questionnaires, participants completed the Operation Span task (OSpan), another set of questionnaires, and the Sniffin Sticks test.

2.3.2 Session 2

The second session was typically scheduled within two or three weeks of session 1 and began at approximately 1pm after an eight-hour period of smoking abstinence. To confirm smoking abstinence, participants' CO levels were collected; those few with a CO above 10 ppm were rescheduled[3]. Participants completed questionnaires related to the parent study and performed the odor-sampling portion of the study. During the odor-sampling task each participant smelled 12 odors and rated each one using the Aroma Questionnaire (Herz & Cupchik, 1992; Herz & Schooler, 2002) (see appendix C for a list of the odors). The order of the odors was semi-fixed such that a pleasant odor was followed by a neutral odor, an unpleasant odor, or a tobacco odor, with the exception of the final two odors, which were both pleasant. Participants then completed other activities as part of the parent study, which are not reported here.

[3] Six participants were asked to reschedule due to excessive CO levels, all of who had acceptable CO levels at their rescheduled session.

2.3.3 Session 3

Session 3 was scheduled for the day after session 2. Participants abstained from smoking for 8-hours and provided a CO reading for verification. Following several tasks related to the parent study participants completed the SCEPT, which was embedded in a packet of questionnaires, and were debriefed.

2.4 DATA ANALYSIS

In order to address the first aim of the study, to determine the degree of correlation between AM specificity on the SCEPT and AM specificity on the Aroma Questionnaire, a two-tailed partial correlation was performed to compute the shared variance between scores on the SCEPT and the Aroma Questionnaire. Age, gender, and Sniffin Stick scores were entered as control variables to eliminate any influence they may have had on the relationship between the generative and direct retrieval measures.

To address the second aim of the study, determining if AM specificity on the generative retrieval measure – compared to direct retrieval – was significantly more associated with WM capacity, a regression model including scores for both retrieval methods was tested. In the regression model the Ospan score was specified as the dependent variable; age, gender, and Sniffin Sticks score were entered first to control for any influence they may have on the regressors of interest. The specificity score on the Aroma Questionnaire was then entered into the model followed by the specificity score on the SCEPT. The score on the Aroma Questionnaire was entered before the score on the SCEPT because prior research states that direct retrieval should not

recruit WM (M. A. Conway & Pleydell-Pearce, 2000). The significance levels of the incremental increase in the R^2 term following the addition of the AM specificity scores to the regression were compared to establish which retrieval method was more associated with WM capacity. Skewed data was transformed as necessary.

Model 1a. $OSpan = B_0 + B_1Age + B_2Gender + B_3SniffinSticks$

Model 1b. $OSpan = B_0 + B_1Age + B_2Gender + B_3SniffinSticks + B_4$Specificity of AMs on Aroma Questionnaire

Model 1c. $OSpan = B_0 + B_1Age + B_2Gender + B_3SniffinSticks + B_4$Specificity of AMs on Aroma Questionnaire + B_5Specificity of AMs on SCEPT

3.0 RESULTS

3.1 DESCRIPTIVE DATA FOR KEY MEASURES

Participants in the current study scored an average of 8.74 (*SD* = 3.29) on the Sniffin Sticks threshold test, which is similar to values found in other studies and suggests a normal sense of smell acuity (Hummel et al., 1997; Neumann et al., 2012). Because the distribution of the Sniffin Sticks scores had a moderately negative skew (-.72), the scores were reversed and a square root transformation was used to attain a normal distribution with minimal skew (.13).

The average partial score for the two block Ospan was 30.23 (*SD* =11.56). While using two blocks of the Ospan is an acceptable way to shorten the task while reliably measuring WM (Foster et al., 2015), I was unable to find a study that reported average partial scores for a two block OSpan. Studies using the full three block OSpan report an average partial score of roughly 55 and a standard deviation between 14 and 15 (Foster et al., 2015; Unsworth et al., 2005). Theoretically, to contrast values on the two block OSpan with prior studies using the three block OSpan, it is "fairly safe" to compare the current scores with a value that is two-thirds of the standard values (C. Draheim, personal communication, July 27, 2016). This method results in a score of 36.30, which suggests that the sample in the current study had a comparable WM capacity.

