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Contributions of Signal-detection Mechanisms and Semantic Memory Representations to Famous Name Recognition

Ben P. Bowles, *University of Western Ontario*

Supervisor: Stefan Köhler, *The University of Western Ontario*
A thesis submitted in partial fulfillment of the requirements for the Doctor of Philosophy degree in Neuroscience
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Contributions of Signal-detection Mechanisms and Semantic Memory
Representations to Famous Name Recognition

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by

Benjamin Paul <u>Bowles</u>

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The University of Western Ontario
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THE UNIVERSITY OF WESTERN ONTARIO
School of Graduate and Postdoctoral Studies

CERTIFICATE OF EXAMINATION

Supervisor   Examiners

_____   _____
Dr. Stefan Köhler   Dr. Mieke Verfaellie

Supervisory Committee

                                                          _____
                                                          Dr. Ken McRae

_____
Dr. J. Bruce Morton

                                                          _____
                                                          Dr. Marc Joanisse

_____
Dr. David Sherry

                                                          _____
                                                          Dr. Chris Viger

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Benjamin Paul <u>Bowles</u>

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Abstract

In past research, investigators have often used the recognition memory paradigm to study the cognitive and neural processes that permit the ability to accurately assess whether or not stimuli are familiar. This paradigm involves presenting stimuli to participants in a study phase, and examining their later recognition of them when these stimuli are subsequently presented again in a later test phase. It is not well understood, however, whether the same mechanisms that support familiarity assessment in recognition memory also support familiarity based on general life experience (e.g., recognizing a famous celebrity in daily life). To address this, I implemented modified recognition memory paradigms for the purpose of better understanding the processes that support famous name recognition. In Chapter 2, I developed a signal-detection model that describes how people discriminate between famous and fictional names. I found that similarly to recognition memory, famous name recognition relies on graded evidence that can be modeled successfully with Gaussian distributions. In Chapter 3, I studied the contributions of semantic knowledge to famous name familiarity, with a focus on recognition experiences in which 'names ring a bell'. I revealed that despite the fact that participants understand this recognition experience to reflect situations where names are familiar but do not provoke retrieval of any related semantic details, they still achieve above-chance performance on an occupation forced-choice task for the same names. Based on these results, I investigated in Chapter 4 whether 'name rings a bell' experiences engage the same brain regions as those that also support the ability to successfully retrieve

semantic knowledge about famous names. Using functional magnetic resonance imaging, I examined whether the brain regions that support 'name rings a bell' experiences overlap with those that support successful identification and correct occupation forced-choice decisions. Two brain areas that I found to be engaged during 'name rings a bell' responses were also engaged while participant's successfully retrieved semantic knowledge for names, which included the left posterior middle temporal gyrus and an inferior aspect of the left ventrolateral prefrontal cortex. Overall, my thesis advances our knowledge of how feelings of familiarity for famous names relate to underlying semantic representations about them.

Keywords

signal-detection theory, gaussian distribution, famous name recognition, person recognition, recognition memory, semantic memory

Co-Authorship Statement

A version of Chapter 2 has recently been accepted for publication: Bowles, B., Harlow, I.M., Meeking, M.M., & Köhler, S. (2011). Discriminating famous from fictional names based on lifetime experience: Evidence in support of a signal-detection model based on finite mixture distributions. Journal of Experimental Psychology: Learning, Memory, & Cognition, *in press*.

The research presented in this thesis reflects a collaborative effort. I designed, conducted, and analyzed all experiments under the supervision of Dr. Stefan Köhler. For Chapter 2, Melissa Meeking assisted in collecting behavioral data, and Iain Harlow provided valuable assistance in the mathematical modeling of receiver-operating characteristics. For Chapter 4, Edward O'Neil and Victoria Barkley provided help with administering the experiment and analyzing the data.

Acknowledgments

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List of Abbreviations

Abbreviation	Term
RK	Remember-know
ROC	Receiver operating characteristic
z-ROC	ROC graph plotted in z-space
PET	Positron emission tomography
Mix	Mixture
UVSD	Unequal-variance signal-detection
SAC	Source of activation & confusion
EVSD	Equal-variance signal-detection
SEM	Standard error of the mean
SD	Standard deviation
DPSD	Dual-process signal-detection
VRDP	Variable recollection dual-process
2HT	Two high-threshold
AIC	Akaike information criterion
BIC	Bayesian information criterion
TR	Time to repetition
NRB	'Name rings a bell'
ANOVA	Analysis of variance
IAC	Interactive activation and competition
PIN	Person Identity Node
FRU	Face Recognition Unit
VRU	Voice Recognition Unit
NRU	Name Recognition Unit
SIU	Semantic Identification Unit
fMRI	Functional magnetic resonance imaging
vlPFC	Ventrolateral prefrontal cortex
MTG	Middle temporal gyrus
AI	Anterior insula
ATL	Anterior temporal lobe
ACC	Anterior cingulate cortex
SMA	Supplementary motor area
RT	Reaction time
GLM	General linear model
Fc_Sem	Forced-choice trials associated with semantic access
Fc_Nosem	Forced-choice trials associated with no semantic access
Fam_Iden	Famous names given 'identify' response
Fam_Nrb	Famous names given 'name rings a bell' response
Fam_Unf	Famous names given 'unfamiliar' response
Fict_Unf	Fictional names given 'unfamiliar' response

Nrb_Lowconf	NRB responses associated with later low confidence
Nrb_Highconf	NRB responses associated with later high confidence
TOT	Tip-of-the-tongue
M	Midline
L	Left
R	Right
BOLD	Blood oxygen level-dependent
ms	Millisecond
s	Second
r	Pearson correlation
p	Probability
df	Degrees of freedom

List of Symbols

Symbol	Term
d'	Discriminability index
T	High-threshold parameter
λ	Lambda - mixture parameter, proportion of famous names to which the participant has been exposed
Φ	Cumulative Gaussian distribution function
σ_{FAM}	The standard deviation of the famous name distribution with exposure
c_k	Memory strength criterion set by the participant for each level of memory strength
G^2	Goodness-of-fit statistic, defined by $[2\sum O_{ij} \log (O_{ij}/E_{ij})]$
Dt	Proportion of targets in the 'detect' state in the 2HT model
Dl	Proportion of lures in the 'reject' state in the 2HT model
β	Quadratic regression coefficient

1 General Introduction

1.1 Outlook

The ability to identify previously encountered stimuli is a critical aspect of human day-to-day functioning. This is particularly evident whenever one needs to accurately recognize a friend in a crowd of strangers (Koffka, 1935, pp. 595-597), or use appropriate landmarks to find one's way back to a previously visited destination. For decades, researchers have used the recognition memory paradigm to ask questions about the cognitive and neural processes that support the detection of prior occurrence (for recent reviews, see Eichenbaum, Yonelinas, & Ranganath, 2007; Skinner & Fernandes, 2007; Squire, Wixted, & Clark, 2007; Yonelinas, 2002). In a typical experiment of this type, participants are first presented with a series of study items (e.g., words, scenes, abstract designs) in an initial study phase. In a later test phase, participants are presented with all of the original study items, intermixed randomly with a set of items that were not previously included in the study phase, and they are asked to indicate which test items they recognize from the prior study phase. An advantage, and indeed, a defining aspect of the recognition memory paradigm is that the experimenter is able to tightly control all aspects of the study episodes that provide a basis for later recognition (e.g., stimulus presentation time). This tight control lends itself well to systematic experimental manipulations, such as how recognition is affected by different types of factors at encoding (e.g., Craik & Lockhart, 1972). Further, it allows for the calculation of meaningful measures of recognition memory performance, and therefore can also be effectively used to assess

memory problems in amnesia (e.g., Milner, 1972). One important aspect of recognition memory that is often overlooked, however, is that it is currently unclear how recognizing an event based on one prior laboratory event relates to recognition that takes place outside the laboratory in real-life situations. Is the recognition memory paradigm informative with respect to understanding the processes that support one's ability to judge the prior occurrence of a co-worker, a famous celebrity, or a common object in daily life?

A quote from an influential article by George Mandler provides motivation for understanding how recognition memory relates to the type of recognition that occurs on a daily basis. With respect to his own recognition memory model, he argued:

> The model should be seen as opening the door to more complex
> investigations as well as to the problem of how things are
> recognized in their wider sense, that is, recognizing what they
> are, not just that they have been encountered before. (p. 269)

For the most part, only a handful of studies have been conducted with the specific aim of understanding how recognition memory relates to one's general ability to recognize the identity of stimuli one knows (see Mandler, 2008, for a review) . Despite the extensive literatures for research related to person recognition, object recognition, and word recognition, to name a few of the many examples, only in

rare cases has work in these domains been linked concretely with the recognition memory literature.

Despite the general segregation of these types of long-term recognition and recognition memory, there are isolated hints that both types of recognition do rely on some common cognitive and brain mechanisms. A well-known empirical finding that speaks to this possibility is the false-fame effect, which refers to the observation that participants are more likely to judge a non-famous name as famous if they were recently presented with it in a study phase (Jacoby, Kelley, Brown, & Jasechko, 1989). For word recognition memory experiments, it has been shown that participants more often erroneously endorse high frequency lure words as previously studied than low frequency lure words (Reder et al., 2000; see Joordens & Hockley, 1999). It is argued that in the case of high-frequency novel lures, participants cannot accurately distinguish between increases in familiarity that are due to high frequency in lifetime exposure versus increases in familiarity that are caused by the recent laboratory encounter. In further support of a link between these two forms of recognition, Nessler et al. (2005) used event-related potentials to demonstrate that the electrophysiological signature associated with recognizing famous faces based on lifetime experience is similar to that which is associated with recognizing non-famous faces based on one laboratory encounter. Further, there also exists some limited evidence that the perirhinal cortex, a structure that is well known to support recognition memory (Eichenbaum, et al., 2007; Skinner & Fernandes, 2007), may also play a role in

recognizing stimuli that one knows based on lifetime experience, such as famous faces (Dietl et al., 2005) or musical excerpts (Plailly, Tillmann, & Royet, 2007).

Although this limited evidence is sparse, it hints at the possibility that there may be common neural and cognitive mechanisms that support recognition that hinges on one temporally specific study episode as well as recognition that hinges on lifetime experience. The broad goal of my thesis is to take initial steps towards unifying the study of these two types of recognition, using famous name recognition as a model. To achieve this, I use paradigms that have traditionally been used exclusively in the field of recognition memory, and I modify them in such a way that they can be used to advance research regarding the cognitive and neural processes that support famous name recognition. In Chapter 2, I develop a signal-detection model that describes how people discriminate between famous and fictional names based on their lifetime experience. In Chapter 3, I study the contributions of semantic knowledge to the process of recognizing famous names, with a focus on the subjective experience in which names appear familiar to participants but do not provoke retrieval of any semantic details that would allow for identification. In the last experimental investigation, I examine the extent to which the brain regions that support the assessment of familiarity for famous names can be dissociated from those that support the successful access of semantic knowledge about them. As many of the procedures used in the current thesis were influenced by findings and paradigms in recognition memory, I provide a brief overview of the recognition memory literature before describing each of these Chapters in greater detail.

1.2 Recognition Memory: Pertinent Background

Decades of research have led most researchers to agree that recognition memory is comprised of two processes, recollection and familiarity (for a review, see Yonelinas, 2002). Recollection supports recognition based on recovery of contextual details of the original stimulus encounter, whereas familiarity brings awareness of a prior encounter in the absence of such contextual recovery. Recollection is proposed to be supported by the hippocampus and its connections to the mammillary bodies and anterior thalamic nuclei, while familiarity is thought to depend on the perirhinal cortex and it's connections to the dorsomedial nucleus of the thalamus (Aggleton & Brown, 1999, 2006; Eichenbaum, et al., 2007; Yonelinas, 2002; but see Squire, 2007). Many different recognition memory paradigms have been developed that are specifically designed to dissociate these two underlying processes in their contributions to recognition memory (for a review, see Yonelinas, 2002). Two of these paradigms that are widely used and which have been particularly influential with respect to the conceptual development of the current thesis are the Remember-Know (RK) paradigm and the Receiver-Operating Characteristic (ROC) procedure.

The RK paradigm, developed by Endel Tulving (Tulving, 1985), was originally designed to probe two qualitatively different subjective states associated with recognition memory that were termed 'Remembering' and 'Knowing'. 'Remembering' was taken to reflect a state of recognition awareness defined by contextual recall and re-experiencing of spatial, temporal, or other sensory aspects of the original event in response to the recognized test item.

Within the context of a recognition memory test phase, for example, participants would be asked to give a 'Remember' response in association with recognition of a stimulus if they can conjure up a specific detail from the original study event, such as a noise that was present or perhaps what they were thinking about the stimulus at that time. By contrast, 'Knowing' is considered a state defined by a strong sense of familiarity with no retrieval of contextual details. In other words, these responses involve familiarity based on the prior encounter, but an absence of any ability to declare the details surrounding that encounter. In explaining this state of isolated familiarity to participants before the experiment begins, the investigator often describes a situation in which a person finds someone else to be very familiar but at the same time has an inability to recall the context in which that person would have been encountered (John Gardiner, C Ramponi, & A Richardson-Klavehn, 1998). Although Tulving was initially concerned exclusively with the nature of the subjective states associated with 'Remember' and 'Know' responses, it is now assumed by many researchers that these two types of recognition responses reflect the outcome of two distinct cognitive processes, namely recollection and familiarity assessment, respectively. Thus, the proportions of these responses in a recognition memory test phase are often used to calculate performance estimates for the underlying recollection and familiarity processes. It is worth noting, however, that the precise calculations one uses in this context depend on the assumptions that one makes about how these two states of awareness relate to their underlying processes. For example, in a redundancy account, the 'Remember' state would involve both the familiarity and the

recollection process, while the 'Know' state would involve only the familiarity process (e.g., Knowlton & Squire, 1995). By contrast, in an independence account, the 'Remember' recognition state may sometimes reflect both processes and in other cases only the recollection process (e.g., Yonelinas, 2001).

The use of the ROC paradigm to study recognition memory has traditionally represented a markedly different way of conceiving the underlying basis of recognition memory. Instead of recognition being defined by qualitatively different subjective states, recognition is defined based on one or more signal-detection processes, typically invoking Gaussian distributions of graded memory evidence (Green & Swets, 1966; Macmillan & Creelman, 2005). To the extent that the distributions of memory evidence for old and new items overlap, performance will necessarily be imperfect, as many test items will be associated with an 'intermediate' familiarity level that cannot reliably be associated with either distribution. The idea that recognition memory is best modeled with signal-detection mechanisms based on graded evidence can be contrasted with an alternative detection approach that was at one time considered favorable, and which emphasizes the role of threshold mechanisms. Threshold models assume that memory evidence is not graded as previously described; rather, recognition is determined probabilistically, such that it either occurs or does not occur on any given trial (for a recent review, see Erdfelder, Küpper-Tetzel, & Mattern, 2011).

The study phase of an ROC paradigm is likely to be similar to any other recognition memory paradigm. In the test phase, however, participants are asked to make graded confidence judgments, often from one to six, with respect to how

sure they are that each test item was previously presented. In a typical experiment of this kind, the response options at the extremes of the scale (e.g., one and six) are taken to indicate that the subject is sure the test item was or was not previously presented; response options two through five indicate graded levels of confidence between these two extremes. Within the context of signal-detection theory, it is assumed that different confidence levels reflect separate response criteria that range from lenient to conservative. Furthermore, items that are perceived to be more familiar and that have more memory strength associated with them are given higher levels of recognition confidence. The confidence rating data for the previously studied targets and the novel lures are plotted on an ROC curve as separate rates of hits versus false alarms, respectively, for all degrees of confidence. By fitting mathematical models to ROC data using maximum likelihood estimation, researchers can compare the suitability of many (sometimes subtly) different signal-detection models for describing recognition memory.

In signal-detection theory, the shape of an ROC graph provides insight into the nature of the underlying memory evidence that gives rise to the ability to discriminate between different classes of items. In general, curvilinear ROC shapes generally imply underlying Gaussian distributions of graded memory evidence, and linear ROC shapes imply discrete recognition states defined based on a specific probability (i.e., threshold models; see Chapter 1 for more detail). Notably, observations that recognition memory ROCs are typically curvilinear (Egan, 1958) were a core reason why the threshold-based models of the 1960s

were eventually rejected (e.g. Krantz, 1969). As observations of curvilinear recognition memory ROCs are now widespread, the majority of researchers correspondingly agree that memory evidence is graded in recognition memory. Despite this, there has been substantial debate with respect to which signal-detection model should be considered most favorable. Although a multitude of signal-detection recognition memory models have been developed, debate in recent years has centered around two particularly well-known and influential competitor models. The first of these, the unequal variance signal-detection model, assumes studied targets and novel lures are each represented with a Gaussian distribution of memory evidence, but with the distribution for the studied targets having larger variance than that for novel lures (for a review, see Wixted, 2007a). By contrast, the dual-process signal-detection model posits that recognition memory is supported by separate recollection and familiarity processes (Yonelinas, 1994, 1999; Yonelinas, Dobbins, Szymanski, Dhaliwal, & King, 1996). This model assumes that familiarity is supported by an equal-variance signal-detection process while recollection is supported by a high-threshold probabilistic process. Thus, the Yonelinas dual-process model incorporates both signal-detection as well as threshold assumptions in its description of recognition memory performance.

Although there has been much focus in the literature surrounding these two recognition memory models, they can be considered representative of a broad distinction in the literature that can be made between recognition memory models that assume one or two retrieval mechanisms (for reviews, see M. W. Brown,

Warburton, & Aggleton, 2010; Malmberg, 2008; Yonelinas, 2002). It is worth

noting, however, that in recent years, even researchers who previously argued for

single-process models are more readily embracing the idea that two processes

contribute to recognition memory (e.g., Wixted, 2007a). An important aspect of

both single-process and dual-process approaches is that they can account for data

collected from the RK paradigm as well as the ROC paradigm in a unified way.

On the one hand, advocates of single-process accounts of recognition memory

generally argue that 'Remembering' and 'Knowing' do not reflect distinct

recognition processes, but simply response criteria that do not differ significantly

from the types of response criteria that confidence judgments represent in ROC

paradigms (e.g. Donaldson, 1996; Wais, Mickes, & Wixted, 2008; Wixted &

Stretch, 2004). On the other hand, Yonelinas and colleagues have shown

performance estimates of recollection and familiarity derived from ROC

paradigms generally agree with those derived from the RK paradigm (Yonelinas,

2001; Yonelinas, Kroll, Dobbins, Lazzara, & Knight, 1998). Regardless of which

of these models should be considered most favorable, an underlying assumption

of both approaches is that they assume recognition memory decisions are to some

extent based on an assessment of familiarity and graded memory strength. Given

that this notion has played such an important role in theorizing in recognition

memory research, a question I ask in my thesis is to what extent such graded

evidence may also support recognition decisions that are tied to a lifetime of

experience, as in the case of famous name recognition. An alternative is that

recognition decisions outside the context of a recognition memory operate strictly

in accordance with threshold mechanisms, with recognition either occurring or not occurring based on discrete recognition probabilities.

1.3 Graded representations

A necessary consequence of memory signals being graded in recognition memory is that some test items neither seem completely unfamiliar, nor do they seem so recognizable that prior occurrence in the earlier study phase can be completely guaranteed by participants. As previously described, such graded memory evidence is mathematically modeled using assumptions derived from signal-detection theory. To anticipate, in Chapter 1, I provide evidence to suggest that Gaussian distributions of graded memory evidence do indeed come into play when participants discriminate between famous and fictional names. That famous name recognition is supported by graded evidence implies that there might be some intermediate state of famous name recognition, whereby names are neither completely unfamiliar, nor confidently identifiable. This is consistent with some aspects of our daily experience; for example, it is not uncommon that names of people seem familiar but at the same time do not provoke retrieval of any semantic details that would allow for identification. Such experiences have been termed 'familiarity-only' experiences in the cognitive psychology literature and have also been the focus of some targeted behavioral investigations (Hanley & Hadfield, 1998; Hanley & Turner, 2000). Moreover, they have been reported in some diary studies focused on the memory errors that people make in daily life that are related to person recognition (Young, Hay, & Ellis, 1985). Might it indeed be the case that this type of recognition state is reflective of some kind of

graded memory evidence? Furthermore, given that semantic knowledge is generally a critical aspect of what differentiates famous from fictional names, might this state also be reflective of some type of partial semantic knowledge signal that is insufficient for full identification?

Much of what we know about partial semantic knowledge comes from patients who exhibit impairments in semantic knowledge as a result of acquired brain damage. For example, partial knowledge has been well studied in patients with semantic dementia, who exhibit degraded semantic knowledge representations that have been linked to progressive atrophy in the anterior temporal lobes (for a review, see Patterson, Nestor, & Rogers, 2007). A well-known aspect of semantic knowledge impairments in this disorder is that they are characterized by progressive loss of more fine-grained aspects of semantic knowledge, with preservation, at early stages of the disease, of courser aspects of semantic knowledge representations. For example, semantic dementia patients are known to name objects at their superordinate category level (e.g. furniture) rather than the more appropriate basic category level (e.g. sofa) when these are presented visually or when they are verbally described (e.g., Warrington, 1975). Further, they tend to retain broader knowledge that pertains to categories, such as the fact that vegetables are often green, but not more fine-grained knowledge, such as the fact that tomatoes are red (Rogers, Patterson, & Graham, 2007). Notably, similar effects have been documented in knowledge in Alzheimer's patients (e.g. Crutch & Warrington, 2006; Hodges, Salmon, & Butters, 1992), as well as patients with Herpes Simplex Encephalitis (Warrington & Shallice, 1984).

Thus, partial semantic knowledge is likely to be a general aspect of semantic knowledge breakdown when it occurs rather than a specific property of impairments seen in semantic dementia.