Two independent raters (L.M. and B.J.) were trained to score the SCEPT and interrater reliability was found to be acceptable (κ = .70). Overall performance on the SCEPT was lower than what was reported by another recent study that used a comparable sample (i.e., non-clinical, mixed gender, and of a similar age range). Trives, Bravo, Postigo, Segura, and Watkins (2016) compared younger and older adults and found that they recalled an average of 3.0 (*SD* = 1.45) and

2.65 (*SD* = 1.47) specific memories respectively; individuals in the current study recalled an average of just 1.15 (*SD* = 1.16) specific memories on the SCEPT. This low score seems to be a function of a disproportionate number of participants scoring a zero (*n* = 31), which led to a strongly (right) skewed distribution (.99). To address the skew all scores were first increased by one and then log transformed (Howell, 2007).

The average total score on the aroma specificity measure was 23.59 *(SD* = 17.58) out of a maximum of 63 (each of the 7 pleasant odors could score up to a 9 on specificity). Herz and Schooler (2002) found an average specificity score of 4.83 (*SD* = .52) per odor cue; the average total Aroma Questionnaire score for our participants indicates that each odor scored a mean of 3.37 on specificity (23.59 ÷ 7 pleasant odors). It is important to note that unlike prior studies that have used the Aroma Questionnaire (Herz & Schooler, 2002), the current study did not *require* individuals to recall a memory for each odor. Seventeen individuals (20%) in the sample did not report recalling a memory for any of the 7 pleasant odors and thus scored a zero on the Aroma Questionnaire specificity measure. Nevertheless, distributional properties were acceptable (skew = .10, kurtosis = -1.21), and no transformations were required.

3.2 EXPERIMENTAL ANALYSES

The hypothesis of aim one, that the two AM measures would be moderately correlated was not supported by the data. When controlling for age, gender, and Sniffin Stick scores the partial correlation between AM specificity on the SCEPT and AM specificity on the Aroma Questionnaire was found to be non-significant, $r(82) = -.02$, $p = .83$.

Contrary to the hypothesis tested in aim two, the association between AM specificity on the SCEPT and WM capacity was not significantly larger than the association between AM specificity on the Aroma Questionnaire and WM capacity. Importantly, the significance level of the incremental increase in the R^2 term was low and non-significant for both measures of AM specificity (Table 1), suggesting that the addition of these terms to the regression did not significantly account for changes in OSpan scores.

Table 1. Regression results for AM specificity

Model *(df)*	**R^2 Change**	**F Change**	**Significance of F Change**
B_0 + B_1Age B_2Gender + B_3SniffinSticks *(1,83)*	0.23	8.40	<0.001
B_0 + B_1Age + B_2Gender + B_3SniffinSticks + B_4Specificity of AMs on Aroma Questionnaire *(1,82)*	0.01	1.14	0.29
B_0 + B_1Age + B_2Gender + B_3SniffinSticks + B_4Specificity of AMs on Aroma Questionnaire + B_5Specificity of AMs on SCEPT *(1,81)*	0.02	2.21	0.14

The dependent variable is OSpan score.

To investigate potential explanations for the null findings of the regression used to assess aim two, I conducted a secondary (post-hoc) analysis. Despite the fact that neither R^2 term reached a significance level of $p < .05$, it is possible that the AM specificity measures could still differ in their relative ability to predict OSpan scores. To further explore this possibility a t-test was performed on the standardized regression coefficients (β) for the SCEPT specificity and aroma specificity measures. The t-test performed on the regression coefficients for the SCEPT and the Aroma Questionnaire was not significant $t(82) = -.40$, $p = .69$, further suggesting that specificity on the SCEPT and the Aroma Questionnaire did not differ in their ability to predict OSpan scores.