In normal individuals, partial semantic knowledge has been less commonly documented than in patient work. One recent study, however, showed that partial semantic knowledge representations might apply in the same way to both patients and normal individuals (Crutch & Warrington, 2006). These authors compared the integrity of semantic knowledge representations for abstract words in normal individuals with both those of patients with semantic dementia and also those with Alzheimer's disease. In three tasks, which assessed abstract word knowledge at varying levels of specificity, participants were asked to make forced-choice judgments that required matching an abstract target word with a synonymous word. The synonym was presented alongside a distractor word with a different meaning, and on each trial the participants were asked to select the synonym of the target word that was presented above. In three tasks of this type, the distractor was either a word with similar meaning to the synonym, an unrelated word, or a word with an opposite meaning. The task is considered to be most difficult when the synonym is presented alongside a closely related distractor, as the most fine-grained representation possible is necessary in this case to distinguish the synonym from the distractor. As the researchers predicted, this latter version of the task was associated with the lowest performance in semantic dementia patients as well as in Alzheimer's patients. By contrast, the

version in which the synonym was presented alongside a distractor with an opposite meaning was associated with the highest performance.

The general assumption that the authors adopted is that a partial knowledge representation for an abstract word may permit distinguishing it from words with entirely dissimilar meaning, but not from words that exhibit a closely related meaning. An interesting aspect of their findings was that this general pattern was also clearly present in normal participants, only to a lesser degree. As argued by Warrington and Crutch (2006), "partial knowledge effects constitute a normal phenomenon but that such effects are exacerbated in the context of neurodegenerative disease" (p. 486). Given that this effect was documented in normal participants who presumably exhibited no obvious semantic knowledge breakdown, this suggests partial semantic knowledge representations may potentially reflect situations in which participants had sufficient exposure to an item to pick up some familiarity and associated knowledge, but an insufficient amount to form the most fine-grained representation possible. As Warrington & Crutch (2006) state,

> Intuitively it seems highly plausible that abstract word knowledge comprises varying levels of specification, as many individuals will have words on the periphery of their vocabulary (determined by education and experience) that are familiar but for which they would not be able to provide a detailed definition. (p. 483)

The first broad point that this study highlights is that semantic representations for words may sometimes exist in an intermediate state, neither fully formed nor completely absent. Further, the authors also suggest a plausible way in which semantic representations may come to exist in this way. Importantly, it seems reasonable to suggest that similar mechanisms could also come into play in the case of famous name recognition. Similar to words, some famous names may be associated with a state of partial knowledge, which may yield feelings of familiarity but not full identification when the name is presented.

1.4 Famous name recognition as a model

In the current thesis, I aimed to address the role of graded evidence, and partial semantic representations, in subjective experiences of familiarity for famous names. An advantage of using famous names for this purpose is that several cognitive models have been developed in the literature that describe the separate mechanisms by which familiarity is assessed and by which semantic knowledge is retrieved for people (e.g. Brédart, Valentine, Calder, & Gassi, 1995; Burton, Bruce, & Johnston, 1990; Valentine, 1996). In earlier models of person recognition, it was posited that familiarity is registered at structural, modality-specific recognition units for faces (FRU), names (NRU), or voices (VRU; Bruce & Young, 1986; Hay & Young, 1982). Such modality-specific model units were postulated to connect to person identity nodes (PIN) that support semantic identification of the familiar person, which in turn interconnect with other units important for name generation. In later implementations developed within the Interaction Activation and Inhibition (IAC) connectionist modeling framework

(McClelland & Rumelhart, 1981), distinct semantic identification units (SIU) were incorporated to represent different types of semantic information, such as occupation or nationality (Burton, et al., 1990). Importantly, in such models, each SIU is bi-directionally connected with all PIN nodes that correspond to people who exhibit the semantic property represented by the given SIU in question. An important aspect that distinguishes these more recent models from earlier models of person recognition (e.g., Bruce & Young, 1986; Hay & Young, 1982) is that familiarity assessment only takes place at a level after all modalities (e.g., faces, names, voices, etc) have converged, rather than at the modality-specific level (for reviews, see Gainotti, 2007a; Young & Burton, 1999).

A distinction between mechanisms to register familiarity for people and mechanisms to access pertinent semantic knowledge about them has partly been motivated by 'familiarity-only' experiences, as previously described. Formally, this type of experience is defined by a subjective sense of familiarity in response to a stimulus (e.g., face, voice, name) that refers to a famous person, but an absence of any ability to recall associated semantic information about them. Interestingly, many patients have been documented in the literature who exhibit preserved abilities in detecting familiarity for famous names, but relative difficulties in retrieving knowledge related to these stimuli. Patients exhibiting this general pattern have been documented to exhibit diverse etiologies, including semantic dementia (patient ST; Giovanello et al., 2003), memory loss resulting from treatment for a vasculitic disorder (patient ME; de Haan & Young, 1991), Herpes Simplex Encephalitis (patient RFR; Crutch & Warrington, 2006;

Warrington & McCarthy, 1988), a left temporal stroke (patient DEL; Verstichel, Cohen, & Crochet, 1996), and widespread fronto-occipital cortical and hippocampal damage resulting from a closed head injury (patient KC; Westmacott & Moscovitch, 2001).

Notably, in some cases, the patients documented to have preserved familiarity but impaired access to pertinent semantic knowledge still exhibited some signs of residual partial knowledge. One well-studied example is patient KC, who became densely amnesic as a result of a head injury associated with a motorcycle accident that caused wide-spread damage to the brain, including bilateral destruction of the hippocampus, a lesion in the right occipital cortex, as well as a lesion in the left fronto-parietal cortex. Westmacott & Moscovitch (2001) examined the extent to which KC was able to acquire new knowledge about famous names since his brain injury approximately twenty years earlier. They specifically tested his ability to recognize the names of famous celebrities who had become famous since his injury, as well as express semantic knowledge about them. Most notably, for names KC could recognize as familiar, semantic knowledge was found to be at chance when probed through explicit recall of occupation. Yet, his occupation knowledge was found to be well above chance when he was asked to make occupation forced-choice judgments. In other words, KC's famous name knowledge was insufficient to permit free recall of occupations, but sufficient to support above-chance performance on a forced-choice task which required choosing an appropriate occupation from among other occupation distractors. Importantly, this suggests that KC's brain tissue may have

permitted the acquisition of only partial and not fully formed semantic

representations for famous names since his injury.

Another example is patient DEL, who presented with damage to the lateral

occipito-temporal gyrus, the cortex lining the collateral sulcus, and the body of

the hippocampal formation, as a result of a left-sided stroke (Verstichel, et al.,

1996). A main problem with patient DEL's memory after the stroke was that he

exhibited a selective impairment in the comprehension and the production of

people's names, but not of people's faces nor of any other type of names (e.g.

landmarks). While Patient DEL was able to accurately pick out famous names

from among non-famous distractors based on familiarity, he was severely

impaired in retrieving pertinent semantic information for the ones he found

familiar. Instead, he often generated non-specific, partial biographical

information, such as, "it tells something to me ... I think he's involved in politics

... his name is probably anglosaxon, but I don't know exactly who he is ...I cannot

imagine his face" (p. 226). Interestingly, DEL exhibited more fully preserved

recovery of semantic information in response to famous face stimuli and also

when given phonological cues, suggesting that his primary deficit may reside in

the link between the lexical representations for famous names and the conceptual

knowledge associated with them. Interestingly, both Westmacott & Moscovitch

(2001), as well as Verstichel (1996) argued that the verbal lexicon necessary for

famous name recognition in patients KC and DEL was intact despite markedly

absent or inaccessible associated semantic knowledge. In the case of patient DEL,

fully formed semantic knowledge was detectable if cued based on a different type

of stimulus (e.g. faces), while in the case of KC only degraded implicit knowledge

could be detected, even using other methodologies.

1.5 Neural correlates of person recognition

Case reports of preserved familiarity with impaired access to fully formed

semantic knowledge raise the question as to what brain regions are implicated in

recognizing people more broadly. A substantial body of patient- and

neuroimaging-based research suggests the anterior temporal lobes (ATL) play an

important role in various processes involved in person-recognition, including the

registration of feelings of familiarity, the access of pertinent conceptual

knowledge, and naming individuals, typically in response to the presentation of

their face (Bruce & Young, 1986; Burton, et al., 1990). Gainotti (2007) reviewed

six neuropsychological studies that documented impairments of person

recognition in patients with intractable epilepsy and who had undergone resection

of either the left or the right ATLs as a surgical intervention (i.e., anterior

temporal lobectomy). He noted in his review that patients who had undergone a

right-sided ATL resection tended to have pronounced impairments in recognizing

famous faces on the basis of familiarity. It was argued that the right ATL plays a

particularly important role in supporting the perceptual representations that allow

for subjective feelings of familiarity in response to faces. While there are some

reports of patients with left ATL damage who have more impaired familiarity for

names than for faces (Eslinger, Easton, Grattan, & Van Hoesen, 1996; Snowden,

Thompson, & Neary, 2004), Gainotti (2007) found that in general, an analogously

selective impairment in famous name familiarity in patients with left ATL

damage was not observed. This pattern either suggests that name familiarity is not as lateralized as face familiarity, or perhaps that name recognition may not be as dependent on the most anterior extent of the temporal lobe. Consistent with some previous influential work (e.g., Damasio, Grabowski, Tranel, Hichwa, & Damasio, 1996), Gainotti (2007) observed that left ATL patients tended to exhibit the most pronounced impairments in producing a name in response to visually presented faces.

The functional neuroimaging literature on person-recognition provides support for a role of the anterior temporal lobes as well. Recent neuroimaging research suggests the left ATL not only supports naming abilities but also the representation of verbal semantic information for people, such as associations between names and associated occupations (Tsukiura, Mochizuki-Kawai, & Fujii, 2006; Tsukiura et al., 2011). This work has also suggested that there may be functional segregation in the left ATLs depending on the type of person knowledge that is being learned and recalled. In a recent study examining the role of the left ATL in person recognition, Brambati et al. (2010) found that the left ATL was preferentially engaged during the recall of specific as compared to superordinate semantic knowledge that pertained to faces (Brambati, Benoit, Monetta, Belleville, & Joubert, 2010). In general, this is consistent with research conducted with semantic dementia patients, which overall suggests that the ATLs may play a particularly important role in representing specific as compared to more general information (Patterson, et al., 2007; see also Rogers et al., 2006). Other investigators reject this interpretation of ATL functioning, however, and

argue this region preferentially supports social and emotional processing with respect to people specifically (Simmons, Reddish, Bellgowan, & Martin, 2009).

As person recognition involves many different processes (e.g., familiarity assessment, semantic knowledge retrieval, naming), it is challenging to make general statements about which brain regions contribute to person recognition generally (for discussion, see Nielson et al., 2010; Tranel, Feinstein, & Manzel, 2011). In most neuroimaging studies of person-recognition, researchers have typically focused on only one of the many components of person-recognition; thus, the existing studies are unsurprisingly varied with respect to the brain regions that have been implicated. In some studies, comparisons have been made between brain activity that is associated with recognizing known famous celebrities and activity associated with recognizing known, personally familiar individuals so as to understand the emotional components of person recognition (Shah et al., 2001; Sugiura, Sassa, Watanabe, & Akitsuki, 2006; Sugiura et al., 2009). These studies have commonly highlighted the precuneus and posterior cingulate as critical structures involved in recognizing people that participants know personally. In other cases, the neural correlates of famous-name recognition have been explicitly compared with those that support famous face recognition in order to dissociate brain structures that support modality-specific representations (e.g., faces versus names) from those that support a common source of semantic knowledge that may be accessed across modalities (Campanella et al., 2001; Gorno-Tempini et al., 1998; Nielson, et al., 2010; Sergent, MacDonald, & Zuck, 1994). In general, these studies have isolated lateralized differences in visual

areas for the recognition of famous names and faces, with preferential support in the left and right hemispheres, respectively. They also implicate primarily left-sided temporal regions in face and name recognition, suggesting that the brain regions that support semantic knowledge for people across modalities may to some extent be lateralized to the left hemisphere. This would be consistent with a recent meta-analysis of the semantic memory literature, which also indicates that the representation of semantic knowledge more broadly (i.e. beyond that pertaining to people) is localized more in the left than in the right hemisphere (Binder, Desai, Graves, & Conant, 2009).

More recently, the concept of autobiographical significance has become recognized as a critical component of famous name and face recognition (Westmacott, Black, Freedman, & Moscovitch, 2004; Westmacott & Moscovitch, 2003). For example, for John Lennon, a participant may be able to recall a particular experience of watching him on television, or of hearing about his assassination. For other people without autobiographical significance, only factual details such as occupation information, which are not tied to any specific event, might be available. Westmacott & Moscovitch (2003) reported that famous names with autobiographical significance are associated with processing benefits on a number of cognitive tasks, including dichotomous famous / non-famous judgments and delayed recognition. In one recent fMRI study, researchers attempted to dissociate the semantic and episodic components of person recognition by asking participants whether they could recall an episodic memory in response to a famous name or face, or whether they could only recall factual

details that pertain to it (Denkova, Botzung, & Manning, 2006). Consistent with theoretical notions that the medial temporal lobe plays a particularly important role in recalling episodic memories that involve spatiotemporal context (e.g. Nadel & Moscovitch, 1997), these authors found the left parahippocampal gyrus was preferentially engaged when an episodic memory could be recalled in response to faces or names but less so when only generic factual details could be recalled. It is also worth noting that medial temporal lobe activation has also been observed in person recognition even in tasks that do not require participants to overtly indicate if they can recall a contextually specific episode (Bernard et al., 2004; Haist, Bowden Gore, & Mao, 2001).

Interestingly, there do not appear to be any published neuroimaging studies of 'familiarity-only' experiences. In most studies of person recognition, participants are usually only asked to indicate whether the names, faces, or voices that are presented to them are familiar (i.e., refer to famous celebrities) or unfamiliar (i.e., refer to non-famous individuals) while undergoing neuroimaging. However, it is worthwhile to note that investigators have typically employed celebrities that are highly famous (e.g., Bill Clinton), and thus participants may, to some extent, retrieve semantic knowledge even if this is not an explicit task requirement for the task at hand. This is particularly relevant for an early, influential Positron Emission Tomography (PET) study that compared brain activation associated with familiarity detection with that associated with making occupation decisions for names and faces (Sergent et al. 1994). This study implicated a common set of brain areas important for both types of judgments,

which included the left middle temporal gyrus and the left inferior prefrontal cortex. However, as only highly famous people were employed, recall of discrete pieces of semantic information may still have occurred in both tasks regardless of whether the task explicitly involved familiarity detection or occupation decisions. In the case of familiarity decisions, accessing available semantic knowledge may be obligatory, as it has been suggested to be in word recognition more broadly (Gold et al., 2006; Neely, 1991). Further, participants may strategically consult their store of semantic knowledge to confirm their suspicion that a familiar name or face indeed refers to a celebrity. Thus, while familiarity decisions for famous names have been examined in past neuroimaging research, 'familiarity-only' experiences, which typically entail a state of familiarity defined by inaccessible semantic knowledge, have not undergone any targeted investigation. Correspondingly, the precise role and anatomical basis of partial knowledge in 'familiarity-only' experiences has also not been investigated systematically.

1.6 Goals, Approach, and Overview

In three separate experimental investigations, I employed recognition paradigms that required participants to discriminate between moderately famous and fictional names based on their general past experience. In each experiment, participants were presented with a list of test items one at a time that comprised targets (i.e., names of famous individuals from media in this case), and lures (i.e., fictional names). Similar to yes-no recognition-memory tasks, participants were asked to discriminate between these two classes of stimuli when they were presented one at a time. One unique aspect of the experimental approach I

employed in my thesis that I specifically avoided the use of highly famous names

that most participants would recognize, such as Bill Clinton. Instead, I used less

famous names that would likely not be confidently recognized by everyone, but at

the same time should commonly be found familiar based on their widespread

exposure in the media (see Table 4-1 for examples). By using only moderately

famous names, I was able to measure in Chapter 2 the signal detection

characteristics that support the ability to discriminate them from fictional names;

critically, this statistical tool is reserved for situations in which discrimination

performance is to some extent imperfect (Macmillan & Creelman, 2005). By

avoiding highly famous names, I also increased the probability of observing and

isolating recognition experiences that were not associated with full identification,

which was critical for Chapters 3 and 4.

As described previously, a critical question I address in Chapter 2 is

whether the type of memory evidence that supports the ability to discriminate

between famous and fictional names is similar to that which supports the ability to

discriminate between previously presented targets and novel lures in recognition

memory. More specifically, as recognition memory is well described by signal-

detection models that employ Gaussian distributions of memory evidence, I

investigate whether this is also the case for participants' discrimination of famous

from fictional names. Similar to an ROC paradigm, I asked participants to rate

their familiarity for famous and fictional names using graded confidence

judgments from one to six, with respect to whether names do or do not refer to a

famous celebrity from the media. One pertinent issue to consider with respect to

this general approach is that it is impossible to guarantee that participants ever had any exposure to the famous names in the first place. This issue must be given careful consideration because this means that it is impossible to tell which aspects of participants' recognition performance are related to encoding and retrieval abilities, and which are related to the presence or absence of any opportunity to encode the famous names in the first place. By contrast, this issue is not a concern in recognition memory, as participants are presented with all the target stimuli in a systematic manner in the study phase. Indeed, the tight control that the recognition memory paradigm confers over the study phase is likely an important reason why researchers have heavily relied upon this paradigm in past research. In the signal-detection model that I employed, I allowed for the effect of lack of exposure by including separate distributions of memory evidence to represent famous names that were and that were not associated with any prior exposure.

In Chapter 3, I aimed to understand the contribution of semantic knowledge to graded familiarity in the context of the signal-detection model I developed in Chapter 2. Given that only famous (and not fictional) names may be associated with some semantic knowledge, what role does the availability of this knowledge play in participant's sense of familiarity for names? The specific focus of Chapter 3 is with respect to the availability of semantic knowledge during experiences in which famous names seem familiar to participants, but do not provoke recall of any contextual details (i.e., the 'name rings a bell'). The paradigm that I used is similar to an RK paradigm, to the extent that it involves isolation of a state of recognition defined by familiarity with no recall of discrete

details. For each famous and each fictional name, participants indicated whether each name was unfamiliar, just rang a bell, or could be identified based on a discrete semantic detail. To examine the role of partial knowledge in 'name ring a bell' experiences, I presented participants with the famous names that they previously indicated rang a bell in a second experimental stage. Specifically, in this stage, participants were required to make occupation forced-choice judgments that required assessing which of several potential occupation options most likely pertained to each of the famous names that they had previously made recognition judgments for. In the latter experiments reported in Chapter 3, I also investigated further the link between familiarity and semantic knowledge by examining whether participants have any awareness of the veracity of the occupation forced-choice judgments that are associated with 'name rings a bell' responses. In doing so, I aimed to examine whether participants might even have some awareness of the presence of the availability of semantic knowledge during 'name rings a bell' experiences.

To anticipate, we clearly documented a link between 'name rings a bell' recognition experiences and available semantic knowledge in Chapter 3. In Chapter 4, I use brain imaging to investigate whether any actual access of semantic knowledge takes place at the moment participants find that names ring a bell. This question is challenging to address based on a behavioral paradigm alone, as we cannot ask participants to make judgments about their semantic knowledge at the same time as they make 'name rings a bell' judgments. The use of functional magnetic resonance imaging, however, permits a means to

separately isolate brain networks associated with 'name rings a bell' experiences, as well as for the successful access of semantic knowledge, and then examine the extent to which these networks share brain regions in common. The experimental approach that I employed in this study involved two stages. In the first stage, participants made recognition judgments in the same way that they had in our prior behavioral investigation (i.e., with 'unfamiliar, ' name rings a bell', or 'identify' responses). In the second stage, we asked participants to make occupation forced-choice decisions for a separate set of famous names. Using data from both experimental stages, we defined a network of brain regions that supported the ability to successfully retrieve semantic knowledge; subsequently, we examined the extent to which 'name rings a bell' recognition responses engaged this network more so than corresponding 'unfamiliar' responses.

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2 Discriminating Famous from Fictional Names based on Long-term Life Experience: Evidence in Support of a Signal-Detection Model based on Finite Mixture Distributions

2.1 Abstract

It is widely accepted that signal detection mechanisms contribute to item-recognition memory decisions that involve discriminations between targets and lures based on a controlled laboratory study episode. Here, we employed mathematical modeling of receiver operating characteristics (ROC) to determine whether and how a signal-detection mechanism contributes to discriminations between moderately famous and fictional names based on lifetime experience. Unique to fame judgments is a lack of control over participants' previous exposure to the stimuli deemed 'targets' by the experimenter; specifically, if they pertain to moderately famous individuals, participants may have had no prior exposure to a substantial proportion of the famous names presented. We adopted established models from the recognition memory literature to examine the quantitative fit that could be obtained through the inclusion of signal detection and threshold mechanisms for two datasets. We first established that a signal detection process operating on graded evidence is critical to account for the fame judgment data we collected. We then determined whether the graded memory evidence for famous names would best be described with one distribution with greater variance than that for the fictional names, or with two finite mixture distributions for famous names that correspond to items with or without prior

exposure, respectively. Our analyses revealed that a model that included a d'

parameter, as well as a mixture parameter, provided the best compromise between

number of parameters and quantitative fit. Additional comparisons between this

equal-variance signal-detection mixture model and a dual-process model, which

included a high-threshold process in addition to a signal-detection process, also

favored the former model. In support of our conjecture that the mixture parameter

captures participants' prior experience, we found that it was increased when the

analysis was restricted to names in occupational categories for which participants

indicated high exposure.

2.2 Introduction

One of the most elementary ways to probe declarative long-term memory is

to examine the ability to recognize stimuli that have been encountered previously.

A large body of research has been conducted with an attempt to characterize the

discrimination processes involved in recognition-memory experiments using

receiver-operating-characteristics (ROC; for recent reviews see Wixted, 2007a;

Yonelinas & Parks, 2007). Participants are typically presented with a set of target

items in a study phase, and are later asked to discriminate between these items

and novel intermixed lures in a test phase. While ROC data can be gleaned from

such paradigms in many ways, most commonly, participants must rate their

confidence that each item was, or was not, encountered in the earlier study phase

on a graded scale, with each response option reflecting a different response

criteria. Debate regarding which model of discrimination processes best accounts

for ROC data from recognition memory experiments has been active, and

sometimes heated, since the first mathematical models were developed more than 50 years ago (e.g. Egan, 1958). Today, the extant models can be grouped into those that rely on signal detection mechanisms, threshold assumptions, or a hybrid of both (Yonelinas & Parks, 2007); further, these models differ in terms of whether they assume one or more than one retrieval process. Signal detection models assume that targets and lures have graded memory strength, and are represented by overlapping Gaussian distributions (Green & Swets, 1966; Macmillan & Creelman, 2005; Wickens, 2002). Although there is no unanimous agreement (e.g., Bröder & Schütz, 2009), most researchers agree that threshold mechanisms by themselves are insufficient to account for item-recognition memory, and that any successful model requires the inclusion of signal-detection mechanisms.

The purpose of the current article is to examine the discrimination processes involved in recognition outside the laboratory, which includes situations such as perceiving a name or a face of a famous person as familiar. In past research, it has often been assumed that recognition based on a discrete study episode in item-recognition memory paradigms provides a means to model recognition that arises out of a lifetime of experience (Atkinson & Juola, 1974, p. 241; Mandler, 1980). The recognition memory paradigm is clearly a convenient means to study recognition processes, as it permits precise experimental control over participants' exposure to the target stimuli and references a specific study episode at the retrieval stage. However, for this very reason it may not be particularly well suited to model 'real-life' recognition decisions that are not tied

to a controlled, discrete study episode, but instead to potentially multiple episodes, which participants may or may not be able to recollect and which may remain temporally undefined to them. While some cognitive theories explicitly postulate similarities in mechanisms between these two types of situations (e.g. the SAC model: Diana, Reder, Arndt, & Park, 2006; Reder et al., 2000), the extent to which they are indeed similar in terms of discrimination processes has largely been unexamined. Most importantly, perhaps, it is even unclear whether the most basic aspect of decisions in item-recognition memory experiments, namely that they are supported by an underlying memory signal that is graded in nature, also characterizes recognition decisions made outside the laboratory.

To investigate the discrimination processes involved in everyday recognition, we presented participants with a selected set of moderately famous names, intermixed with matched fictional names, and asked them to rate their confidence that each name referred to a famous person from the media. By modeling famous names as targets, and fictional names as lures, we were able to examine the discrimination processes that differentiate famous from fictional names using the same analytical and statistical techniques employed in past research on recognition memory that involved a study phase in the laboratory. Specifically, we employed maximum likelihood estimation to model our data with reference to well-established threshold and signal-detection discrimination mechanisms derived from the recognition memory literature.

Inherent in the approach that employs fame judgments to probe real-life recognition is the notion that participants' life experience with the famous names

(i.e., target stimuli) is reflected in their memory strength or familiarity, which provides the basis for discriminating them from non-famous, fictional names (i.e. the lure stimuli). As a result, unlike in recognition memory paradigms, where stimulus exposure is controlled, participants may never have had any exposure at all to some of the famous names deemed target stimuli by the experimenter. How might this lack of exposure be reflected in the distributions that represent memory evidence for famous names overall? Given that some of the famous names for which participants have had no exposure are likely to be associated with particularly low memory evidence as compared to famous names with exposure, the variance in the distribution of evidence for famous names overall is likely to be greater than that for fictional names. This scenario could perhaps be captured through an unequal-variance signal detection (UVSD) model, i.e. one of the more popular models in the recognition-memory literature (Wixted, 2007a). However, given that exposed and non-exposed items can be seen to reflect two distinct classes of target stimuli, it is more likely that famous names may in fact be better described with two Gaussian distributions, rather than a single Gaussian distribution with greater variance. As famous names with no exposure are not associated with any specific memory evidence generated by prior experience, they should be represented with the same distribution of memory evidence as fictional names. In contrast, famous names with exposure should be represented as a distribution with increased memory strength.

To discern whether one distribution with greater variance or two separate distributions best describes the memory evidence for famous names, we first

Table 2-1: Equations for the UVSD Mixture Model

Famous

$P(R = 1) = (1 - \lambda)*\Phi(c_1, 0, 1) + \lambda*\Phi(c_1, d', \sigma_{FAM})$

$P(R = 2) = (1 - \lambda)*(\Phi(c_2, 0, 1) - \Phi(c_1, 0, 1)) + \lambda*(\Phi(c_2, d', \sigma_{FAM}) - \Phi(c_1, d', \sigma_{FAM}))$

$P(R = 3) = (1 - \lambda)*(\Phi(c_3, 0, 1) - \Phi(c_2, 0, 1)) + \lambda*(\Phi(c_3, d', \sigma_{FAM}) - \Phi(c_2, d', \sigma_{FAM}))$

$P(R = 4) = (1 - \lambda)*(\Phi(c_4, 0, 1) - \Phi(c_3, 0, 1)) + \lambda*(\Phi(c_4, d', \sigma_{FAM}) - \Phi(c_3, d', \sigma_{FAM}))$

$P(R = 5) = (1 - \lambda)*(\Phi(c_5, 0, 1) - \Phi(c_4, 0, 1)) + \lambda*(\Phi(c_5, d', \sigma_{FAM}) - \Phi(c_4, d', \sigma_{FAM}))$

$P(R = 6) = (1 - \lambda)*(1 - \Phi(c_5, 0, 1)) + \lambda*(1-\Phi(c_5, d', \sigma_{FAM}))$

Fictional

$p(R = 1) = \Phi(c_1, 0, 1)$

$p(R = 2) = \Phi(c_2, 0, 1) - \Phi(c_1, 0, 1)$

$p(R = 3) = \Phi(c_3, 0, 1) - \Phi(c_2, 0, 1)$

$p(R = 4) = \Phi(c_4, 0, 1) - \Phi(c_3, 0, 1)$

$p(R = 5) = \Phi(c_5, 0, 1) - \Phi(c_4, 0, 1)$

$p(R = 6) = 1 - \Phi(c_5, 0, 1)$

Note: $p(R = i)$ denotes the probability of response category i $(i = 1,2,...,6)$; Φ denotes the cumulative Gaussian distribution function; d' denotes the separation in standard deviation units between the distribution for famous names with exposure and that for fictional names; λ denotes the proportion of famous names to which the participant has been exposed; σ_{FAM} represents the standard deviation of the famous name distribution with exposure; and c_k is a memory strength criterion set by the participant for each level of memory strength
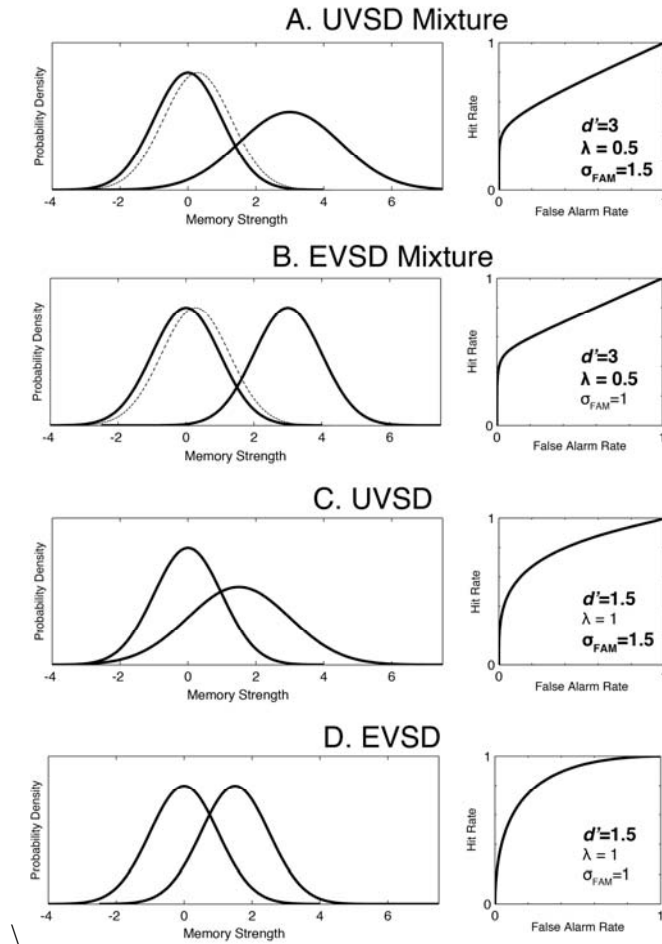
Figure 2-1: Visual illustration of the UVSD mixture model and associated nested models in terms of Gaussian distributions and associated ROC plots.

Values of freely varying parameters are indicated in bold and set for visual illustration only. The UVSD mixture model (A, full model) includes three freely varying theoretically relevant parameters (d', λ, and σ_{FAM}). Setting σ_{FAM}=1 yields the EVSD mixture model (B) and setting λ=1 yields the UVSD model (C), respectively. Setting both σ_{FAM}=1 and λ=1 yields the EVSD model (D). In A and B the distribution of famous names with no exposure is depicted by a slightly offset broken line, and has an identical mean strength and variance to the adjacent fictional name

modeled the discrimination of famous from fictional names using a signal

detection model that includes both components. Specifically, the model we

employed includes one parameter that defines the proportion of famous names

associated with prior exposure, and one parameter that defines the ratio between

the variance of the famous name distribution with exposure and the variance of

the distribution for fictional names. Mathematically, this full model can be

described as an unequal variance signal detection model with finite mixture

distributions (henceforth labeled the UVSD mixture model; see Figure 1a, and

Table 1 for full model equations). The generalized equation for the proportion of

endorsed famous names in this model is given by:

$$p(\text{ 'yes' } \leq \text{ k } | \text{ 'famous'}) = (1- \lambda)\Phi(c_k, 0, 1) + \lambda\Phi(c_k, d', \sigma_{FAM})$$

Here Φ denotes the Gaussian distribution function; d' represents the distance in

memory strength between the distribution for famous names with exposure and

that for fictional names; λ denotes the proportion of famous names to which the

participant has been exposed (ranging from 0 to 1); σ_{FAM} represents the standard

deviation of the famous name distribution with exposure (constrained to be

greater than the fictional name distribution, arbitrarily set to 1); and c_k is a

memory strength criterion set by the participant for each level of memory

strength. The generalized equation for the proportion of endorsed fictional names

in this model is given by:

$$p(\text{ 'yes' } \leq k \mid \text{ 'fictional' }) = \Phi(c_k, 0, 1)$$

In the current model, when $\sigma_{FAM} = 1$, the variance of the famous name distribution with exposure becomes equal in variance to the fictional name distribution. It is worth noting that this two-parameter model, which we label the equal-variance signal detection (EVSD) mixture model, has been suggested previously to account for recognition memory by DeCarlo (2002; see Discussion for further detail). Setting $\lambda=1$ in the UVSD mixture model yields the UVSD model, which some researchers favor as the most suitable model of recognition memory in the literature (e.g. Wixted, 2007a). Restricting both $\lambda=1$ and $\sigma_{FAM}=1$ yields the simplest signal detection model, the EVSD model, which is often considered to be the most basic framework of signal detection theory (Green & Swets, 1966; Macmillan & Creelman, 2005; Wickens, 2002). Figure 1 illustrates these models in terms of Gaussian distributions and corresponding idealized ROC plots. Here, we evaluated the fit of the proposed UVSD mixture model, and compared it with its associated nested models: the EVSD mixture model, the UVSD model, and the EVSD model, with particular emphasis on the former two nested models, given the limited ability of the EVSD model to provide a good fit. Specifically, we examined the relative importance of the two most important parameters of interest (λ and σ_{FAM}) by comparing the full UVSD mixture model with the two models where each of these two specific parameters is restricted in isolation (i.e. the UVSD and EVSD mixture models, respectively).

Table 2-2: Equations for the DPSD Mixture Model

Famous

$p(R = 1) = T + (1 - T)*((1 - \lambda)*\Phi(c_1, 0, 1) + \lambda*\Phi(c_1, d', 1))$
$p(R = 2) = (1 - T)*((1 - \lambda)*(\Phi(c_2, 0, 1) - \Phi(c_1, 0, 1)) + \lambda*(\Phi(c_2, d', 1) - \Phi(c_1, d', 1)))$
$p(R = 3) = (1 - T)*((1 - \lambda)*(\Phi(c_3, 0, 1) - \Phi(c_2, 0, 1)) + \lambda*(\Phi(c_3, d', 1) - \Phi(c_2, d', 1)))$
$p(R = 4) = (1 - T)*((1 - \lambda)*(\Phi(c_4, 0, 1) - \Phi(c_3, 0, 1)) + \lambda*(\Phi(c_4, d', 1) - \Phi(c_3, d', 1)))$
$p(R = 5) = (1 - T)*((1 - \lambda)*(\Phi(c_5, 0, 1) - \Phi(c_4, 0, 1)) + \lambda*(\Phi(c_5, d', 1) - \Phi(c_4, d', 1)))$
$p(R = 6) = (1 - T)*((1 - \lambda)*(1 - \Phi(c_5, 0, 1)) + \lambda*(1 - \Phi(c_5, d', 1)))$

Fictional

$p(R = 1) = \Phi(c_1, 0, 1)$
$p(R = 2) = \Phi(c_2, 0, 1) - \Phi(c_1, 0, 1)$
$p(R = 3) = \Phi(c_3, 0, 1) - \Phi(c_2, 0, 1)$
$p(R = 4) = \Phi(c_4, 0, 1) - \Phi(c_3, 0, 1)$
$p(R = 5) = \Phi(c_5, 0, 1) - \Phi(c_4, 0, 1)$
$p(R = 6) = 1 - \Phi(c_5, 0, 1)$

Note: T denotes the proportion of famous names endorsed within a probabilistic high-threshold process. All other parameters as per the UVSD mixture Model (see Table 1).

While the models discussed so far are limited to the inclusion of signal-detection mechanisms, some models in recognition memory, most notably the dual-process signal-detection model (DPSD), invoke both types of detection processes. The DPSD model includes two independent processes that contribute to discrimination: recollection, which is reflected as the proportion of recognized targets in the context of a single high-threshold discrimination process, and familiarity, which is reflected in an equal-variance signal detection process (Yonelinas, 1994, 1999). Recollection is reflected in recognition associated with recall of contextual details, while familiarity is associated with recognition in the absence of such recall. The DPSD model has been closely compared to the UVSD model in the literature (e.g. Parks & Yonelinas, 2007; Wixted, 2007b), and often provides comparable results at the level of quantitative fit. Given the popularity of the DPSD model, and given prior evidence suggesting that recollection can contribute to fame judgments (Piolino, Lamidey, Desgranges, & Eustache, 2007; Westmacott & Moscovitch, 2003), we also performed our analyses with a DPSD mixture model. In the DPSD mixture model that we employed, instead of allowing the famous name distribution with exposure to have a greater variance than the fictional distribution, we allowed for the contribution of an independent high-threshold process. The generalized equation for the proportion of endorsed famous names in this model is given by:

$$p(\text{ 'yes' } \leq \text{ k } | \text{ 'famous'}) = T + (1 - T)*((1 - \lambda)*\Phi(c_1, 0, 1) + \lambda*\Phi(c_1, d', 1))$$

Here, *T* corresponds to recollection, or the proportion of famous names detected via a high-threshold process (fictional names identical to preceding full model; see Table 2 for full model equations). If one sets $\lambda=1$ then mathematically the model collapses into the DPSD model; moreover, setting $T = 0$ yields the EVSD mixture model previously described. By examining various nested models within this full model, we directly compared the importance of a mixture parameter (λ) and a parameter that denotes the proportion of accurately recognized targets within the context of a high-threshold process (*T*).

2.3 Experiment 1

2.3.1 Participants

Seventeen University of Western Ontario students (7 females) with a mean age of 24.7 years (range 18-32 years) participated in the study and were compensated for their time. Two participants were removed from the analysis because they confidently recognized less than 10 percent of the famous names presented. The study received expedited research ethics approval in the Psychology Department at the University of Western Ontario.

2.3.2 Materials

Three hundred and five famous names were acquired from Internet websites (e.g. www.canadians.ca, www.wikipedia.org, www.imdb.com). Celebrities were sampled from various nationalities but we ensured that each of them had a high likelihood of some media exposure in the country where the
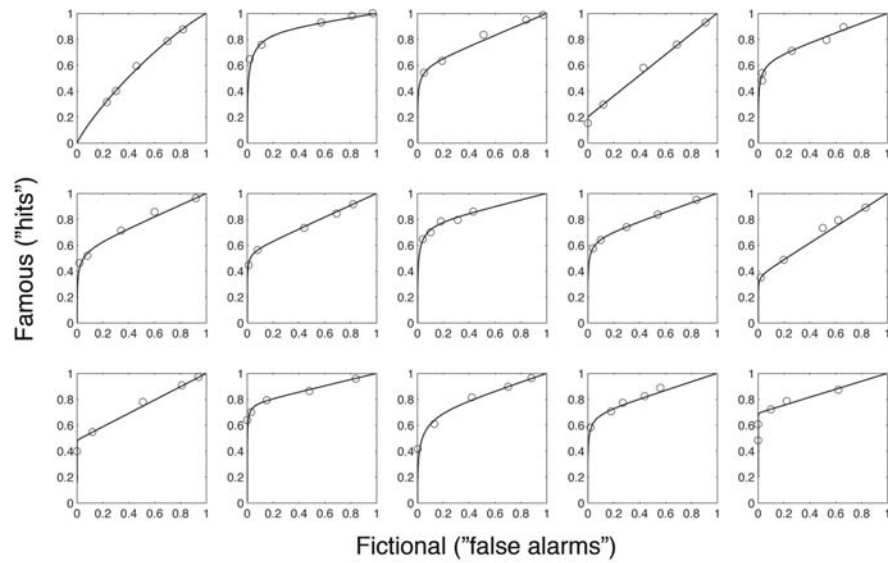
Figure 2-2: Raw ROC data fitted with EVSD mixture model

Each participant's empirical raw ROC data superimposed on the best-fitting
EVSD mixture model fit plotted for data from Experiment 1. Hit and false alarm
rates reflect the proportions of famous and fictional names that exceed the
memory strength designated by each of the five response criteria.

study was conducted (i.e. Canada). At the same time, names corresponding to individuals that would likely elicit confident recognition by every participant (e.g. Barack Obama) were avoided. Chosen famous names were sampled broadly from different categories, namely business people (e.g. Ross Perot), comedians (e.g. Howie Mandel), models (e.g. Lauren Hutton), authors (e.g. Alice Munro), film actors (e.g. Meryl Streep), politicians (e.g. Michael Ignatieff), athletes (e.g. Ed Belfour), TV actors (e.g. Cynthia Nixon), musicians (e.g. Carrie Underwood), and people that did not fit clearly into any of the above categories (e.g. Roberta Bondar, i.e. Canada's first female astronaut). Using the Wikipedia online encyclopedia (http://www.wikipedia.org), all names were checked to ensure that they corresponded to a famous person that became famous after WWII and were not well known in the media based on a middle name (e.g. Billy Bob Thornton). Ninety-five fictional names were created by randomly combining first and last names from the U.S. Census Bureau 1990 database (http://www.census.gov/genealogy/www/). Famous and fictional names were matched on the total number of letters and syllables, and the sum frequency of first and last names based on information acquired from the U.S. Census database. We ensured no fictional names inadvertently referred to famous names by verifying that the name was not associated with a specific entry in the Wikipedia online encyclopedia.

2.3.3 Experimental Procedure

Participants were told that they would view a list of names composed of approximately three-quarters famous names and one-quarter fictional names. It

was made clear that famous names referred to the names of famous people that participants might have encountered in the media and that fictional names referred to random combinations of first and last names that did not refer to a publicly known individual. Famous and fictional names were presented to participants in a random order one at a time in the center of a computer screen using E-Prime software (Psychology Software Tools, Inc, www.pstnet.com). Participants were required to make recognition decisions and to indicate their confidence in these decisions; using a computer keyboard, participants made their judgments by responding on a scale from 1 ("sure the name is fictional") to 6 ("sure the name is famous"); responses 2 through 5 were used for intermediate degrees of confidence. Responses were given in a self-paced manner, and a sheet with a visual depiction of the response options was visible at all times during the experiment.

After completing the recognition-confidence ratings for all famous names, participants were asked to rate their relative degree of perceived day-to-day exposure to the nine different aspects of the media associated with the nine occupations listed above (e.g. 'sports' for athletes, etc). Specifically, participants were asked to rank-order the different media domains based on their perceived lifetime exposure.

2.3.4 Modeling Approach

First, we used maximum likelihood estimation to fit each participant's data separately to various discrimination models derived from the recognition

memory literature. We concentrated on the examination of ROC at the individual

subject level based on research showing that artifacts can be introduced when

ROC data are averaged (Malmberg & Xu, 2006). Optimizations were performed

using the 'fminunc' function in MATLAB (The Mathworks, Inc,

www.mathworks.com), employing several different parameter starting values;

optimizations were also validated using Excel Solver (Frontline Systems, Inc,

www.solver.com). Additional visual examinations were conducted to ensure that

each model fit matched each participant's empirical raw data (see Figure 2 for

raw data and superimposed model fits obtained with the EVSD mixture model).

For each fit, we minimized the negative log likelihood of the data [$-\sum N_i \log p_i$],

where N_i is the number of responses in category i and p_i is the probability of

response i predicted by the model (see Ogilvie & Creelman, 1968).