4.0 DISCUSSION

AM is implicated in a broad range of psychological functioning but compared to other categories of memory, it has received far less attention. This study sought to test the retrieval processes and mechanisms involved in AM. In particular, the two primary aims were designed to address questions regarding aspects of AM access. The first aim was to investigate the degree to which two distinct measures of AM would provide convergent data. Specifically, the study examined the correlation between AM specificity on a generative retrieval task, the SCEPT, and AM specificity on a direct retrieval task, the Aroma Questionnaire. Presumably both types of measures would index to some extent the same underlying construct, yet prior to the current study this relationship has only been investigated once (Addis et al., 2012). The second aim was to determine if WM performance predicted specificity on the generative and direct AM retrieval tasks equally. Models of AM posit that direct retrieval methods do not rely on executive functioning (M. A. Conway & Pleydell-Pearce, 2000), but no research has examined how WM, a component of executive functioning, is related to direct AM access.

The current study did not find evidence that generative retrieval and direct retrieval are correlated, nor did it reveal that generative AM retrieval, as compared to direct AM retrieval, was better predicted by OSpan score. The complete absence of the predicted correlation between the direct retrieval and generative retrieval measures was surprising given that to at least some degree both types of retrieval should access the same store of self-relevant memories and thus would be expected to demonstrate some overlap. The null results for aim two also were unanticipated because prior research in both healthy and disordered populations has found a relationship between WM executive processes and generative memory specificity (Ros et al., 2009; Williams et al.,

2007). Moreover, because the leading model of AM distinguishes direct retrieval from generative retrieval, as direct retrieval does not rely on executive resources, (M. A. Conway & Pleydell-Pearce, 2000), the lack of a difference between the two is puzzling. These inconsistencies between prior research and the current study highlight the need to determine if there were methodological reasons that might explain the current data.

4.1 METHODOLOGICAL CONCERNS

The first issue to address concerns power. Power analyses were performed prior to subject recruitment to ensure that power would be sufficient to detect an anticipated medium size effect. That is, a sample size of 87 was indicated to run both the two tailed partial correlation used to test aim one and the regression used in aim two. In addition, the sample size of the current study was larger than those used in other studies that have demonstrated a significant relationship between WM and generative AM retrieval (Ros et al., 2009; Williams et al., 2007). Moreover, inspection of the data suggest that the two measures of AM were entirely uncorrelated ($r < .03$) and the r^2 values pertinent to Aim 2 were $< .02$, suggesting that power was not the issue.

Given that there was adequate power for the analyses, it is possible that the null results may have been due to measurement error associated with the three main variables of interest: the OSpan, the Aroma Questionnaire, and the SCEPT. All the measures used in the current study were selected based on their satisfactory performance in past research, but it is possible that these measures did not perform in the expected manner for the current study and thus may have resulted in an inability to sensitively test the study aims.

The OSpan is one of the most widely used and validated measure to index WM capacity (A. R. A. Conway et al., 2005). The current study used an abbreviated (Foster et al., 2015), automated (Unsworth et al., 2005) version of the OSpan to limit experimenter and time burden associated with the traditional OSpan; both the shorter and automated versions have been shown to correlate well with the original OSpan (Foster et al., 2015; Unsworth et al., 2005). The likelihood that the OSpan measure performed differently in the current study seems low considering that participants' scores followed a normal distribution and were similar to the average scores reported in other papers (once the difference in the number of blocks was accounted for). Moreover, as anticipated, age and OSpan were inversely correlated, $p < .001$, adding further evidence that the OSpan measure functioned according to expectations.

The Aroma Questionnaire, which was used to measure direct AM retrieval, has been used in a number of studies to examine participants' reactions to odors (Herz, 1998, 2004; Herz & Schooler, 2002). Inspection of Aroma Questionnaire data revealed that the scores followed a normal distribution. The average specificity score of each odor cue on the 9-point scale was lower in the current study, 3.37, than has been previously reported, 4.83 (Herz & Schooler, 2002). Roughly 20% of the sample did not recall a memory for any of the odors and scored a zero on the Aroma Questionnaire. These zero values, which in turn lowered the group average, are likely, however, because the current study administered the Aroma Questionnaire differently than past research by asking for a specificity rating *if* a memory was cued rather than requiring an individual to recall a memory for each odor. This methodological difference was intentional, as it was thought to be critical to allow for truly generative recall procedure, which must be stimulus driven. Still, it is notable that about 20% of the participants did not experience a single odor cued memory. A possible explanation is that the odors were not novel enough to result in memory cuing for some