2.3.5 Comparison of the Two High-threshold Model with the UVSD Model

We began by examining whether famous-name recognition is supported

by graded mnemonic evidence (i.e., a signal-detection process) or by purely

discrete threshold mechanisms. Although the majority of the recognition memory

ROCs examined in the literature are curvilinear, and thus preferentially support

the notion that graded evidence supports recognition memory judgments, other

investigators have argued that the extant research has not adequately ruled out

threshold models such as the two high-threshold (2HT) model (e.g. Bröder &

Schütz, 2009; Erdfelder, Küpper-Tetzel, & Mattern, 2011; Krantz, 1969;

Malmberg, 2002). Thus, we compared the quantitative fit provided by the 2HT

model, with that provided by the UVSD model[1]. As the UVSD and 2HT models have the same number of model parameters and have been particularly well studied in the recognition memory literature, they provide a good way to assess whether fame judgments are supported by signal-detection or threshold mechanisms. The 2HT model assumes two discrete memory states, represented by two separate model parameters which are constrained to vary between zero and one; targets can be in the 'detect' state with some probability (Dt), and lures can be in a 'reject' state with some other probability (Dl) (Erdfelder, et al., 2011; Macmillan, Rotello, & Verde, 2005; Snodgrass & Corwin, 1988). Target and lure items that are in neither of these two states are thus by definition in an indeterminate state, and are endorsed as targets with a specific probability dependent on the level of bias applied by the participant. Thus, the model that we employed also includes five parameters for varying degrees of bias in addition to the two separate parameters for detecting targets and rejecting lures.

Mean parameter values as well as goodness-of-fit statistics are indicated in Table 3. The results suggest that, for the 2HT model, 44 percent of famous names were in the 'detect' state, whereas 7 percent of the fictional names were in the 'reject' state. For the UVSD model, the results suggest that on average, the mean of the famous name distribution had a variance that was 1.81 times that of the

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[1] We also explored whether the less commonly implemented single high-threshold model (Luce, 1963) may provide a satisfactory account. We rejected it as it was deemed to provide an inferior fit as compared to the 2HT account using all means of model comparisons. Nested likelihood-ratio tests showed that the additional inclusion of the Dl parameter in the 2HT model statistically improved the fit of the single high-threshold model ($\chi^2(15) = 37.04$, $p < 0.001$).

fictional name distribution, with a mean offset by 0.87 standard deviations from the fictional name distribution. Notably, the ratio of variances for famous name targets as compared to fictional name lures is larger as compared to the ratio of variances between targets and lures in recognition memory (approximately 1.25; see Ratcliff, Sheu, & Gronlund, 1992). To compare the UVSD model to the 2HT model directly, we first computed the G^2 statistic[2] to examine the hypothesis that these models should be rejected (see Sokal & Rohlf, 1994). Examination of these values showed that the null hypothesis, i.e., the notion that the model provided an adequate fit of the data, was rejected for both the 2HT model ($\chi^2 (30) = 180.53$, $p < 0.001$), as well as the UVSD model ($\chi^2 (30) = 100.83$, $p < 0.001$) (See Table 3). Although both models were rejected it is worth noting that G^2 is numerically lower in the UVSD model as compared to the 2HT model, suggesting that the former model provides the better fit.

Next, we calculated Akaike's Information Criterion (AIC: Akaike, 1974) and the Bayesian Information Criterion (BIC: Schwarz, 1978) for all individual fits[3]. Both information criteria were found to be lower for the UVSD model, as

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[2] The G^2 statistic is defined by $[2\sum O_{ij} \log (O_{ij}/E_{ij})]$ and well fit by a chi-squared distribution. The G^2 has been shown to be a more suitable goodness-of-fit statistic than the similar chi-squared statistic (Sokal & Rohlf, 1994). In all analyses that we report, statistics for the chi-square test were also examined but did not differ in any considerable way from the G^2 statistics we report, neither in value nor in terms of significance.

[3] The AIC and the BIC take into consideration the estimated log likelihood and the number of free parameters in each model, and thus provide a relative gauge of the suitability of many comparable models; the model with the lowest value should be preferred. While both statistics involve a penalty for a larger number of parameters, the penalty for additional parameters is larger for BIC. As both the 2HT model and the UVSD model have the same number of parameters, similar comparative information could be gleaned simply be examining the minimized negative log

compared to the 2HT model, when values for all participants were summed

together, again pointing to a better fit of the former model (see Table 3). This

pattern was also present on both measures in nine of the 15 individual participants

examined. Thus, all measures converge in demonstrating the superiority of the

UVSD model over the 2HT model in terms of quantitative fit. This result provides

support for the notion that the discrimination processes involved in famous-name

recognition cannot be fully captured by a model that solely relies on threshold

mechanisms, and by extension highlights the importance of including a process

based on graded memory evidence.

2.3.6 UVSD Mixture Model Analysis

Next, we fit the data with the UVSD mixture model, as described in the

Introduction, to determine whether one or two distributions best capture the

underlying memory evidence for famous names that was shown to be graded in

our initial set of analyses. The full UVSD mixture model involved solving for

eight free parameters: five criteria and three theoretically relevant model

parameters (Figure 1a; d', λ, and σ_{FAM}). The EVSD mixture (Figure 1b) model

and the UVSD model (Figure 1c) were obtained by separately restricting either

$\sigma_{FAM}=1$ or $\lambda=1$, respectively. The EVSD model was defined by having only one

famous name distribution with the same variance as the fictional name

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likelihood values themselves. We include values of AIC and BIC for purpose of comparison with
subsequently described models.

distribution; thus, it corresponded to a model in which both $\sigma_{FAM}=1$ and $\lambda=1$.

Testing of the four model fits using the G^2 statistic showed that the null

hypothesis that the model fit the data was rejected for the EVSD model ($\chi^2(60) =$

469.74, $p < 0.001$), the UVSD model ($\chi^2(45) = 100.83$, $p < 0.001$), and the UVSD

mixture model ($\chi^2(30) = 47.57$, $p < 0.05$), but not for the EVSD mixture model

($\chi^2(45) = 57.34$, $p = 0.10$) (See Table 4). Table 4 shows goodness-of-fit statistics

across participants for all four models examined. Examination of the AIC and

BIC at the level of fits for individual participants revealed that the EVSD mixture

model was the best fit in 13 out of 15 participants for both measures. The AIC and

the BIC were also lowest for the EVSD mixture model when the data were

summed across participants. This provides further evidence to suggest this model

provides the best compromise between quantitative fit and number of parameters.

Given that the quantitative fit of the UVSD model and the EVSD mixture

model are reasonably similar, we investigated in another way which of these two

models should be considered more appropriate. Specifically, we used log-

likelihood ratio tests[4] to examine the relative statistical importance of the mixture

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[4] To compare models, we performed nested likelihood ratio tests, defined by D = -2(log(likelihood for null model) – log(likelihood for alternative model)). This test statistic is well described by a chi-square distribution with degrees of freedom corresponding to the difference in parameters between the two models compared. Note that in those likelihood ratio tests that we report here, the simpler model is defined based on a parameter that is fixed on the boundary of the parameter space (ranging between zero and one) in the more complex model to which it is compared. Some caution should apply when interpreting p-values from nested likelihood tests when this is the case; research indicates p-values yielded from such tests may be more conservative than their true values (Self & Liang, 1987).

parameter versus the ratio variance parameter in describing the current data. We compared the fit of the full UVSD mixture model, which includes d', λ, and σ_{FAM} as freely varying parameters, with both the fit of the EVSD mixture model and the UVSD mixture model, which only include d' and either λ or σ_{FAM}, respectively. Using these two comparisons, we separately assessed the relative importance of these two latter parameters to the fit of the full model. The full UVSD mixture model was a significant improvement over the UVSD model (χ^2 (15) = 53.25, $p <$ 0.001), but not a significant improvement over the EVSD mixture model (χ^2 (15) = 9.79 p = 0.83). In other words, even when the variance of the famous name distribution was already allowed to be greater than that of the fictional name distribution, the introduction of a second, separate distribution for famous names (with the same mean and variance as the fictional distribution) significantly improved the model fit. In contrast, when the mixture parameter λ was already included as a freely varying parameter in the model, the introduction of an additional parameter that allowed the famous-name distribution with prior exposure to have a greater variance than the fictional name distribution did not significantly improve the model fit.

2.3.7 Analyses of z-ROCs

Next, we examined the linearity of the ROC data plotted in z-space. In these analyses, we used the correction recommended by Snodgrass and Corwin (1988) to correct for undefined values caused by zero counts for a given confidence level in a given stimulus class. While both the EVSD and UVSD

models predict linear *z*-ROCs, models with finite mixture distributions can accommodate curvilinear *z*-ROCs as well (see DeCarlo, 2002). We fitted the five points on each participant's *z*-ROC curve to a quadratic equation and examined the quadratic coefficients (β) for all participants individually. On average, quadratic parameters were statistically above zero indicating slightly concave *z*-ROCs (mean β =0.055, $t(14)$=3.32, $p < 0.01$). As other types of discrimination models can result in curvilinear z-ROCs (e.g. the DPSD Model, see Yonelinas, 1994, 1999), we cannot claim that this reflects the specific presence of mixture distributions in the data. However, it provides additional evidence that neither the UVSD model nor the EVSD model can adequately describe the data, given that both models predict strictly linear *z*-ROCs.

2.3.8 Dual-Process Signal Detection Mixture Model Analysis

Another influential model in the recognition memory literature is the dual-process signal detection (DPSD) model developed by Yonelinas (1994, 1999). This model posits that recognition is best described by two independent processes, namely familiarity and recollection. Like the UVSD model, the DPSD model employs a *d'* parameter corresponding to the distance in z-coordinates between target and lure distributions (corresponding to familiarity). However, the DPSD model invokes a parameter representing the proportion of recollected items in the context of a high-threshold process instead of a parameter representing the difference in variances between target and lure distributions (i.e., as in the UVSD

Table 2-3: Comparison of the 2HT model with the UVSD model

Experiment 1

| | | Goodness-of-fit statistics | | | | | Estimated parameter values | | | |
| | | | | | | | 2HT | | UVSD | |
	# parameters	*df*	G^2	*p* (G^2)	Sum AIC	Sum BIC	Mean Dt	Mean Dl	Mean *d'*	Mean σ_{FAM}
2HT	105	45	180.54	< 0.001	17869.50	18204.76	0.44	0.07		
UVSD	105	45	100.83	< 0.001	17789.79	18125.05			0.86	1.81

Experiment 2

| | | Goodness-of-fit statistics | | | | | Estimated parameter values | | | |
| | | | | | | | 2HT | | UVSD | |
	# parameters	*df*	G^2	*p* (G^2)	Sum AIC	Sum BIC	Mean Dt	Mean Dl	Mean *d'*	Mean σ_{FAM}
2HT	84	36	366.97	< 0.001	14932.54	15182.00	0.35	0.08		
UVSD	84	36	67.63	0.02	14633.20	14882.66			0.87	1.91

Table 2-4: Goodness-of-fit statistics and estimated parameters for the UVSD mixture model analysis for both Experiments

Experiment 1

	# parameters	df	G^2	p (G^2)	Sum AIC	Sum BIC	Mean d'	Mean λ	Mean σ_{FAM}
			Goodness-of-fit statistics				Estimated parameter values		
EVSD	90	60	469.74	< 0.001	18128.70	18416.07	**1.01**	1.00	1.00
EVSD Mix	105	45	57.37	0.10	17746.33	18081.59	**3.59**	**0.59**	1.00
UVSD	105	45	100.83	< 0.001	17789.79	18125.05	**0.86**	1.00	**1.81**
UVSD Mix	120	30	47.57	0.02	17766.54	18149.69	**1.69**	**0.66**	**1.83**

Experiment 1 – high threshold analysis

	# parameters	df	G^2	p (G^2)	Sum AIC	Sum BIC	Mean d'	Mean λ	Mean σ_{FAM}
			Goodness-of-fit statistics				Estimated parameter values		
EVSD	90	60	332.75	< 0.001	8728.68	9016.04	**1.33**	1.00	1.00
EVSD Mix	105	45	44.49	0.49	8470.41	8805.67	**3.73**	**0.68**	1.00
UVSD	105	45	69.87	0.01	8495.80	8831.06	**1.05**	1.00	**1.94**
UVSD Mix	120	30	36.94	0.18	8492.87	8876.02	**2.06**	**0.74**	**1.68**

Experiment 2

	# parameters	df	G^2	p (G^2)	Sum AIC	Sum BIC	Mean d'	Mean λ	Mean σ_{FAM}
			Goodness-of-fit statistics				Estimated parameter values		
EVSD	72	48	376.24	< 0.001	14917.81	15131.64	**1.05**	1.00	1.00
EVSD Mix	84	36	35.48	0.84	14601.04	14850.51	**3.72**	**0.55**	0.00
UVSD	84	36	67.63	0.02	14633.20	14882.66	**0.87**	1.00	**1.91**
UVSD Mix	96	24	23.44	0.80	14613.01	14898.11	**1.59**	**0.66**	**2.30**

Note: parameter estimates in bold indicate freely varying parameters.

Table 2-5: Goodness-of-fit statistics and estimated parameters for the DPSD mixture model analysis for both Experiments

Experiment 1

	# parameters	df	G^2	$p(G^2)$	Sum AIC	Sum BIC	Mean d'	Mean λ	Mean T
			Goodness-of-fit statistics				Estimated parameter values		
EVSD	90	60	469.74	< 0.001	18128.70	18416.07	**1.01**	1.00	0.00
EVSD Mix	105	45	57.37	0.10	17746.33	18081.59	**3.59**	**0.59**	0.00
DPSD	105	45	92.95	< 0.001	17781.91	18117.17	**0.36**	1.00	**0.43**
DPSD Mix	120	30	43.57	0.05	17762.53	18145.68	**1.66**	**0.47**	**0.32**

Experiment 2

	# parameters	df	G^2	$p(G^2)$	Sum AIC	Sum BIC	Mean d'	Mean λ	Mean T
			Goodness-of-fit statistics				Estimated parameter values		
EVSD	72	48	376.24	< 0.001	14917.81	15131.64	**1.05**	1.00	0.00
EVSD Mix	84	36	35.48	0.84	14601.04	14850.51	**3.72**	**0.55**	0.00
DPSD	84	36	134.51	< 0.001	14700.08	14949.55	**0.58**	1.00	**0.35**
DPSD Mix	96	24	22.72	0.83	14612.29	14897.39	**2.82**	**0.45**	**0.28**

Note: parameter estimates in bold indicate freely varying parameters.

model). Importantly, as the DPSD model implements a threshold function, it could also account for the asymmetry observed in the present ROCs, which appear to exhibit a strong linear component based on visual examination (See Figure 2). Moreover, the model also predicts curvilinearity in z-space for recognition-memory decisions. The asymmetry in native space and the curvilinearity in z-space that we observed in the current data may point to the contribution of a high-threshold process, a notion that would be in line with previous research suggesting that a recollective process contribute to recognition of famous names based on life-time exposure (Piolino, et al., 2007; Westmacott & Moscovitch, 2003).

Thus, we also examined a DPSD mixture model that included parameters for d', λ, and a high-threshold parameter T (see Table 2 for complete model equations). By comparing various nested models within this full model, we aimed to determine whether the DPSD model might be a more suitable alternative than the EVSD mixture model to account for the presently acquired data. Moreover, using this modeling approach, we explored whether evidence in favor of a threshold process would emerge in the context of famous-name recognition when a parameter to account for lack of exposure is already included in the model. Setting either $T=0$ or $\lambda=1$ in the DPSD mixture model yields the EVSD mixture model or the DPSD model, respectively; restricting both parameters in this way at the same time results in the EVSD model. Table 4 shows goodness-of-fit statistics across participants for all four models examined. Testing of the four model fits

using the G^2 statistic showed that the null hypothesis (that the model fit the data) was rejected for the EVSD model (χ^2 (60) = 469.74, p < 0.001), the DPSD model (χ^2 (45) = 92.95, p < 0.001), but not for the EVSD mixture model (χ^2 (45) = 57.37, p = 0.10) or DPSD mixture model (χ^2 (30) = 43.57, p < 0.052). The EVSD mixture model was considered most suitable based on examination of AIC and BIC when all participants were considered together (See Table 5), and in the majority of participants when considered individually (8/15). The DPSD mixture model was a significant improvement over the DPSD Model (χ^2 (15) = 49.38, p < 0.001) but, critically, not over the EVSD mixture model (χ^2 (15) = 13.80, p = 0.54). From a statistical modeling perspective, this pattern of results points to the necessity of including the mixture parameter, but not the high-threshold parameter, in accounting for the current data.

2.3.9 Exposure Analysis

Within the context of our approach, it is assumed that the λ parameter in the UVSD mixture and EVSD mixture models represents the proportion of famous names that participants have had some exposure to in their lifetime. If this assumption is correct, λ should increase when participants have had lifetime exposure to a greater proportion of the famous names presented. Our rank-order data on self-rated exposure to the various media domains provides a means to test this notion. Thus, we performed our analysis again for the best-fitting EVSD mixture model, including all fictional names but only those famous names in the two occupational categories for which participants indicated highest day-to-day

exposure. In other words, this analysis included famous names specifically selected for each participant based on their individual occupation exposure ratings. With the criteria specified, we selected on average 101.80 famous names for each participant (min: 82: max: 116).

Analyses based on a paired t-test revealed that the mean λ was significantly greater ($\lambda = 0.68$) in the analysis that only included high-exposure items than the one that included the entire set of famous-names ($\lambda = 0.59$; $t(14) = 6.44$, $p < 0.001$; see Figure 3). That λ increases when the analysis is limited to high-exposure famous names is consistent with our interpretation that it reflects the proportion of famous names that participants have encountered in their lifetime. Notably, when we compared the fit of the full UVSD mixture model with its associated nested models only for high-exposure items, the analysis also favored the same model (i.e., the EVSD mixture model) that emerged as the best fit when analyses included all items (See Table 4). The AIC and the BIC were the lowest for the EVSD mixture model, and this was the case for 10 of the 15 participants examined. Similar to the analysis that included all famous names, the full UVSD mixture model was a significant improvement over the UVSD model (χ^2 (15) = 32.93, $p < 0.005$), but not a significant improvement over the EVSD mixture model (χ^2 (15) = 7.54, $p = 0.94$).

2.4 Experiment 2

To determine whether our modeling conclusions would generalize to another data set obtained with the same task, we collected data from another set of 12 participants. Comparing the UVSD model with the 2HT model, the UVSD

model again provided the superior fit overall (see Table 3). Subject-by-subject

analyses of BIC and AIC revealed that these estimates were lower for the UVSD

model as compared to the 2HT model overall, and in nine of the 12 participants

tested. In the UVSD mixture analysis, we found that both the EVSD mixture

model and the UVSD mixture models were considered acceptable fits of the data

using the G^2 statistic (See Table 4). As in Experiment 1, both the AIC and the BIC

were lowest for the EVSD mixture model, and this was the case for 9 of the 12

participants when examined individually. Similar to our first sample, we

observed, using likelihood ratio tests, that the UVSD mixture model offered a

significant improvement over the UVSD model (χ^2 (12) = 44.18, $p < 0.001$), but

not a significant improvement over the EVSD mixture model (χ^2 (12) = 12.03, $p =$

0.44).

In the DPSD mixture analysis, we found that both the EVSD mixture and

the DPSD mixture models were considered acceptable fits of the data using the G^2

statistic (See Table 5). Both the AIC and the BIC were lowest for the EVSD

mixture model, and this was the case for 10 of the 12 participants examined

individually. Similar to our first sample, we observed that the DPSD mixture

model was a significant improvement over the DPSD model (χ^2 (12) = 111.80, $p <$

0.001), but not a significant improvement over the EVSD mixture model (χ^2 (12)

= 12.76, $p = 0.39$). In line with our previous experiment, these results suggest that

the EVSD mixture model is the most suitable signal detection model to capture

discriminations between famous and fictional names.
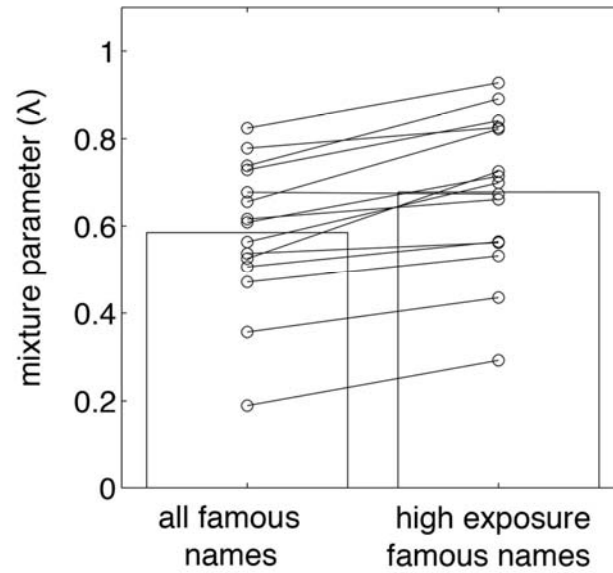
Figure 2-3: Exposure Analysis

Mixture parameters in analysis for Experiment 1 that included all famous names, and that which included only the famous names in the two occupational categories which participants indicated highest day-to-day exposure.