individuals. Recent research has shown that a novel stimulus is a significantly better cue for specific memories and that repeated cues (such as a familiar smell or scene) are more likely to cue general memories or information (Dorthe Berntsen, Staugaard, & Sørensen, 2013). Nevertheless, in light of prior findings using odor to elicit AM (Herz, 1998, 2004; Herz & Schooler, 2002) and the current data, where 80% of participants successfully recalled at least one memory while sniffing an odor, there is reason to continue to use odor cues to measure direct AM retrieval. The promise associated with using odors to test AM is especially indicated, as to date there has been virtually no research using direct measures to assess AM retrieval.

The most problematic measure in the study was the SCEPT, which exhibited lower than expected scores. The SCEPT is a measure of generative AM retrieval that was specifically designed to be used with nonclinical populations and was selected for the current study over the more commonly used AMT because the AMT has been found to have ceiling effects with non-clinical samples (Raes et al., 2007). The SCEPT was initially administered to a college aged sample and demonstrated the expected relationship between depressed mood and OGM in a non-clinical sample, suggesting that it is a valid measure of generative AM retrieval (Raes et al., 2007). More recently, Trives et al. (2016) found that the SCEPT yielded similar specificity scores for both healthy young and older adults (3.00 and 2.65 respectively). In the current study, however, the average number of specific memories recalled was quite low (1.15), had high variability (*SD* = 1.16), and had a large number of zero values (31 of the 87 participants). A possible explanation for these differences is that, though not a clinical sample, the smokers in the present study likely are at increased risk for experiencing mental health disorders, like depression and anxiety (Boden, Fergusson, & Horwood, 2010; Glassman, 1993; Johnson et al., 2000)[4]. Unfortunately, the SCEPT

[4] The current study did not collect data on mental health diagnoses making it impossible to address this point.

has not been validated with a sample similar to the one used in the current study, which makes it difficult to speculate why the scores were so much lower. While the SCEPT is a more logical choice to measure generative AM retrieval in a non-clinical sample compared to the AMT, it is possible that the SCEPT does not function as expected in a population that is more vulnerable to mental health disorders, like smokers. In the current study it appears that near floor effects on the SCEPT may have made it difficult to sensitively evaluate its relation to the OSPAN or the Aroma Questionnaire, thus inhibiting testing of aims one and two.

In addition to the methodological limitations that were encountered with the SCEPT, there are other limitations worthy of mention. First, the study sample was a subset of individuals from a larger parent study investigating cigarette craving and olfaction; as a result, all participants were moderate smokers. This limits the degree to which the data would generalize to never- or ex-smokers, as it has been found that smokers differ from non-smokers in a variety of ways such as having poorer mental health (Glassman, 1993), impaired delayed discounting (Mitchell & Wilson, 2012), and lower socioeconomic status (Reid et al., 2010). It is worth noting, however, that almost 20% of adults in the United States currently smoke (Jamal et al., 2015), revealing the importance of understanding how this group functions and how they may differ from nonsmokers. In the future, however, researchers may want to explore the aims of this study in a non-smoking sample to increase generalizability and provide a chance to compare AM retrieval mechanisms between smokers and nonsmokers.

Parts of the parent study required an eight-hour smoking abstinence period for all participants. As a result, individuals completed the Aroma Questionnaire while in some degree of nicotine withdrawal, which is known to cause negative mood (Hughes & Hatsukami, 1986). While it is possible that this withdrawal state biased direct AM retrieval uniquely because it was the only

measure completed during nicotine withdrawal, evidence concerning the impact of negative mood on AM retrieval is mixed with regard to how it alters retrieved AM valence (Sakaki, 2007). Further, negative affect associated with mild nicotine deprivation does not appear to alter retrieved AM specificity (Rubin et al., 1984). Nevertheless, future studies would be wise to remove the possibility of nicotine withdrawal when testing various facets of AM, unless, of course, that withdrawal was the target of the investigation.

4.2 IMPLICATIONS AND FUTURE DIRECTIONS

Because the SCEPT may have suffered from floor effects it is possible that participants' scores did not accurately reflect their generative AM retrieval. Accordingly, it is difficult to elaborate on the theoretical implications of these null results. Nevertheless, this study was the first to measure AM specificity using an olfactory based direct retrieval measure in conjunction with a more traditional generative retrieval measure, both of which are thought to be putative measures of AM. It was notable that there was no evidence of any overlap between an AM measure requiring direct, bottom-up, retrieval to olfactory cues and one requiring generative, top-down, processing to sentence stems. If future studies replicated these null findings using different samples or different measurements of generative retrieval, it would suggest the need to reconsider just what is and what is not central to the construct of AM. Unfortunately, given the potential concerns with floor effects in the current study, it is clear that additional research is needed before such an argument can be made with confidence.

Although it was not a goal of this study, the issues encountered highlight the seemingly straight-forward yet often neglected importance of selecting memory measures that have been

validated for the particular sample being used. Specifically, the current study calls into question the use of the SCEPT with a sample of community dwelling smokers. Moving forward, it would be informative to more fully investigate individual differences in AM performance, with an emphasis on individuals who generate very few memories on the various tasks. Two of the three main measures in the current study, the SCEPT and the Aroma Questionnaire, contained a high percentage of zero values, which was a surprising result and may indicate important potential differences between responders and non-responders. Particularly with the SCEPT, it could be useful to interview participants after they complete the measure to understand what led to zero scores, whether it be concerns with comprehension, motivation, or something altogether different.

Future work focusing on generative AM measures would be useful to investigate if particular groups simultaneously perform poorly on the SCEPT, by exhibiting floor effects, and the AMT, by exhibiting ceiling effects. Raes et al. (2007) compared the SCEPT and the AMT, but their sample was limited to college students and was mostly female. The intentionally vague nature of the SCEPT and the intentionally explicit nature of the AMT could represent two endpoints that suboptimally account for individuals who may fall in the middle on cognitive performance (i.e., a smoker who experiences higher stress and is more prone to affective disturbances).

In summary, the current study did not find evidence that direct and generative retrieval is correlated, nor did it find evidence that WM is predictive of performance on either AM retrieval method. These results may be the consequence of measurement concerns, but they do highlight an important methodological issue that should inform future research. As AM research extends to include more diverse populations (e.g., smokers) it is critical that researchers ensure the validity of the particular measures for that sample. Current measures need be examined with heterogeneous samples if they are to be used with broad swaths of the population, and researchers should keep in

mind that existing measures may require modification to be effective in their sample of interest. Given the importance of AM for both normative and psychopathological functioning, it remains critical to validate a range of AM retrieval measures that clarify the boundaries of the construct. To date, it is unclear how AM derived from direct and generative assessments relate to each other. It also remains unknown whether they each capture distinct parts of the same elephant or instead whether the construct of AM may need to be subdivided into separable constructs.

APPENDIX A

ODOR SAMPLING QUESTIONNAIRE

1. This scent was

Extremely Unpleasant				Neutral				Extremely Pleasant
1	2	3	4	5	6	7	8	9

2. This scent was

Not at all Intense								Extremely Intense
1	2	3	4	5	6	7	8	9

3. This scent was

Not at all Familiar								Extremely Familiar
1	2	3	4	5	6	7	8	9

4. Does this scent bring up any **feelings** or **emotions** for you? (circle yes or no) Yes No

If "yes" please write down as many as you feel and rate each one using the scale on the right.
If "no" please skip to question #5.

Emotion/Feeling **How strong is the feeling/emotion for you?**

	Extremely Weak							Extremely Strong	
a. _____	1	2	3	4	5	6	7	8	9
b. _____	1	2	3	4	5	6	7	8	9
c. _____	1	2	3	4	5	6	7	8	9

5. Does this scent bring back any **memories** for you? (circle yes or no) Yes No

If "yes", please describe the memory in 1-2 sentences, using the space below. *If "no" please skip to question #9.*