2.5 Discussion

In this study we employed mathematical modeling of ROC data to characterize the discrimination processes that support the recognition of famous names based on lifetime experience. For this purpose, we adopted established models from the recognition memory literature that included signal-detection and threshold mechanisms. We first compared a popular threshold model, the 2HT model, with the UVSD model and found evidence in support of the latter. Given that these two models are particularly well-studied examples of pure threshold and pure signal-detection models in the recognition memory literature, these results thus argue in favor of graded underlying memory evidence rather than discrete retrieval states in fame judgments. We then explored whether the graded distribution of memory evidence for famous names would be best described with one distribution with greater variance than that for the fictional names, or with two finite mixture distributions for famous names that correspond to items with and without prior exposure. To discern between these two possibilities, we fit our data with a model that incorporated a mixture parameter that reflected the proportion of famous names with exposure, as well as a parameter that reflected the ratio between the variance of the distribution for famous names with exposure and that for fictional names (i.e., the UVSD mixture model). We compared this full model with two nested models in which each of these two parameters was restricted separately, yielding the UVSD model and the EVSD mixture model, respectively. Examination of likelihood ratios, analyses of Akaike and Bayesian

information criteria, and regression analyses of z-transformed ROC data revealed that the EVSD mixture model provided the best compromise between number of parameters and quantitative fit. Additional comparisons with a separate DPSD mixture model, which included a high-threshold parameter instead of a parameter for unequal variances, also favored the EVSD mixture model. After including the discrimination parameter and the mixture parameter in our signal-detection model, no other statistical parameters (i.e. neither σ_{FAM} in the case of the UVSD mixture model, nor T in the case of the DPSD mixture model) led to a statistical improvement in model fit.

To our knowledge, the present findings provide the first demonstration that recognition of famous names based on past life experience involves a discrimination process that operates on graded memory evidence, i.e. a signal-detection mechanism. Although there seems to be a broad consensus in the recognition-memory literature that a signal-detection processes contributes to recognition of prior exposure based on a discrete study episode, the application of these principles to recognition discriminations based on prior exposure outside the laboratory has received little attention in psychological research so far. Investigations in other domains of cognitive psychology, however, have recently begun to adopt this methodology for related questions involving other types of recognition judgments. For example, it has been shown that lexical decision judgments made in response to words presented for only 30 ms are supported by an equal-variance signal-detection mechanism, which is assumed to reflect a fast-acting familiarity process that can be dissociated from the word identification

process that takes place in later stages (Jacobs, Graf, & Kinder, 2003; see also Brown & Steyvers, 2005; Paap, Chun, & Vonnahme, 1999). Similarly, other research has shown that recognizing letter strings from a previously learned artificial grammar is also best described purely in terms of signal-detection mechanisms and underlying graded evidence (Kinder & Assmann, 2000).

Although the majority of studies on recognition memory interpret the curvilinearity of ROCs generated with confidence judgments within a signal-detection framework, some investigators have argued that threshold models in combination with suitable response mappings can also produce curvilinear ROCs under these circumstances (Krantz, 1969; Larkin, 1965; Malmberg, 2002; see also Erdfelder et al., 2011). This type of concern may also be raised when interpreting the present data as they involved confidence judgments. However, a threshold-account of curvilinear ROCs along the lines mentioned has been criticized based on lack of parsimony (Hilford, Glanzer, Kim, & DeCarlo, 2002, p. 507). In addition, recognition memory ROCs generated with bias manipulations, rather than confidence ratings, have also yielded curvilinear ROCs in many cases (Fortin, Wright, & Eichenbaum, 2004; Ratcliff, et al., 1992). Given that, according to a threshold model, recognition judgments should always generate linear ROCs when based on bias manipulations (Malmberg, 2002), these results converge with confidence-rating experiments in supporting signal-detection mechanisms instead. In keeping with these arguments, we interpret the current results as strong support for the signal-detection framework that is favored in the field at large (Wixted, 2007a; Yonelinas & Parks, 2007).

More specifically, the signal-detection framework also provides an intuitive and parsimonious way to understand differences at the level of ROCs between the judgments made in recognition memory experiments versus those made in the famous name recognition task employed here. Critically, the two situations differ with respect to what specific type of signal-detection model should be considered most favorable. Unique to famous name recognition is a lack of control over participants' previous exposure to the stimuli deemed 'targets' by the experimenter. One consequence is that recognition may be tied to any number of life events, which are temporally undefined to the participant. Another consequence is that participants may in fact have had no life exposure to a proportion of the target items in the experiment, in effect making them indistinguishable from fictional names from the participants' point of view. This latter aspect of the current recognition task was successfully captured in the modeling approach employed here by implementing a mixture parameter that allowed a proportion of famous names to have the same memory-strength distribution as fictional names. Indeed, the results of our modeling analyses reveal that the mixture parameter, which we take to reflect the proportion of famous names associated with prior exposure, was necessary in that it consistently added to the model fit when compared to an otherwise identical model. In contrast, it is unclear how pure threshold mechanisms could account for the impact of exposure just described. With respect to the 2HT model, for example, while one can postulate distinct memory states for exposed and unexposed famous names, it

remains unclear what process would allow an individual to determine which

fictional names would fall into the 'reject' as compared to the indeterminate state.

The shapes of the individual participant ROCs, as illustrated in Figure 2,

merit further discussion as well. The current ROCs appear more asymmetrical and

linear than ROCs typically gleaned from recognition memory experiments (see

Parks & Yonelinas, 2007, for review). This difference cannot be explained based

on the use of famous names as stimuli, given that item-recognition memory

experiments with famous names as stimuli have also yielded ROCs that are more

curvilinear than those currently observed (e.g. Stenberg, Hellman, & Johansson,

2008). In item-recognition memory, the observed asymmetry is often accounted

for by invoking greater variance for the target distribution than for the lure

distribution, as is the case for the UVSD model (for a review, see Wixted, 2007a).

According to the DPSD model, the asymmetry results from an independent high-

threshold detection process, which supports the recollection of a certain

proportion of studied targets (Yonelinas, 1994, 1999). In the model proposed by

DeCarlo (2002), the asymmetry is evident because unattended items are

represented in a separate distribution with identical mean and variance to that for

the novel lures. This model is identical, in mathematical terms, to the EVSD

mixture model that best captures the current data. In effect, the present EVSD

mixture model treats famous names with or without exposure in the same way as

how DeCarlo (2002)'s model treats targets that were attended or unattended at

study. Thus, in the current implementation of the EVSD mixture model for

famous name recognition, we would argue that the current ROCs are particularly

asymmetrical because a very large proportion of target famous names were never encountered.

Indeed, in the most favorable EVSD mixture model, estimates of the mixture parameter suggest that on average 0.41 of all famous names were associated with no life experience (i.e., 1 - λ; see Table 4). Such a high estimate is plausible within the context of our use of only moderately famous names from many different occupational categories, for which participants had varying degrees of exposure. In line with our interpretation of λ as an index of prior exposure, when we restricted our analysis to include only famous names that were associated with those segments of the media for which participants had self-rated high exposure, the EVSD mixture model estimate for famous names without exposure dropped to 0.32. The strategy that we employ to provide additional validity for λ as an index of exposure (i.e., by restricting our analysis to high-exposure items) is similar to that employed in DeCarlo (2002) to describe the role of λ as a measure of participants' attention in the study phase of recognition memory experiments. In that article, it was observed that certain variables predicted to have positive influences on attention, such as longer presentation time, are associated with increases in λ, similar to the currently observed effect of occupation exposure.

Other studies also point to a role for finite mixture distributions in recognition memory. Most notably, Sherman et al. (2003) proposed a modification of the DPSD model, the variable recollection dual-process (VRDP) model, which postulates two separate Gaussian distributions, each with a freely

varying mean and variance, for familiarity evidence and for recollection evidence. In subsequent developments of the VRDP model, the variances of all distributions were set to one, and only the means of the familiarity and recollection distributions were allowed to vary (Onyper, Zhang, & Howard, 2010). Notably, this latter VRDP model is mathematically very similar to the currently proposed EVSD mixture model. Our model differs in that only one target distribution (i.e. for famous names with exposure) varies in mean memory evidence; the other distribution (i.e. for famous names without exposure) is fixed to be equal in mean and in variance to the fictional name distribution. This latter modeling decision was theoretically motivated; as we proposed that famous names without exposure should be identical to fictional names from the participants' point of view, we predicted they would be best described with the same Gaussian distribution. In support of this hypothesis, additional analyses revealed no statistical benefit from allowing the non-exposed famous name distribution to have a mean greater than zero.

It is also worth noting that finite mixture distributions have been employed in memory decisions other than those pertaining to item recognition memory. For example, DeCarlo (2003, 2008) has proposed that source decisions can also be described accurately with finite mixture distributions if one considers that some source information may be either available or unavailable. An interesting commonality in the findings of DeCarlo (2008) and those reported here is that unequal variances among separate Gaussian distributions seem to be unnecessary once a mixture parameter is included in the fitted model. Moreover, finite mixture

models have also been used to account for associative recognition, in which participants are required to discriminate between intact and rearranged pairs of stimuli (e.g. word-pairs). For example, Kelley & Wixted (2001) proposed that, while item familiarity can be represented adequately with one Gaussian distribution, associative information may best be captured with a 'some-or-none' variable, or two finite mixture distributions that correspond to items with and without any associative information, respectively (for a comparison with other related models, see Macho, 2004).

In terms of the psychological nature of the processes at work, an important aspect of the current data concerns the potential role of recollection of episodic detail for the famous names presented. In our analyses, we tested whether a high-threshold parameter (T), identical to the one that indexes recollection in DPSD model, significantly improved the model fit once the mixture parameter had been introduced. We found no evidence for improved fit with such a recollection parameter. This finding appears to be inconsistent with recent work, not based on ROC methodology, that points to involvement of recollection processes in the processing of famous names. Past studies have shown that some famous names are particularly likely to elicit recall of a specific prior personal experience pertaining to the celebrity, which gives these names autobiographical significance as compared to other famous names (Piolino, et al., 2007; Westmacott & Moscovitch, 2003). For example, for John Lennon, a participant may be able to recall a particular experience of watching him on television, or of hearing about his assassination. Westmacott & Moscovitch (2003) reported that famous names

with autobiographical significance are associated with processing benefits on a number of cognitive tasks, including dichotomous fame judgments. These findings, however, were based on the use of famous names that were very well known to participants. This characteristic of their stimulus set is reflected in the fact that discrimination performance, again unlike in the current data, was almost perfect in that study. Thus, it is possible that recollection only contributes to discrimination when the famous names are associated with more familiarity and/or semantic knowledge than what would be present for the moderately famous names used in our study. In addition, the influence of autobiographical significance was reflected in changes in reaction times for identified names, rather than changes in confidence in the context of a detection model. Overall, it appears that recollection may not contribute to fame judgments under all circumstances. However, given the methodological differences between the small number of studies that have examined the issue, further work is clearly necessary to obtain a better understanding of the role of recollection in fame judgments and other memory decisions traditionally related to semantic memory.

A further issue for future investigations is to determine whether and how the graded memory evidence for famous names that we isolate here relates to the presence and degree of available semantic knowledge. In computational implementations of recognition processes for concepts (rather than people), such as the Source of Activation Confusion (SAC) model, familiarity is reflected in variable degrees of activation at a specific semantic node that pertains to the concept in question (Diana, et al., 2006; Reder, et al., 2000). In global matching

models, graded recognition judgments have been assumed to be sensitive to the summed similarity of the test probe to all of the study items (Clark & Gronlund, 1996). Put into the context of famous-name recognition, participants' graded judgments may be a direct reflection of the degree of relevant semantic knowledge that is available to them, and may also be partially determined by the semantic similarity of the name in question to all other famous names that participants know. On the other hand, research has shown that names can appear famous to participants simply because they were encountered recently, irrespective of any semantic knowledge participants may have (i.e. the false fame effect; Jacoby, Kelley, Brown, & Jasechko, 1989). Considered together, the evidence currently available does not allow for any firm conclusion as to the specific role of semantic knowledge in fame judgments. Regardless, the current mathematical characterization provides a starting point for understanding the nature of the memory signal that allows them to be discriminated from fictional names.

Finally, our results have relevance with respect to the degree to which recognition memory experiments can be considered an appropriate model of recognition experiences outside the laboratory, which are not tied to one controlled study episode. That recognition memory can provide a suitable model for recognition decisions outside the laboratory is often assumed implicitly in research based on the use of recognition memory tasks with experimentally controlled study phases. The widely used remember-know paradigm, for example, involves instructions that require participants to use 'know' for recognition

experiences that have subjective similarity to perceiving a person outside the

laboratory as familiar (e.g. Gardiner, Ramponi, & Richardson-Klavehn, 1998) .

Another particularly influential example of using real-life recognition experiences

to motivate research that employs the recognition memory paradigm is the

butcher-on-the-bus phenomenon first described by Mandler (1980). This

phenomenon refers to a subjective experience in which someone who is known in

one particular context can appear particularly familiar when encountered in a

different context without initial identification. Again this can be seen as an

example of a recognition experience that would typically hinge on lifetime

experience with multiple encounters, rather than one specific episode, as would be

modeled in the recognition memory paradigm. While there appear to be many

differences between recognition judgments based on lifetime experience, such as

the fame judgments employed here, and typical item-recognition memory tasks,

the current work shows that recognition decisions based on lifetime exposure and

those based on a experimentally controlled study phase are similar in at least one

important way: They can both be well described by invoking graded evidence in

the context of signal-detection mechanisms.

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3 The Role of Semantic Knowledge in 'Familiarity-only' Experiences for Names

3.1 Abstract

Situations in which a name of a person is perceived as familiar but does not provoke recall of any pertinent knowledge about them are a common occurrence in daily life. Observations of such 'familiarity-only' experiences have motivated theories of person recognition that incorporate separate stages for familiarity assessment and for the access of person-related semantic knowledge. Here, we ask whether such experiences for famous names do indeed reflect a state of person recognition that is completely decoupled from semantic knowledge, as the term itself suggests. In three experiments, we combined a name-recognition task with a task that involved forced-choice occupation judgments. In Experiment 1, we found that participants showed above-chance forced-choice occupation accuracy for famous names previously given 'familiarity-only' responses. In Experiment 2, we showed that this pattern is not due to the effects of priming, nor due to differences in semantic retrieval cues presented in the two stages. By probing participants' confidence in their forced-choice judgments, we also showed that participants might have some meta-awareness of the occupation knowledge they express in association with 'name rings a bell' judgments. In Experiment 3, we demonstrated that degrees of name familiarity, as reflected in name recognition confidence, are related both to forced-choice occupation accuracy and to associated confidence. Overall, these results suggest that some

meaningful semantic knowledge is available during 'familiarity-only' responses, and that the expression of semantic knowledge about famous names is graded along a continuum. These findings are interpreted and discussed in the context of current connectionist models of person recognition.

3.2 Introduction

Social situations in which someone mentions a person's name and the listener indicates familiarity, in the absence of any readily available knowledge about the person referred to, are common in daily life. Indeed, they are so common as to have motivated a unique idiom in the English language that signifies such experiences: 'That name rings a bell!' In the psychological literature, this phenomenon is often referred to as a 'familiarity-only' experience and has been documented in diary-based research on day-to-day memory errors (Young, et al., 1985; see also Hay, Young, & Ellis, 1991). According to anecdotal observations captured in such diaries, some familiarity-only experiences become resolved through repeated attempts to access relevant semantic knowledge or though the direct provision of additional information; however, a substantial number of them remain unresolved. In subsequent behavioral investigations, familiarity-only experiences for faces and voices have also been documented in the laboratory (e.g., Hanley & Hadfield, 1998; Hanley & Turner, 2000). Interestingly, in the neuropsychological literature, a number of patients with brain damage have been reported to exhibit consistently impaired access to semantic knowledge about well-known famous names while retaining a preserved sense of familiarity for them (e.g. de Haan & Young, 1991; Verstichel, et al., 1996;

Warrington & McCarthy, 1988; Westmacott & Moscovitch, 2001; for a review,

see Gainotti, 2007). These patient-findings converge with prior behavioral

investigations in healthy individuals insofar as they point to a phenomenological

impression of familiarity for famous names that can be dissociated from states

that involve successful access of relevant semantic knowledge. In the current

article, we ask: Do subjective familiarity-only experiences reflect instances of

person recognition in which relevant semantic knowledge is absent, or could they

be associated with partial knowledge that can be revealed when probed in targeted

ways?

Observations of familiarity-only experiences have motivated models of

person recognition that posit that the assessment of familiarity occurs at a stage of

processing that takes place prior to the access of relevant semantic knowledge

(e.g. Bruce & Young, 1986; Burton, et al., 1990). Further strong support for this

notion has been derived from observations that familiarity decisions are typically

performed faster than those that require access to semantic knowledge such as that

regarding occupation (Young, McWeeny, Hay, & Ellis, 1986). In earlier models

of person recognition, it was posited that familiarity is registered at structural

modality-specific recognition units for faces (FRU), names (NRU), or voices

(VRU; Bruce & Young, 1986; Hay & Young, 1982). Such modality-specific units

were postulated to connect to person identity nodes (PIN) that support semantic

identification, which in turn interconnect with other units important for name

generation. In the more recent influential Interaction Activation and Inhibition

(IAC) model that was developed within a connectionist-modeling framework

(McClelland & Rumelhart, 1981), distinct semantic identification units (SIU) were incorporated to represent different types of semantic information, such as occupation or nationality (Burton, et al., 1990). In this revised framework, each SIU is reciprocally connected with all PINs that correspond to people who exhibit the specific semantic property that it represents. Another change that was implemented in this more recent model is that familiarity assessment is assumed to be based on activation at a modality-general PIN after input from modality-specific nodes (e.g., for faces, voices, and names) have converged (see Gainotti, 2007a for a review). Although these basic aspects of the IAC model have remained more or less unchanged since its inception, it is worth noting that it has been extended in some ways since then. For example, specific word-recognition units have been added to represent first and separate last names separately (Burton & Bruce, 1993); an image processing layer for face recognition that operates via principal components has been incorporated as well (Burton, Bruce, & Hancock, 1999).

In the IAC model of person recognition, familiarity-only experiences are thought to occur in response to the presentation of a person's face, name, or voice when activation at the PIN passes an arbitrary activation threshold but activation at SIUs remains at a sub-threshold level (for a review, see Young & Burton, 1999). In healthy individuals, this could happen as a result of a transient attenuation or block between the PIN and connected SIUs (but see Hanley & Turner, 2000 for an alternate account). In one neurological patient, ME, who suffered memory difficulties that resulted from a vasculitic disorder, a persistent

block of this type was proposed to underlie that individual's inability to access

semantic knowledge about famous names and faces that she found familiar (de

Haan & Young, 1991). This report has also been discussed in detail in several

subsequent articles as support for the IAC model of person recognition (Burton,

Young, Bruce, Johnston, & Ellis, 1991; Young & Burton, 1999). For a series of

faces and names that were presented to her, ME was asked to rate her perceived

familiarity for the items on a 7-point scale. For stimuli considered familiar, she

was asked to recall the individual's occupation, and for faces, their name as well.

The results of this investigation showed that ME exhibited preserved familiarity

for both names and faces, with a simultaneously impaired ability to access

pertinent semantic knowledge about these stimuli. Interestingly, at the same time,

she could also accurately match face and name cues for a given celebrity.

Interpreted in the context of the IAC model, it was suggested that ME's person

recognition system functions normally only up until the point at which NRUs and

FRUs converge (i.e., at the PINs), but not past this point where semantic

knowledge is assessed (i.e., at the SIUs). In this account, normal activity at the

PINs in ME's person recognition system was proposed to support both her

preserved ability to assess familiarity for both names and faces and her ability to

appropriately match face and name cues.

One aspect of patient ME's case study that merits consideration is that the

investigators relied on free recall to assess whether she had any available semantic

knowledge for the stimuli she found familiar, i.e., she was asked to conjure up a

specific semantic detail in response to the name or face presented. In terms of the

IAC model, it has been posited that the lack of any supra-threshold activation at SIUs in ME's person recognition may underlie her inability to recall any semantic knowledge about names and faces she finds familiar (Burton, et al., 1991). In many other studies as well, performance in free recall tasks has been equated with semantic knowledge retrieval and/or above-threshold SIU activation (e.g. de Haan & Young, 1991; Hanley & Turner, 2000; Hay, Young, & Ellis, 1991a; Snowden, et al., 2004; but see Hanley & Cowell, 1998). However, a substantial body of research on memory for materials acquired in the laboratory suggests that the nature of the retrieval cue is critical in determining whether memory representations for previously encountered items are available or not; the literature at large suggests that probing memory through recall offers limited sensitivity to detect available memory representations due to the high strategic demands in search processes (e.g., Davidson, Troyer, & Moscovitch, 2006; Tulving & Pearlstone, 1966). In other words, the ability to access relevant semantic knowledge during retrieval depends not only on the availability of that information but also on the sensitivity of the task employed, as well as the presence of appropriate retrieval cues. For some tasks, such as naming famous faces, the importance of providing specific types of retrieval cues such as the individual's initials have already been demonstrated (Hanley & Cowell, 1988; Schweinberger, Herholz, & Sommer, 1997). Thus, it is possible that in some prior investigations, such as that involving patient ME, 'familiarity-only' experiences may have been associated with some semantic knowledge that went undetected because of a reliance of free recall tasks to detect that knowledge. Support for this

interpretation comes from other patients with neurological disorders who have been documented to have difficulties in accessing semantic knowledge about names and faces they found familiar (Verstichel, et al., 1996; Warrington & McCarthy, 1988; Westmacott & Moscovitch, 2001). In three case studies, the documented patients (i.e., DEL, RFR, KC) exhibited preserved abilities in assessing familiarity for famous names, but were found to exhibit some partial knowledge for these stimuli that was detectable with more sensitive forced-choice and cued recall tasks.