6. How **emotionally intense** is your memory?

Extremely Weak								Extremely Strong
1	2	3	4	5	6	7	8	9

7. How **specific** is your memory?

Extremely Vague								Extremely Specific
1	2	3	4	5	6	7	8	9

8. How **pleasant** is your memory?

Extremely Unpleasant				Neutral				Extremely Pleasant
1	2	3	4	5	6	7	8	9

9. How do you feel right now?

Extremely Bad				Neutral				Extremely Good
1	2	3	4	5	6	7	8	9

10. What do you think you smelled?

APPENDIX B

LIST OF MEASURES FOR PARENT STUDY ON OLFACTORY STIMULI AND CRAVING REDUCTION

- Participant identification number
- Odor condition
- Number of hours since participant last smoked Session 1
- Number of cigarettes participant has smoked in the past 24 hours Session 1
- Baseline breath carbon monoxide reading Session 1
- Aroma Questionnaire
- Sniffin' Sticks Smell Threshold Task
- Odor assigned to participant at Session 2
- Number of hours since participant last smoked Session 2
- Number of cigarettes participant has smoked in the past 24 hours Session 2
- Abstinent breath carbon monoxide reading Session 2
- Urge 1 Urge rating collected prior to cue exposure in Session 2
- Urge 2 Urge rating collected during cue exposure in Session 2
- Urge 3 Urge rating collected during peak craving odor exposure in Session 2
- Urge 4 Urge rating collected at 1 minute odor re-exposure in Session 2
- Urge 5 Urge rating collected at 2 minute odor re-exposure in Session 2
- Urge 6 Urge rating collected at 3 minute odor re-exposure in Session 2
- Urge 7 Urge rating collected at 4 minute odor re-exposure in Session 2
- Urge 8 Urge rating collected at 5 minute odor re-exposure in Session 2
- Smoking Choice Task
- Odor assigned to participant at Session 3
- Number of hours since participant last smoked Session 3
- Number of cigarettes participant has smoked in the past 24 hours Session 3
- Abstinent breath carbon monoxide reading Session 3
- Urge 1 Urge rating collected prior to cue exposure in Session 3
- Urge 2 Urge rating collected during cue exposure in Session 3
- Urge 3 Urge rating collected during peak craving odor exposure in Session 3
- Did subject smoke a cigarette during the break?
- Anticipated Duration and Intensity Scale
- Smoking Consequences Questionnaire-Brief
- Smoking Consequences Questionnaire Items from the longer SCQ (Copeland et al., 1995), which were eliminated from the SCQ-B

- Gender
- Age
- Race
- Ethnicity
- Marital Status
- Highest Grade Completed
- Income
- Attention to and Importance of Odors
- Number of smokers living in participant's household (including participant)
- Number of participant's five closest friends that smoke
- Number of participant's five closest friends that are ex-smokers
- How many people in participant's office or place of work are smokers?
- Spouse's or partner's smoking status
- How does participant's spouse or partner (or closest friend, if single) feel about participant's smoking?
- Which cigarette would participant most hate to give up?
- In what three situations is participant most likely to smoke?
- Has someone close to participant been urging them to quit smoking?
- Nicotine Dependence Syndrome Scale
- Fagerström Test for Nicotine Dependence
- Smoking-specific Felt Attitudinal Ambivalence Scale
- Brief Wisconsin Inventory of Smoking Dependence Motives
- Contemplation Ladder Sessions 1 and 3
- Smoking Abstinence Questionnaire
- NEO-FFI Personality Inventory
- Schutte Self Report Emotional Intelligence Test
- Sentence Completion for Events of the Past Test
- Balanced Inventory of Desirable Responding – Version 6
- Mindful Attention Awareness Scale
- Social Thoughts Scale Sessions 2 and 3
- Experiences in Close Relationships

APPENDIX C

LIST OF ODORS AND THEIR DESIGNATION AS PLEASANT, UNPLEASANT, NEUTRAL, OR TOBACCO

1. Cumin - pleasant
2. Chocolate - pleasant
3. Participant's Own Cigarette - tobacco
4. Lily of the Valley (Muguet) - pleasant
5. Lemon - pleasant
6. Apple - pleasant
7. Amyl Vinyl Carbinol - unpleasant
8. Nothing - neutral
9. Amsterdam Shag - tobacco
10. Peppermint - pleasant
11. Vanilla - pleasant
12. Danish Export - tobacco

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