In simulations of person-recognition processes conducted using the IAC model, the investigator typically uses arbitrarily defined numerical activation thresholds at PIN and SIU nodes to simulate the presence or absence of familiarity and semantic knowledge, respectively (for a review, see Young & Burton, 1999). In other words, although activation varies continuously at all nodes within the IAC model, it is thus assumed that both familiarity and semantic knowledge retrieval involve binary states defined based on these thresholds. As previously mentioned, familiarity-only experiences occur when activation is supra-threshold at PIN nodes but sub-threshold at SIU nodes. However, it is worth noting that as long as there is still some link between the PIN and associated SIUs, increases in activation at a PIN will still always lead to some increases in activation at connected SIUs, even if activation levels at these SIUs remain sub-threshold. Within the context of IAC simulations, it is typically assumed that any such increases in SIU activation does not manifest in any available semantic knowledge if no SIU eventually exhibits supra-threshold activation. Another

possibility, however, is that such sub-threshold increases in activation might be associated with the availability of some semantic knowledge, even if such increases are insufficient to support free recall. Such semantic knowledge may only be detectable in the context of tasks that are particularly sensitive to available mnemonic representations, and that offer specific cues to minimize search demands. This would be in keeping with the general idea that semantic knowledge in response to a cue can sometimes be graded, being neither fully absent nor fully present, similar to that documented in other states such as the tip-of-the-tongue phenomena (R. Brown & McNeill, 1966; Maril, Simons, Weaver, & Schacter, 2005; for a review, see Schwartz & Metcalfe, 2011). Even in the context of the IAC modeling literature, the notion that semantic knowledge is graded and tracks the precise level of activation at SIU nodes is also consistent with some prior investigations. For example, in simulations of 'familiarity-only' experiences conducted by Hanley & Turner (2000) using the IAC model, it was assumed that varying amounts of SIU activation reflect varying probabilities of semantic retrieval.

In the current study, we conducted three experiments to examine the potential availability of accurate semantic knowledge associated with subjective 'familiarity-only' experiences for famous names. We predicted that 'familiarity-only' experiences for famous names might be associated with some available, objectively accurate knowledge when an appropriately sensitive task is employed to detect this knowledge. We made this prediction based on both the presumed increases in activation at SIUs during 'familiarity-only' experiences, and previous

observations that preserved familiarity for famous names have generally been accompanied by some available knowledge in past patient reports. In each experiment, we assessed famous name recognition in one stage and the availability of pertinent semantic knowledge in a separate stage, using the same set of famous and fictional names. To probe semantic knowledge, we employed a forced-choice task that required participants to choose an occupation associated with each famous name from a list of several possible alternatives. Our selection of a forced-choice paradigm was motivated by past research in episodic and semantic memory which has demonstrated that this task provides a highly sensitive means to access stored information that is difficult to declare otherwise (e.g., Holdstock et al., 2002; Standing, 1973; Voss, Baym, & Paller, 2008; Westmacott & Moscovitch, 2001). We specifically focused on occupation knowledge due to its suggested central importance in the organization of semantic memory related to proper names (Crutch & Warrington, 2004; Darling & Valentine, 2005; but see Barry, Johnston, & Scanlan, 1998).

3.3 Experiment 1

In Experiment 1, we started by investigating whether subjective familiarity-only experiences ('name rings a bell' responses) do indeed carry a memory signal that discriminates between famous and fictional names. We then determined whether these subjective familiarity-only experiences were associated with some objectively accurate semantic knowledge. In the first stage, participants made recognition judgments for famous and fictional names, with response options designed to isolate a familiarity-only state. For each name, participants

were asked to indicate whether it was unfamiliar, familiar-only (i.e., whether it rang a bell), or whether it could be identified based on the retrieval of at least one distinct semantic detail. In a subsequent stage, we assessed semantic knowledge for the same set of famous names by asking participants to make forced-choice occupation judgments. We hypothesized that although participants may not recall any distinct piece of semantic knowledge in response to a name cue in 'familiarity-only' experiences, accurate semantic knowledge may still be revealed for these responses while making forced-choice semantic judgments.

3.3.1 Participants

Twelve fluent English-speaking students at the University of Western Ontario participated in the study (mean age = 21.50, SD = 2.28). They gave written informed consent and were compensated for their participation. The study received expedited research-ethics approval in the Department of Psychology at the University of Western Ontario.

3.3.2 Materials

Using internet databases, including Wikipedia (www.wikipedia.org) and The Internet Movie Database (http://www.imdb.com/), we created a set of 208 famous names corresponding to moderately known present and past (post world-war II) celebrities from seven occupation categories. Our categories included comedians, actors (film and/or TV), authors/poets, musicians, athletes, politicians, and TV/radio personalities (hosts). Celebrities were sampled from various nationalities but we ensured that each of them had a high likelihood of some

media exposure in the country where the study was conducted (i.e., Canada). All selected celebrities were known by their first and last name. Celebrities were not considered for our set if, (a) they were well known by a slang name, (b) their name had accents, punctuation, or non-English characters, (c) their name referred to more than one notable individual, or (d) typical reference to their name in the media included a middle name (e.g., Billy Bob Thornton). The final list of famous name stimuli was prepared in such a way that each of the seven occupation categories applied equally often for the entire set (i.e., each type of occupation was correct 41 times). Towards this end, we took into consideration that some celebrities had multiple occupations, i.e., were considered famous in multiple domains. Based on this list composition, a chance rate of performance on the occupation task could be computed by averaging the proportions of the seven possible occupations considered correct for each individual (e.g. 1/7, 2/7, 3/7, etc.) across the entire set; the resulting chance rate corresponded to 0.197.

For the name recognition-task, a set of 100 fictional names was generated that closely matched (i.e., did not differ statistically from) the list of 208 famous names in terms of the number of syllables, length, and frequency, using the U.S. Census Bureau 1990 database (http://www.census.gov/genealogy/www/). Matching was performed separately for first and last names, as well as for their combination. Again, only names were considered that did not include any accents, punctuation, or non-English characters. The final sets of first and last names were combined randomly, and we ensured that no resulting combination inadvertently referred to famous individuals.

3.3.3 Procedure

The experiment consisted of two stages. In the first stage, participants were presented with an intermixed list of 208 famous names and 100 fictional names, presented in random order one at a time in self-paced manner on a computer. Responses were made with a computer keyboard. For each name, subjects were instructed to decide whether the name, (a) is unfamiliar, (b) rings a bell, or (c) is identifiable based on recall of at least one distinct piece of semantic information. Participants were informed they should use the 'rings a bell' response if they recognized the name as familiar but could not recall anything about the corresponding person. In a practice phase involving 10 names (5 famous, 5 fictional) participants had to justify their responses, allowing the experimenter to verify correct employment of these response categories. Following this phase, participants were unexpectedly presented again with only the 208 famous names they had encountered previously. For each name, subjects were asked to indicate in a self-paced manner whether the name referred to 1) an author or poet, 2) a comedian, 3) an actor, 4) a musician, 5) an athlete, 6) a politician, or 7) a TV/Radio/Media personality. For each trial, participants viewed these response options on the computer screen below each famous name, and made their choice with a computer keyboard. As indicated in the previous section, across the set of famous names employed, the seven occupations were distributed with equal probability. For each forced-choice occupation response, participants were instructed to offer their best guess even if the name seemed unfamiliar to them. Occupation judgments were obtained in a separate stage after completion of

all recognition judgments to ensure that participants' name recognition judgments were not influenced in a strategic manner by their awareness that semantic knowledge would also be tested explicitly.

3.3.4 Results and Discussion

We first verified with a chi-squared test that participants applied the three recognition responses in different proportions to famous names as compared to fictional names ($\chi^2 = 463.41$, $p < 0.001$), suggesting that they discriminated between both types of stimuli. Critical for the focus of the current investigation, we found that the 'rings a bell' response was given in higher proportion to famous than to fictional names ($t(11) = 3.22$, $p < 0.01$, two-tailed), indicating that this response conveyed a meaningful memory signal (see Figure 1a). For stage two, we examined participants' performance on the forced-choice occupation judgments, separated according to the distinct type of recognition response provided in stage one for the same items. Occupation forced-choice response accuracy was determined based on the a priori designation of which celebrities were associated with which occupations. First, t-tests were used to examine whether 'name rings a bell' responses were associated with above-chance occupation forced-choice responding (i.e., > 0.218). Critically, 'name rings a bell' responses were associated with above chance performance on the forced-choice occupation judgments ($t(11) = 6.04$, $p < 0.001$, one-tailed; see Figure 1b), even though participants provided this response type in stage one with a subjective sense that they could not recall any related knowledge. Next, we used a one factor repeated-measures ANOVA, with repeated planned comparisons, to compare

occupation forced-choice accuracy associated with the three types of recognition responses. Overall, there were differences in occupation forced-choice accuracy between the three recognition responses ($F(2, 22) = 234.47$, $p < 0.001$). Planned comparisons revealed that occupation accuracy associated with 'name rings a bell' responses was higher than that for famous names previously classified as 'unfamiliar' ($F(1, 11) = 13.56$, $p < 0.005$); in turn, occupation accuracy associated with 'identify' response was higher than that associated with 'name rings a bell' responses ($F(1,11) = 262.72$, $p < 0.001$).

Together, these results suggest that when participants indicate that a name only feels familiar, their responses do convey a meaningful recognition signal. Further, they demonstrate that 'name rings a bell' responses are also associated with the availability of some semantic knowledge on a subsequent forced-choice occupation task. An important question that arises from Experiment 1, however, is whether participants have any awareness of the occupation knowledge they possess in association with 'name rings a bell' experiences. When participants cannot identify the person associated with a famous name that they find familiar, do they show any awareness of the potential availability of some meaningful occupation knowledge, which we demonstrated to be present here? It is possible that awareness of the potential availability of some meaningful occupation knowledge is driving the documented repeated attempts of people to resolve familiarity-only experiences in daily life, which have been described in diary studies on memory errors involving person recognition (Young, et al., 1985). At the same time, research in other domains has shown that successful forced-choice
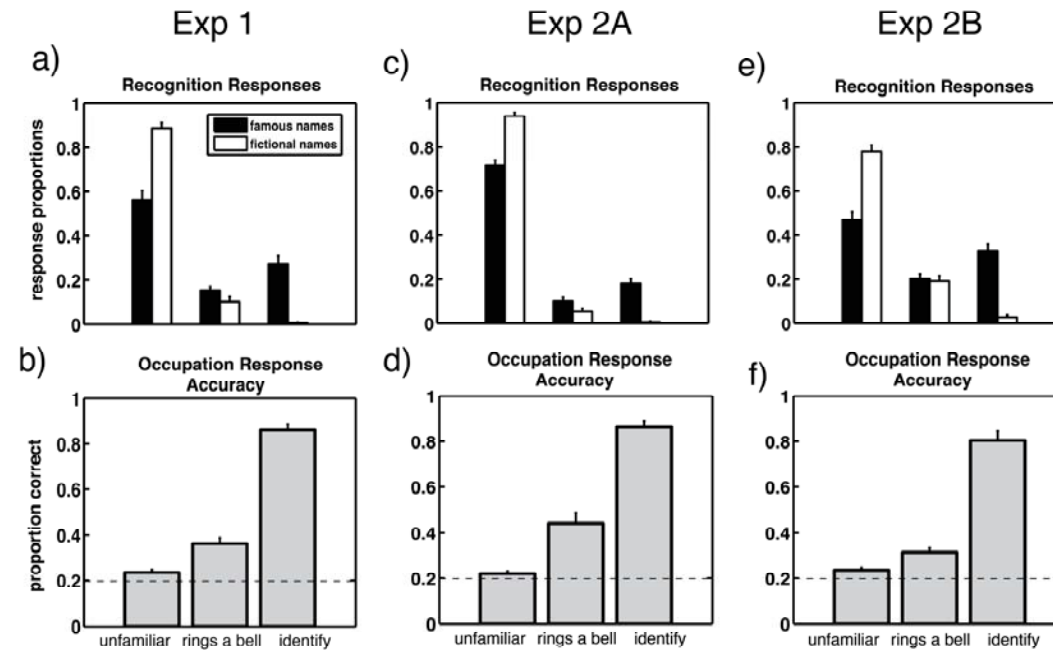
Figure 3-1: Results for Experiments 1 and 2

Top panel: Proportion of different recognition responses provided to famous and fictional names in the name recognition stage in Experiments 1 (a), 2A (c), and 2B (e). Bottom panel: corresponding proportions of accurate occupation judgments for famous names in the occupation response stage as a function of recognition response type (b, d, f). Black dashed line indicates chance occupation accuracy. Error bars depict SEM.

judgments can reflect completely implicit knowledge (Köhler & Moscovitch,
1997; Paller, Voss, & Westerberg, 2009; Weiskrantz, 1990); thus, participants
may make accurate forced-choice occupation responses in association with 'name
rings a bell' responses with no awareness at all of their veracity.

3.4 Experiment 2A and 2B

In Experiment 2, we investigated whether or not participants have any
awareness of the occupation knowledge they can express in association with
'name rings a bell' responses. To get at this issue, participants were required to
indicate how likely they perceived their occupation response to be correct, using a
graded confidence scale from one to six, immediately after they made this
response. We also introduced several other modifications in Experiments 2 that
were intended to rule out the possibility that the link we observed between 'name
rings a bell' responses and the availability of semantic knowledge was due to
order and / or cue effects Given the two-phase structure of Experiment 1, it may
be the case that the initial recognition judgments primed the availability of
semantic knowledge, such that it only became available during the subsequent
presentation. Such a scenario could explain why participants only expressed
meaningful semantic knowledge for those names that rang a bell during the
second and not the first stage. When considered in the IAC model, SIUs may have
been below threshold during the initial presentation, but rose above threshold
during the subsequent presentation. To address this concern in Experiment 2, we
employed two versions that differed in the order in which the two stages were
administered. In Experiment 2A, the name-recognition task was administered first

(as in Experiment 1), and in Experiment 2B, the occupation task was administered first.

Aside from priming, another possibility is that the association that we documented between 'name rings a bell' responses and occupation forced-choice accuracy is related to differences in the semantic retrieval cues that were present during the two stages. For example, it might be the case that semantic knowledge only became available in the second stage because the occupation types were only provided after name-recognition judgments had been completed, or because they were visually apparent in each trial during the occupation forced-choice judgments but not the name-recognition judgments. In Experiment 2, we minimized the potential impact of differences in retrieval cues by matching them as closely as possible across both judgments. Towards this end, we asked participants to memorize the seven occupation response options at the very beginning of the experimental session and recall them to the experimenter so we could ensure that they had memorized them. This requirement for memorization allowed us to remove any cues pertaining to occupation in the corresponding experimental stage. Specifically, participants were asked to type in an occupation in response to the presentation of the name as the sole cue, based on their prior memorization of the occupation response options, rather than choose one option among seven concurrently presented alternatives.

3.4.1 Participants

Sixteen fluent English-speaking students at the University of Western Ontario participated in Experiment 2A (mean age = 20.75, SD = 2.11) and 21

more in Experiment 2B (mean age = 22.81, SD = 3.49). The data from two

participants were removed from Experiment 2A based on a substantial number of

responses in the occupation phase that were not interpretable. In such cases,

participants pressed the [ENTER] button prematurely or typed a response that was

not one of the pre-assigned occupations. A total sample of 14 participants was

included. Participants gave written informed consent and were compensated for

their participation.

3.4.2 Materials and Procedure

The materials and procedure in both Experiment 2A and 2B were identical

to Experiment 1 with the following changes. At the beginning of the experiment,

participants were instructed to memorize the seven occupation categories from

which all famous names to be presented were drawn (i.e., comedians, actors,

authors/poets, musicians, athletes, politicians, and TV/radio personalities) using

cue cards. They were instructed to recall these seven options before beginning the

first stage of the experiment. In Experiment 2A, the introduction and practice

phase for the name-recognition stage were otherwise the same as in Experiment 1.

At the beginning of stage two in Experiment 2A, which required occupation

judgments to be made, participants were reminded of the seven occupation

response options, and were again required to recall these before testing began.

Participants were instructed to type in the appropriate occupation from the list of

options they had previously memorized, and were given a practice phase as in

Experiment 1. Following their occupation response participants were required to

express their confidence in the accuracy of the choice they just provided, by using

a scale from one to six. The lowest point of this scale was assigned to responses that were perceived to be complete guesses, while six reflected responses associated with the highest confidence; responses two through five were assigned intermediate levels of confidence.

Experiment 2B was identical to Experiment 2A except that the order of the two tasks was reversed, with participants completing occupation judgments prior to name-recognition judgments. In addition, participants in Experiment 2B were explicitly instructed to base the name recognition judgments that they made in the second experimental stage on their life experience prior to entering the laboratory (i.e., from the media), rather than the single test exposure in the previous occupation stage. In Experiment 2A and 2B, the same sets of famous and fictional names were included in both stages of the experiment; participants were informed that two thirds of items from the total set of names referred to famous people at the beginning of each stage.

3.4.3 Results

As in Experiment 1, we first examined whether the different response options were associated with a meaningful memory signal. Chi-squared tests revealed that the response proportions differed between famous and fictional names in Experiment 2A ($\chi^2 = 43433.87$, $p < 0.001$) and Experiment 2B ($\chi^2 = 31580.87$, $p < 0.001$). In Experiment 2A, there was a greater proportion of 'name rings a bell' responses given to famous than to fictional names ($t(13) = 3.04$, $p < 0.01$, two-tailed, Figure 1c). In Experiment 2B, however, no significant difference between these raw proportions was observed ($t(20) = 0.79$, $p = 0.44$, two-tailed;

Figure 1e). The lack of accurate discrimination reflected in 'name rings a bell' responses in the second stage of Experiment 2B is likely related to the order in which the two types of judgments were completed. Specifically, as the name-recognition judgments were completed after the forced-choice occupation judgments had been provided for the same names, it is likely that participants' familiarity for the fictional names in the name-recognition stage was increased by prior exposure in the occupation stage. This would be consistent with previous research that has demonstrated participants can mistake fictional names as famous based on a recent study encounter (Jacoby, Kelley, Brown, & Jasechko, 1989). Furthermore, fictional names may have undergone greater increases in familiarity overall as compared to famous names based on the prior presentation, given that in general, items with lower pre-experimental familiarity tend to increase in familiarity more than those of higher pre-experimental familiarity as a result of a single study exposure (e.g., Coane, Balota, Dolan, & Jacoby, 2011; see General Discussion for further consideration).

To examine the accuracy of participants' occupation knowledge, we scored each participant's written answer for each famous name based on the occupation they typed in response to each name. In a small number of cases, participants gave responses that were not interpretable and they were excluded from all analyses. In both Experiments, 'name rings a bell' responses were

Table 3-1: Confidence data for Experiment 2

Experiment 2A

	Occupation confidence					
	'completely guessing '		… 'unsure' …			'sure correct'
	1	2	3	4	5	6
'unfamiliar	0.55 (0.08)	0.28 (0.05)	0.10 (0.02)	0.05 (0.02)	0.02 (0.01)	0.01 (0.01)
'rings a bell'	0.15 (0.04)	0.24 (0.03)	0.23 (0.04)	0.17 (0.03)	0.12 (0.03)	0.09 (0.03)
'identify'	0.02 (0.01)	0.01 (0.01)	0.01 (0.00)	0.04 (0.01)	0.10 (0.02)	0.81 (0.04)

Experiment 2B

	'completely guessing '		… 'unsure' …			'sure correct'
	1	2	3	4	5	6
'unfamiliar'	0.39 (0.06)	0.28 (0.02)	0.16 (0.03)	0.09 (0.02)	0.05 (0.02)	0.02 (0.01)
'rings a bell'	0.18 (0.03)	0.21 (0.02)	0.20 (0.02)	0.21 (0.03)	0.12 (0.02)	0.08 (0.01)
'identify'	0.04 (0.02)	0.05 (0.03)	0.02 (0.01)	0.05 (0.01)	0.10 (0.01)	0.74 (0.06)

Proportion of each occupation confidence level given for each recognition response in Experiments 2A and 2B, aggregated across participants. Value in brackets depicts SEM.

associated with above-chance occupation accuracy (Experiment 2A; $t(13) = 5.26$, $p < 0.001$: Experiment 2B; 'rings a bell': $t(20) = 6.33$, $p < 0.001$). One factor repeated-measure ANOVAs revealed significant differences in occupation forced-choice accuracy associated with the three different recognition responses in Experiment 2A ($F(2, 26) = 138.43$, $p < 0.001$) and Experiment 2B ($F(2, 40) = 171.60$, $p < 0.001$). 'Name rings a bell' responses were associated with higher occupation accuracy than 'unfamiliar' responses in both experiments (Experiment 2A: $F(1,13) = 23.74$, $p < 0.001$; Experiment 2B: $t(1, 20) = 15.92$, $p < 0.005$). 'Semantic recall' responses were also associated with higher occupation accuracy than 'ring a bell' responses in both experiments (Experiment 2A: $F(1,13) = 90.79$, $p < 0.001$; Experiment 2B: $t(1, 20) = 238.46$, $p < 0.001$).

In the second set of analyses, we focused on participants' occupation confidence judgments. We used these judgments to investigate whether participants had any awareness of the potential availability of accurate occupation knowledge when encountering names that elicited a 'rings a bell' response. Awareness of the availability of semantic could be reflected in a pattern of results showing that 'name rings a bell' responses are associated with more confidence in occupation judgments than 'unfamiliar' responses for famous names. Table 1 shows the proportion of each of the six confidence levels given for each response option, aggregated across participants. We first verified, using a one factor repeated-measures ANOVA, that participants' average confidence in occupation responding for famous names differed based on the three recognition responses (Experiment 2A: $F(2, 26) = 197.78$, $p < 0.001$; Experiment 2B: $F(2,40) = 110.33$,

$p < 0.001$). Critical for the current hypothesis, 'name rings a bell' responses were associated with greater occupation confidence than 'unfamiliar' responses in both Experiments (Experiment 2A: $F(1, 13) = 58.22$, $p < 0.001$; Experiment 2B: $F(1, 20) = 50.84$, $p < 0.001$). We also found that 'identify' responses were also associated with higher confidence than 'name rings a bell' responses (Experiment 2A: $F(1, 13) = 151.07$, $p < 0.001$; Experiment 2B: $F(1, 20) = 126.35$, $p < 0.001$).

To address the issue of whether probing for name-recognition judgments primed the availability of occupation knowledge in the second stage, we formally investigated whether there were any statistically significant differences between Experiment 2B and 2A in terms of occupation forced-choice accuracy. We first performed a one-factor repeated-measures ANOVA that included forced-choice occupation accuracy as a dependent variable, recognition response as a within-subjects factor, and experiment (i.e., Experiment 2A, Experiment 2B) as a between-subjects factor. We found that there was an interaction between recognition response and experiment ($F(2,66) = 3.88$, $p < 0.05$). Not surprisingly, the main effect of response type was significant ($F(2,66) = 296.11$, $p < 0.001$), but the main effect of experiment was not ($F(1,33) = 3.84$, $p = 0.06$). Using a pooled error term from this analysis, we contrasted accuracy between Experiment 2A and Experiment 2B for individual response types. Occupation forced-choice accuracy for 'familiarity-only' experiences was greater when name-recognition judgments were made first and occupation judgments second, as compared to vice versa ($F(1, 95.44) = 14.85$, $p = 0.001$); occupation accuracy was not different between Experiment 2A and Experiment 2B for 'unfamiliar' responses ($F(1, 95.44) = 0.20$,

$p = 0.96$), nor for 'identify' responses ($F(1, 95.44) = 3.01$, $p = 0.86$. Thus, this

analysis did reveal differences in occupation forced-choice accuracy depending

on the order that the two judgments were made. Critical for the current

hypothesis, however, is that 'name rings a bell' responses conveyed above-chance

accuracy in both orders.

Overall, the results of Experiments 2A and 2B replicate the link we

observed between 'name rings a bell' responses and above-chance forced-choice

occupation accuracy, and extended these findings further by documenting that this

effect is not explainable entirely based on priming effects nor the differences in

retrieval cues between the two stages. In Experiment 2A, where the name-

recognition phase was probed before the occupation knowledge phase, 'name

rings a bell' responses again discriminated between famous and fictional names.

In both Experiments 2A and 2B, famous names for which participants gave a

'name rings a bell' response were associated with above-chance occupation

accuracy. Further, with respect to our question regarding whether such accuracy is

associated with subjective awareness, we found higher average occupation

response confidence in association with 'name rings a bell' responses than

'unfamiliar' responses in both Experiment 2A and 2B (see Table 1). This raises

the possibility that participants may even have some awareness of occupation

knowledge during 'name rings a bell' responses.

Most importantly, these results provide additional support for the notion

that 'name rings a bell' responses are associated with some available semantic

knowledge. Importantly, the modifications that we introduced in Experiment 2

allowed us to rule out two plausible alternative explanations for our main finding

in Experiment 1. Namely, we ruled out that the availability of semantic

knowledge associated with 'name rings a bell responses' is solely a consequence

of priming through a preceding presentation in the experiment or a consequence

of the provision of additional cues in the occupation judgments. Specifically, we

showed that the general relationship holds even when participants are informed

about the occupation options upfront in the name recognition stage (i.e.,

Experiment 2A), and even when they complete the occupation judgments in an

initial unprimed presentation.

3.5 Experiment 3

In our previous experiments, we demonstrated that 'familiarity-only'

experiences for famous names are associated with the availability of a meaningful

semantic signal. We interpret these results to suggest that available semantic

knowledge is best described as a continuum, perhaps reflected in the numerically

graded activation levels at SIUs, rather than in terms of binary states (i.e., absent

versus present). In Experiment 3, we aimed to obtain further empirical support for

this notion by employing graded name-recognition confidence responses for the

fame judgment task. Specifically, we replaced our three categorical response

options in the name-recognition stage with a 6-point scale that reflected

confidence as to whether or not a given name referred to a famous person.

Notably, in IAC models, both the nodes that reflect familiarity (i.e., the PINs) and

those that reflect semantic knowledge (i.e., the SIUs) are bi-directionally

connected. If one assumes activation at PINs and SIUs reflect graded degrees of

familiarity and semantic knowledge, respectively, increases in familiarity should be tightly linked to increases in semantic knowledge. Thus, we hypothesized that such graded name-recognition confidence judgments would be significantly correlated both with occupation forced-choice accuracy and with related confidence judgments.

3.5.1 Participants

Twelve fluent English-speaking students at the University of Western Ontario participated in the study (mean age = 23.00, SD = 2.63). They gave written informed consent and were compensated for their participation.

3.5.2 Materials and Procedure

The materials and procedure were identical to those in Experiment 1, except for two notable differences. In stage 1, participants were asked to rate their confidence in recognizing each name on a 6-point scale, with '6' indicating the highest confidence that the name refers to a famous celebrity, and '1' indicating the highest confidence that it did not; responses two through five were assigned intermediate degrees of famous name confidence. In stage 2, after completing each forced-choice occupation judgment, participants were asked to rate their confidence that their choice was correct, again using a graded 6-point scale (as in Experiments 2A and 2B).

3.5.3 Results and Discussion

Our analyses focused on whether degrees of familiarity with famous names, as measured with name-confidence judgments, were correlated with

objectively scored forced-choice accuracy and with subjective reports of

confidence in those occupation responses. As in Experiment 1, we found that

perceived familiarity of famous names was closely tied to objective accuracy on

the forced-choice occupation judgments. Figure 2a provides a visual depiction of

the occupation accuracy data for Experiment 3, collapsed across participants and

binned according to perceived familiarity on our 6-point scale. Overall, responses

one through three were not associated with above-chance occupation responding,

while responses four through six did convey above-chance occupation accuracy

(all $p < 0.01$). Such a pattern is revealing when one considers that responses one

through three were associated with rejecting names as non-famous, while

responses four through six were associated with endorsing them as famous. When

examined at the level of individual participants in item-based analyses, graded

familiarity values were significantly correlated with objective semantic accuracy

in 11 of the 12 participants ($p < 0.001$; mean for all participants: $r = 0.43$,

SD=0.15, calculated using Fisher z-transformation, see Silver & Dunlap, 1987).

Next we examined the relationship between degrees of famous name

familiarity, as reflected in name recognition confidence, and occupation

confidence; Figure 2b shows the tight correlation between familiarity and

occupation confidence, again aggregated across participants and binned according

to the different levels of confidence in fame judgments. When we examined

correlations between the degree of fame confidence and occupation confidence in

individual participants on a trial-by-trial basis, we also observed a consistently

strong relationship between reported familiarity and the subjective confidence in

occupation judgments in all participants (mean $r = 0.64$, SD=0.10, range=0.52-0.87, all $p < 0.001$). Together, these results demonstrate that degrees of perceived familiarity for famous names are strongly correlated with both objective occupation response accuracy as well as confidence in such forced-choice occupation judgments. These results provide evidence to support the idea that participants can make a meaningful distinction between different levels of familiarity: name-recognition judgments were found to be tightly linked to the availability of meaningful semantic knowledge, regardless of whether this is assessed with a measure of objective accuracy or a subjective measure of confidence.

3.6 General Discussion

In Experiments 1 and 2, we probed the availability of semantic knowledge in subjective familiarity-only experiences by combining a name-recognition task that required discriminations between famous and fictional names with a forced-choice occupation task. In Experiment 1, we found that 'name rings a bell' experiences discriminated between famous and fictional names. Moreover, for famous names, they were also associated with above-chance accuracy on corresponding forced-choice occupation judgments. The results of Experiment 2A and 2B were consistent with those of Experiment 1, and additionally suggested that in the case of 'name rings a bell' responses, participants have some meta-awareness of their associated occupation knowledge; participants' occupation confidence ratings were higher for 'name rings a bell' responses as compared to 'unfamiliar' responses in both Experiment 2A and 2B. Furthermore, Experiment 2
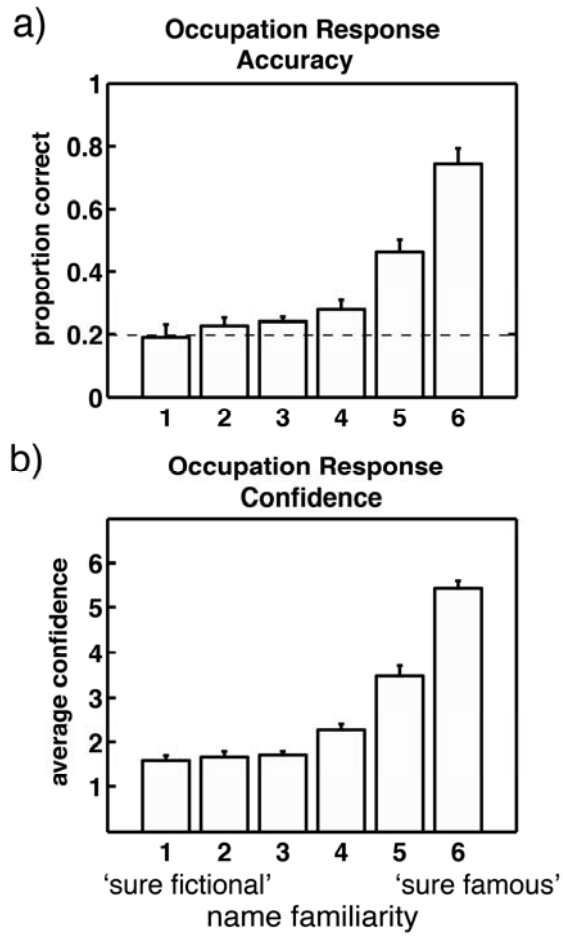
Figure 3-2: Results for Experiment 3

(a) Proportion of correct occupation judgments in stage 2 as
a function of fame recognition confidence in Experiment 3, and (b)
corresponding average occupation response confidence as a function of
fame recognition confidence. Black dashed line in (a) indicates chance
performance. Error bars depict SEM.

also ruled out the possibility that the observed pattern could be explained entirely based on priming between the name-recognition and occupation stages, or based on differences in retrieval cues between these two stages. Overall, the findings from Experiments 1 and 2 suggest that 'familiarity-only' responses to famous names are associated with the availability of a meaningful semantic signal. In Experiment 3, we asked participants to indicate graded levels of confidence for their fame recognition judgments, taken to reflect varying degrees of name familiarity, instead of recognition judgments defined based on the perceived presence or absence of semantic recall. In line with the idea that semantic knowledge is represented along a continuum, we showed that degrees of name familiarity are correlated both with objective forced-choice occupation accuracy as well as corresponding confidence in occupation responses.

The IAC model of person recognition accounts for 'familiarity-only' experiences by positing that they are the result of supra-threshold activation at the PINs in combination with sub-threshold activation at connected SIUs. In this account of familiarity-only experiences, however, supra-threshold activation at a PIN will still lead to some (even if sub-threshold) increases in activation at connected SIUs, as long as there is some link between these two types of nodes. Thus, in the case of 'familiarity-only' experiences, one way in which participants could achieve above-chance performance in the forced-choice occupation task is by comparing the precise degree of activation at the SIUs representing the seven occupation options in response to a famous name. Even if all SIUs are sub-threshold, the correct occupation choice may be chosen by considering which

corresponding SIU has the strongest activation. Notably, this account is not necessarily inconsistent with the idea that free recall has a distinct threshold at SIUs; it may be the case that the numerical threshold for free recall is just greater than that for above-chance forced-choice occupation accuracy.

Notably, our interpretation that the availability of semantic knowledge in 'familiarity-only' is driven by sub-threshold SIU activation has relevance to other empirical findings. A pertinent example is semantic priming; participants are faster to recognize names and faces that are preceded by a recently encountered, related person in the same or different modality, respectively (e.g., McNeill & Burton, 2002; Young, Flude, Hellawell, & Ellis, 1994). Such priming effects have even been argued to occur outside of conscious awareness, as they have been demonstrated in individuals with prosopagnosia, who cannot recognize faces overtly (e.g. de Haan, Young, & Newcombe, 1987; for a review, see Young & Burton, 1999), and in healthy participants when stimuli are presented too quickly to be registered consciously (Morrison, Bruce, & Burton, 2000; Wiese & Schweinberger, 2011). These effects can be explained within the model based on the reciprocal connections between each SIU, and the multiple PINs that represent all individuals who exhibit the corresponding semantic property in question (Burton, et al., 1991). Specifically, when a name or a face is recognized and the corresponding PIN for that individual reaches the threshold for familiarity, activation at connected SIU nodes will also increase correspondingly. In turn, such increases in SIU activation will also lead to activation of PINs that correspond to related individuals as well. For example, if Princess Diana's name

is presented, her PIN will increase in activation, but so too will the PIN node for

Kate Middleton, as the PINs for these two individuals share many SIUs ('royalty',

'British', etc). In this case, the sub-threshold increase in activation at the PIN for

Kate Middleton leads to reductions in the time it takes to recognize her when her

face or name is presented directly on a subsequent occasion.

In empirical findings such as semantic priming, sub-threshold SIU

activation is assumed to influence behavior via a decrease in reaction time, i.e.

participants are faster in detecting familiarity for famous face and name stimuli

that are preceded by a related person stimulus. Pertinently, our suggestion that

sub-threshold SIU activity can be accessed directly in a forced-choice task

conflicts somewhat with some previous ideas in this literature. For example, in

IAC simulations performed by Young & Burton (1999), the authors assumed that

sub-threshold activity at PIN nodes in the IAC model cannot manifest in the

accuracy of performance in a forced-choice familiarity task. Based on IAC

simulations that were intended to model the person recognition system of a patient

with prosopagnosia, they argued that even forced-choice familiarity judgments

require supra-threshold PIN activity. Thus, while the current discussion pertains

to SIUs and not PINs, our interpretation may nevertheless not be entirely

consistent with the assumptions adopted by Young & Burton (1999). However,

suggestion that sub-threshold SIU activation manifests as available semantic

knowledge seems the most plausible way to make sense of our findings in terms

of the organization of the IAC model. Importantly, our suggestion that familiarity-

only experiences may be associated with some degree of partial knowledge,

whether or not one considers this to be reflective of sub-threshold SIU activation, is consistent with what is known about other similar phenomenological states. For example, in both the 'tip-of-the-tongue' state as well as the 'feeling of knowing' state, participants can often express some degree of meaningful but fragmentary partial knowledge that pertains to the presented stimulus (Koriat & Lieblich, 1974; for a recent review, see Schwartz & Metcalfe, 2011). Furthermore, in cases where conceptual knowledge is affected by neurological disorders such as semantic dementia, it typically breaks down gradually, such that access to more specific conceptual knowledge is impaired at first, with loss of more general corresponding knowledge lost later in the disease (for a review, see Patterson, Nestor, & Rogers, 2007; for similar effects in normal individuals, see Crutch & Warrington, 2006). Thus, our results are consistent with the literature at large in suggesting that in some situations, only partial knowledge is available for a currently presented stimulus, and that the degree to which such partial knowledge is observable is contingent on the way in which this knowledge is probed.

The results from Experiment 3 provide support for the idea that name familiarity is also best described in terms of a graded continuum, rather than in terms of binary states. We found that degrees of famous name familiarity are highly correlated both with occupation accuracy and with degrees of occupation-response confidence. Within IAC models, these correlations can be explained based on reciprocal connections between PIN and SIU nodes, as these connections necessitate that in general, activation at PIN and SIU nodes will be correlated to some degree. Notably, this result also has relevance to the extensive

literature that has focused on receiver-operating characteristics (ROC) in recognition memory (Macmillan & Creelman, 2005). In experiments conducted within this domain of experimental research, participants are generally required to study a set of study items (e.g. words), and in a later test phase, they are presented with an intermixed list of items that includes all old target items and a set of novel lure items. Participants make recognition judgments with respect to their level of confidence that each test item was or was not previously presented. Researchers working in this field generally agree that recognition memory is well described by invoking graded Gaussian distributions of memory evidence in the context of signal-detection theory (for reviews, see Wixted, 2007; Yonelinas & Parks, 2007; but see Malmberg, 2002). It is assumed in such signal-detection models that increasing degrees of recognition confidence are associated with both more conservative response criteria and with more memory evidence that pertains to prior occurrence.

Notably, in a recent study from our lab, we used mathematical modeling to show that graded name-recognition confidence judgments of the same kind made in the first stage of Experiment 3 are also well described with signal-detection mechanisms and graded memory evidence (Bowles, Harlow, Meeking, & Kohler, *in press*). We also tested an alternative detection approach that assumes recognition either occurs or does not occur on any trial based on discrete probabilities (i.e., threshold accounts; for a recent review, see Erdfelder et al., 2011). While formal signal-detection mechanisms are rarely discussed in the person recognition literature, the latter type of model seems to be in keeping with

the assumption inherent in the IAC model that familiarity is thought to be absent or present on any trial based on a discrete activation threshold. Notably, in two separate datasets, the fit of both a one-high-threshold and a two-high-threshold model was found be inferior as compared to a signal-detection model that employed Gaussian distributions of memory evidence. Thus, our results argue in favor of graded evidence in fame recognition, and that participants can use varying levels of such evidence to set corresponding criteria in fame judgments. Within the context of the IAC model, it is possible to interpret this graded evidence as corresponding to varying levels of numerical activation at PIN nodes. Regardless, both the current results as well as those previously reported in Bowles al., argue against the notion that familiarity is either present or absent on any given trial.

An important aspect of our study that merits discussion is that semantic knowledge was probed in a separate stage of the experiment than the name-recognition judgments in all our work presented here. Thus, these data do not allow us to conclude with any certainty that access of available knowledge does indeed take place at the moment when subjective familiarity-only experiences occur. Indeed, this would be the case for data based on any similar paradigm, as it is not possible to probe both for a subjective sense of familiarity and access of semantic knowledge simultaneously. The issue is of particular interest in Experiments 1 and 3, in which participants completed the occupation judgments after all name recognitions had been completed. It is possible, given this experimental set-up, that the initial presentation of the famous names primed the

availability of semantic knowledge only during the second stage. In Experiment 2, we ruled this out by showing that the same general pattern was observed regardless of whether the occupation judgments were made before or after the name-recognition stage. Moreover, in both Experiments 2A and 2B, we also minimized the differences in retrieval cues between these two different stages. Thus, the results argue strongly for the availability of some semantic knowledge during 'name rings a bell' responses overall. It also seems likely, given that 'familiarity-only' experiences are known to be associated with extended semantic search efforts (Young, et al., 1985), that some access of this available knowledge also takes place during this type of response as well.

Notably, our results cannot speak to whether familiarity may be more clearly dissociable from semantic knowledge in neurological patients who have presented with preserved familiarity for names but impaired access to semantic knowledge. In some studies, such as that involving patient ME, which exclusively relied on free recall, observations of purported familiarity-only experiences may have been accompanied by semantic knowledge that went undetected. It is worth noting that in other patients who had difficulties retrieving semantic knowledge about names they found familiar, some partial knowledge was detectable only with tasks that are generally agreed to be more sensitive than free recall. Research conducted in patient KC, who became densely amnesic as a result of a head injury associated with a motorcycle accident, provides support this idea (Westmacott & Moscovitch, 2001). Specifically, KC was found to exhibit no pertinent knowledge for familiar famous names when probed through explicit free recall. Yet, similar

to the findings regarding 'name rings a bell' experiences reported in the current study, his occupation knowledge was found to be well above chance when he was asked to make forced-choice judgments.

One further aspect of our data that merits discussion is that participants endorsed a significantly greater proportion of 'name rings a bell' responses to famous as compared to fictional names in Experiment 1 and 2A, but not in Experiment 2B. In Experiment 2B, there was no significant difference between the proportions of 'name rings a bell' responses that were given to famous as compared to fictional names. In Experiment 2B, it is likely that when participants made fame judgments to famous and fictional names in the second stage, their prior exposure to these names in the occupation judgments influenced their recognition judgments. Although participants were instructed to use the 'name rings a bell' response for familiarity based on life experience, previous research has documented that participants can sometimes mistake pre-experimental familiarity with that based on a recent study exposure when recognizing famous names (i.e. the false fame effect; see Jacoby, et al., 1989). It is also worth noting that whether or not 'name rings a bell' responses are considered to be reflective of accurate discrimination in Experiment 2B, as well as in all other experiments presented here, is dependent on the assumptions one uses to compute a discriminability index for such responses. Specifically, a direct comparison of raw proportions of 'name rings a bell' responses for famous and fictional names, as was done in all analyses, assumes that the process that leads to 'rings a bell' responses is not operative at the time when 'recognize with semantic recall'

responses are provided (see Jones, 1987). This can be formally described as an exclusivity account, and has been discussed extensively in the context of the Remember-Know procedure in research on recognition memory (e.g. Gardiner & Parkin, 1990; Gardiner, Ramponi, & Richardson-Klavehn, 1998). However, there are other plausible conceptualizations of the relationship between 'name rings a bell' responses and those based on semantic identification, including accounts that are based on a redundancy or an independence relationship. In a redundancy account, for example, the underlying familiarity process would be reflected both in 'name rings a bell' responses as well as in 'recognize with semantic recall' responses (see Joordens & Merikle, 1993 for an application). Given that in situations in which SIU activation is supra-threshold PINs should also be supra-threshold, a redundancy account may also be considered a viable option in the context of the IAC model of person recognition. As this is one of the first studies that directly addresses the relationship between familiarity and semantic knowledge for names with a procedure similar to the Remember-know paradigm, we have concentrated on comparing the raw rates of 'name rings a bell' responses for famous versus fictional names within an exclusivity account. It is worth noting, that if one were to calculate familiarity accuracy using corrected proportions, under the assumptions of a redundancy account, 'name rings a bell' responses would be reflective of significant discriminability even in Experiment 2B ($p < 0.005$).

In sum, the current findings suggest that feelings of familiarity towards proper names of people are not as clearly separable from semantic knowledge as

the term 'familiarity-only experience' suggests. Instead, these states may be

associated with partially activated knowledge, perhaps similar to what has been

reported for states such as the tip of the tongue phenomenon and feeling-of-

knowing (Schwartz & Metcalfe, 2011). Although people may be unable to recall a

piece of semantic knowledge in response to the name of a person, this cannot be

taken as evidence that no semantic knowledge is available, or even that people

have no sense of awareness of the potential availability of relevant accurate

knowledge. Within the context of the IAC model, the knowledge that we reveal in

association with 'name rings a bell' responses may be considered reflective of

increased, albeit sub-threshold, activation at SIU nodes. Finally, our finding that

participants report some meta-awareness of semantic knowledge in association

with 'name rings a bell' responses is also consistent with the notion that this

recognition stage may involve some repeated search attempts for identifying

information.

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4 That name rings a bell! 'Familiarity-only' experiences engage brain regions that support semantic retrieval

4.1 Abstract

Little is known about the neural basis of 'familiarity-only' experiences, in which the name or face of a person is perceived as familiar, but relevant semantic knowledge cannot be readily retrieved. One possibility is that these experiences engage the same brain regions as those that support successful identification of the relevant individual, but to a lesser degree. Alternatively, given that 'familiarity-only' experiences do not involve any successful semantic retrieval, they may engage entirely distinct brain areas as compared to successful identification. Here, we used event-related fMRI to examine the extent to which 'familiarity-only' responses for famous names engage the same brain regions as those that support semantic decisions and full identification. In the first phase of the experiment, participants were asked to indicate whether famous and fictional names were unfamiliar, familiar-only, or whether the name could be identified based on semantic recall. To help isolate brain regions involved in successful semantic access, participants were subsequently presented with a separate set of famous names, and were asked to complete a forced-choice occupation task. Our analyses revealed partial overlap between regions supporting 'familiarity-only' responses and those supporting successful access of semantic knowledge in the left posterior middle temporal gyrus and an inferior aspect of the left ventrolateral

prefrontal cortex. Notably, a more dorsal region of bilateral ventrolateral prefrontal cortex was found to support 'familiarity-only' experiences for names more so than successful identification. In addition, activity in bilateral perirhinal cortex was linked to assessing the potential availability of partial knowledge in this recognition state. Overall, these results suggest that 'familiarity-only' experiences for famous names engage both common and distinct brain regions as compared to successful semantic access.

4.2 Introduction

The experience of familiarity for a name, coupled with a peculiar inability to identify the person in question, is a common experience in daily life. Indeed, such experiences are sufficiently common as to have motivated a unique idiom in the English language that signifies them: 'That name rings a bell!' In healthy individuals, familiarity-only experiences have been documented in diary studies of memory errors (Young, Hay, & Ellis, 1985), as well as in several behavioral investigations. (Hanley & Hadfield, 1998; Hanley & Turner, 2000). Such experiences have been accounted for in the context of contemporary connectionist models of person recognition (Brédart, Valentine, Calder, & Gassi, 1995; Burton & Bruce, 1993; Burton, Bruce, & Johnston, 1990; Valentine, 1996), which employ the interactive activation and competition modeling framework (IAC; McClelland & Rumelhart, 1981). In such models, familiarity is registered at a person identity node (PIN), at the point at which separate modality-specific recognition systems for faces, names, and voices converge. Activation of the PIN

permits access to various connected semantic identification units (SIU), which reflect specific semantic characteristics of people (e.g. 'actor', 'musician', 'royalty'). Within this framework, 'familiarity-only' experiences have been suggested to occur when activation levels are supra-threshold at the PIN that represents the person at hand, but sub-threshold at connected SIUs as a result of a presumed blocking between these two types of nodes (for a review, see Hanley & Cohen, 2008; Young & Burton, 1999). Here we ask whether a distinction between the registration of familiarity, and the successful retrieval of semantic knowledge, manifests at the neural level in the context of famous name recognition. In other words, to what extent are those areas of the brain that support familiarity-only experiences for names separable from those areas that are engaged in states that involve successful access of semantic knowledge about them?

The notion that familiarity for famous names may be dissociable from accessing semantic knowledge about them finds support in a number of neuropsychological case reports. Several neurological patients have been found to exhibit disproportionate impairments in accessing semantic knowledge about famous names that they perceive as familiar. The most well known example of this behavioral pattern was patient ME, reported in Haan & Young (1991; see Young & Burton, 1999, for further discussion). This individual developed memory problems after treatment for a vasculitic disorder that appeared to be accompanied by no obvious brain damage. For a series of faces and names, she was asked to rate her perceived familiarity for these test stimuli on a 7-point scale; for those she considered familiar, she was asked to recall the individual's

occupation, and for faces, their name as well. She had fully preserved abilities in finding names or faces familiar, but at the same time was unable to recall the occupation, nor any other type of information that pertained to those stimuli. ME's impairment was taken as support for the idea that familiarity is assessed at a stage of person recognition that takes place prior to the access of semantic knowledge; it was further postulated that her impairment might be related to a problem in the link between PINs and connected SIUs.

While the report of ME is the only one of this type that was interpreted within IAC models, other patients have also been documented to exhibit a preserved ability to recognize famous names along with disproportionate difficulties in accessing semantic knowledge about them. One such patient, DEL, underwent damage to the left medial temporal lobe in addition to an area of the left posterior occipital-temporal lobe as a result of a left temporal lobe stroke (Verstichel, Cohen, & Crochet, 1996). Consequently, DEL exhibited a specific impairment in accessing semantic knowledge about names he found familiar and in recalling them when presented with a face or a verbal definition. One noteworthy aspect of DEL's case is that he maintained a fully preserved ability to recall semantic knowledge in response to faces. Thus, his inability to recall semantic knowledge normally in response to names appears to be related to problems in the link between the lexical representations for peoples' names and stored semantic knowledge about those names. In other patients who exhibited disproportionate impairments in retrieving semantic knowledge about familiar names, the problem appeared to be more related to the semantic knowledge

representations themselves rather than simply access to them. This was true of KC, who obtained damage to the bilateral medial temporal lobe as well as to the left frontal and parietal cortices as a result of a closed head injury (Westmacott & Moscovitch, 2003). It is also true of ST, a patient with semantic dementia whose damage included the bilateral superior parietal cortex as well as the left anterior temporal lobe (Giovanello, Alexander, & Verfaellie, 2003; see also patient RFR, McCarthy, Kopelman, & Warrington, 2005; Warrington & McCarthy, 1988).

While the case reports reviewed above are rather heterogeneous with respect to both etiology and underlying brain damage, the patients under investigation all exhibited a relatively preserved ability to find names familiar, in the context of a more pronounced impairment in retrieving pertinent semantic knowledge about them. Interestingly, in most cases, these patients still demonstrated some preserved semantic knowledge in response to names, which could be revealed in cued-recall and forced-choice tasks. Although Patient DEL could not recall the same amount of semantic information in response to names that he could for faces, he could still conjure up some partial information in response to presented names, such as a vague sense regarding the occupation of the individual. Somewhat similarly, KC achieved above chance performance on a forced-choice occupation task for famous names he found familiar but for which claimed he did know anything about (Westmacott & Moscovitch, 2001). While patient ME showed no such evidence of any preserved partial semantic knowledge for names or faces, the exclusive reliance on free recall in that study leaves open the possibility that residual knowledge could have been detected with

other more sensitive tasks (e.g., forced-choice tasks). The idea that preserved

familiarity for famous names may be accompanied by some degree of partial

semantic knowledge is also consistent with previous behavioral investigations in

our lab with normal individuals (i.e., Chapter 3). Specifically, we demonstrated

that for famous names for which subjects previously reported 'familiar-only'

experiences, they scored above chance on a subsequent forced-choice occupation

task. Moreover, we also found that participants had higher confidence in forced-

choice occupation judgments for famous names that they had previously reported

to be 'familiar-only' as compared to those judged 'unfamiliar'.

Based on the heterogeneity of the lesions in the previously described

patients, it is challenging to generate clear conclusions as to which specific brain

areas may be important for assessing familiarity for famous names, and which

areas may be more involved in the storage and / or retrieval of relevant semantic

knowledge. Although three of these individuals (RFR, KC, DEL) were found to

exhibit damage to the left parahippocampal gyrus, the additional brain damage in

patients KC and RFR limits conclusions concerning this area of overlap in these

patients. In general, the pertinent brain imaging literature is equally problematic

with respect to making predictions regarding which brain areas support these two

specific components of famous name recognition, but for different reasons. The

majority of the existing brain imaging studies of famous name recognition have

involved the use of highly famous names as stimuli, which were selected such that

they would not only be familiar to participants, but would also readily provoke

retrieval of semantic knowledge that would allow for full identification (e.g.,

Nielson et al., 2010; Sugiura et al., 2009).

To the extent that semantic knowledge retrieval is an important part of

successfully identifying famous names (Bruce & Young, 1986; Burton & Bruce,

1993), using highly famous names is appropriate if the goal is to uncover the

brain areas that support famous name recognition. However, when names are

employed for which identification is possible in each trial, it is challenging to

derive conclusions about whether the resulting brain activity patterns reflect the

process of assessing familiarity for the famous names, that of accessing semantic

knowledge about them, or both (see Nielson, et al., 2010; Tranel, Feinstein, &

Manzel, 2011, for further discussion of this point). Although in most functional

brain imaging studies participants have been only asked to detect whether or not

the presented names are familiar during scanning (e.g., Gorno-Tempini et al.,

1998; Sugiura, Sassa, Watanabe, & Akitsuki, 2006; Sugiura, et al., 2009), it is

likely that some semantic knowledge was accessed obligatorily, given that this

has been argued to be the case in word recognition more generally (e.g., Neely,

1991). Alternatively, some semantic retrieval processes may have been engaged

strategically by participants to confirm that familiar famous names did indeed

refer to celebrities. Notably, to our knowledge, no study of famous name

recognition has separated trials that were only associated with experiences of

familiarity from those that were also associated with semantic knowledge

retrieval. A powerful approach to isolate states of familiarity has been developed

in research with the study-test paradigms, in which recognition is assessed with

reference to one discrete study episode rather than a lifetime of experiences. In the Remember-Know paradigm, for example, participants are asked to make a subjective judgment as to whether stimuli are familiar based on the prior study phase (i.e., a 'Know' response) or whether they provoke recall of contextual details surrounding the original encounter (i.e., a 'Remember' response; Tulving, 1985). Using this approach, investigators have implicated some areas, such as the perirhinal cortex, in supporting subjective experiences of familiarity, and others, such as the hippocampus, in recalling contextual detail about the original study event (for reviews, see Eichenbaum, Yonelinas, & Ranganath, 2007; Skinner & Fernandes, 2007).

Several studies in the literature are informative with respect to which brain areas support successful famous name recognition generally, without any specific attempt to separate familiarity from semantic knowledge retrieval. The anterior temporal lobes (ATL) have been widely implicated in person recognition (for reviews, see Gainotti, 2007a, 2007b), including in studies on famous name recognition specifically (Gorno-Tempini, et al., 1998; Sergent, MacDonald, & Zuck, 1994; Sugiura, et al., 2006; Sugiura, et al., 2009). In two recent studies that employed event-related functional magnetic resonance imaging (fMRI), Sugiura and colleagues found that the bilateral ATLs were active in a task that required confirming that names of celebrities and personally known individuals were familiar. The left ATL was also implicated in another study that compared the brain regions that were engaged while participants detected the familiarity of famous names with those that were engaged while they made forced-choice

occupation decisions (Sergent, et al., 1994). Interestingly, these authors found that left ATL was engaged by occupation judgments and not by familiarity decisions. While this is inconsistent with the more recent studies by Sugiura and colleagues, a role of the left ATL in accessing semantic information about people is consistent with several other findings. For example, in a more recent study, the left ATL was found to be more involved in accessing specific information about faces of celebrities (e.g., that George Bush's face refers to a president), as compared to more general information (e.g., that George Bush's face refers to a politician) (Brambati, Benoit, Monetta, Belleville, & Joubert, 2010). Together, these findings raise the possibility that the left ATL supports the retrieval of semantic knowledge about people, and that in the previously described studies by Sugiura et al. (2006, 2009), this structure may have reflected the obligatorily access of semantic knowledge.

An adjacent area that has been widely implicated in famous name recognition is the left middle temporal gyrus (MTG) (Gorno-Tempini, et al., 1998; Nielson, et al., 2010; Sergent, et al., 1994; Sugiura, et al., 2006; Sugiura, et al., 2009). Interestingly, both Nielson et al. (1994) and Gorno-Tempini et al. (1998) found that this area was more engaged by the presentation of both famous faces and famous names as compared to corresponding non-famous faces and names. Thus, this brain area may support semantic representations about people regardless of stimulus modality. This notion is broadly consistent with the previously mentioned meta-analysis (Binder, et al., 2009), and two recent studies of functional connectivity based on resting state activity (Buckner et al., 2009;

Turken & Dronkers, 2011), in which it was suggested that this area serves as a critical hub in the semantic memory system. A further area that is often engaged during famous name recognition tasks, but less often discussed in any detail in this context, is the left ventrolateral prefrontal cortex (vlPFC) (Gorno-Tempini, et al., 1998; Sergent, et al., 1994; Sugiura, et al., 2009). While the precise role of the left vlPFC is debated in the literature at large (Thompson-Schill, D'Esposito, Aguirre, & Farah, 1997; Wagner, Paré-Blagoev, Clark, & Poldrack, 2001), it has been argued in a number of accounts that this structure supports top-down control in semantic retrieval by selecting semantic knowledge representations that are pertinent to the task at hand (for reviews, see Badre & Wagner, 2007; Race, Kuhl, Badre, & Wagner, 2009).

In the current article we ask to what extent the process of assessing familiarity for famous names is dissociable from that of accessing pertinent semantic knowledge in terms of underlying brain regions. Our predictions were based both on previous patient studies, which suggested some preserved semantic knowledge tends to accompany preserved familiarity for famous names, and also based on the availability of semantic knowledge in NRB responses. Specifically, we predicted that the same brain regions that support the successful retrieval of semantic knowledge about famous names would also be engaged during NRB responses. Another possibility is that NRB responses engage brain areas that are distinct from those that support the ability to successfully retrieve semantic knowledge about them. This latter notion would be more in keeping with a core assumption of IAC models of person recognition; namely, that familiarity

assessment occurs at a distinct stage of person recognition as compared to the

stage at which pertinent semantic knowledge is accessed. To address this

question, we employed a functional magnetic resonance imaging (fMRI)

experiment that employed two stages. In the first stage, we presented moderately

famous names to participants one at a time while they were being scanned with

functional magnetic resonance imaging (fMRI). We asked participants to decide

whether the presented names were unfamiliar, seemed familiar but did not

provoke retrieval of related semantic details, or could be identified based on recall

of at least one specific semantic detail. In a second phase of the experiment, we

measured semantic knowledge directly by presenting a separate set of famous

names to participants, and asking them to choose the celebrity's occupation from

among four other occupation distractors in the context of a forced-choice task. By

using a separate set of famous names for judgments in the second stage, we aimed

to minimize any confounding influence of priming between the two stages. We

specifically focused on occupation knowledge due to its suggested central

importance in the organization of semantic memory related to proper names

(Crutch & Warrington, 2004; Darling & Valentine, 2005; but see Barry, Johnston,

& Scanlan, 1998). In addition, unlike in previous studies of famous name

recognition, we exclusively used famous names that were not so famous as to be

readily identifiable by all participants (e.g., Barack Obama), but at the same time,

were sufficiently common so as to frequently provoke NRB responses.

  In light of the general trend in past work to use highly famous names for

which some semantic knowledge could likely be retrieved, we made the strongest

predictions with respect to which brain areas would support retrieving semantic

knowledge for these stimuli. Specifically, we predicted that the left ATL, the left

MTG, and the left vlPFC, would specifically support the identification response in

the first stage as well as responses that conveyed successful access to occupation

knowledge in the second stage. As we predicted the NRB recognition state likely

involves both of these two processes to some extent, we hypothesized that these

structures might also be more engaged by famous names given NRB responses

than by corresponding names given 'unfamiliar' responses. We also hypothesized

that one area, the perirhinal cortex, might specifically be involved in some aspect

of NRB experiences, as this structure is widely agreed to play an important role in

supporting familiarity assessment in study-test paradigms (Aggleton & Brown,

1999; Eichenbaum, et al., 2007). While some studies suggest this structure also

contributes to familiarity judgments that are linked to semantic representations

that develop in the course of general lifetime experience (Dietl et al., 2005;

Plailly, Tillmann, & Royet, 2007; Rolls, Franco, & Stringer, 2005), only a paucity

of extant research speaks to this possibility at present.

4.3 Participants

Sixteen right-handed healthy individuals (8 male; age range 20–31 years)

participated in the study. All participants had normal or corrected-to-normal

vision and gave written informed consent. Participants were screened for the

absence of a history of neurological disease, and received compensation for their

participation. This study received approval from the Health Sciences Research

Ethics Board at the University of Western Ontario. For technical reasons, one participant did not complete one name-recognition phase run and one occupation phase run. Another participant was unable to complete the last three runs in the occupation phase. One run with name-recognition judgments had to be excluded in an additional participant, as it did not contain any NRB responses. In all of these cases, all remaining data were included in the analyses presented here.

4.4 Materials

A set of 300 famous names was selected that referred to individuals moderately well known in the media based on five different primary occupation types (i.e., authors, athletes, actors, politicians, and TV/radio personalities; see Table 1 for examples of employed famous name stimuli). Celebrities were of various nationalities but we ensured that each of them had a high likelihood of some media exposure in the country where the study was conducted (i.e., Canada). All selected celebrities were individuals typically referred to by their first and last name in the media. Celebrities were not considered for our set if, (a) they were well known by a slang name, (b) their name had accents, punctuation or non-English characters, (c) their name referred to more than one celebrity, or (d) typical reference to their name in the media included a middle name (e.g., Billy Bob Thornton). In addition, we avoided very well known famous names that would be confidently recognized by most participants (e.g., Barack Obama). Individuals were sampled with roughly equal likelihood from the five different occupation types for the entire list of 300 famous names (range: 63-69 for each occupation type). The set of 300 famous names was divided into two matched sets

of 150 names for separate use in the two phases of the experiment (i.e., the initial

name-recognition phase, and the later occupation phase). These two sets of

famous names were matched on sex distribution (59.3% male) and on the

frequency of their first and last names based on information available in the U.S.

Census Bureau 1990 database (http://www.census.gov/genealogy/www/). First

and last names that were not available in this database were assumed to have a

frequency of zero. In addition, the two famous-name sets were also matched on

the average number of syllables and letters, considering first and last names

separately.

For each occupation type within each of the two famous-name sets, there

was approximately equal representation of male and female celebrities.

Importantly, the two lists of famous names were prepared in such a way that each

of the five occupation categories applied approximately equally often (i.e., each of

the five occupation types was correct between 31 and 35 times for each of the two

sets). Towards this end, we took into consideration that a small number of

celebrities had multiple occupations, i.e., were considered famous in more than

one domain. Based on this list composition, a chance rate of performance on the

occupation task could be computed by averaging the proportions of the five

possible occupations considered correct for each individual (e.g., 1/5, 2/5, 3/5,

etc.) across each set of 150 famous names. As the majority of famous names were

only associated with one correct answer, the chance level of performance was

close to 1/5; more specifically, the resulting chance rates for the two sets of

famous names corresponded to 0.216 and 0.22 for the first and second sets,

respectively. For practical purposes, we used the average for both sets (i.e., 0.218) in all analyses aimed at assessing whether forced-choice occupation responding was at an above-chance level.

For the initial name-recognition phase, each of these two sets of 150 famous names was matched with a distinct set of 50 fictional names that did not refer to any famous persons. Fictional names were created by separately selecting an appropriate set of matched first and last names, and then combining them in such a way that no combination inadvertently referred to any famous celebrity. We used the Wikipedia online encyclopedia (http://www.wikipedia.org) to verify this was the case in all instances. We selected a set of fictional first names by taking a pseudorandom sample of first names from the famous name set, avoiding those that may be rare or particularly distinctive (e.g., Zinedane, for the famous soccer player). In turn, the 50 fictional last names were selected by first selecting a pseudorandom sample of fifty of the famous last names, and then, for each one, selecting a last name in the U.S. Census database that was approximately matched in terms of number of syllables and length. Fictional first and last names were combined with the constraint that each famous-name set was matched to its corresponding fictional name-set for frequency, length, and number of syllables, considering first and last names separately.

4.5 Experimental Design & Procedure

The experiment included ten fMRI runs in a fast event-related design (see Figure 1). In the first five runs, participants made name-recognition judgments, and in the second five runs, participants made occupation judgments. Participants

encountered a different set of famous names in each task. The assignment of the two sets of famous names to the two tasks was counterbalanced across participants. Order of runs within each task was also counterbalanced across participants. For each run, trial order and jitter were optimized using the "OptSeq2" algorithm (http://surfer. nmr.mgh.harvard.edu/optseq/). Each of the five runs for each task employed 30 famous names, and each name-recognition run additionally included 10 fictional names, that were intermixed based on the optseq2 algorithm. Each trial lasted for four seconds (i.e., 2 TRs), with intervening periods of jitter, which involved presentation of a central fixation cross (+) for varying duration (range: 2s -12s; see Figure 1). During the last second of each fixation period, the fixation cross became bolded to warn participants about the upcoming onset of the next event.

For the name-recognition phase, participants were informed that a series of randomly intermixed famous and fictional names would be presented during scanning one at a time (see Figure 1A). They were instructed to indicate for each name whether it, 1) was unfamiliar, 2) seemed familiar but could not be identified, or 3) could be identified based on the retrieval of at least one distinct piece of semantic information. The second response option was reserved for recognition situations in which participants had a sense that they had some prior experience with the name based on media exposure, but could not recall any distinct piece of semantic knowledge about it. Participants were given a short practice phase before the experiment began, in a screening session and outside the scanner just prior to scanning, to ensure that they understood and could correctly

apply these response options in a confident manner.

The occupation phase involved two consecutive judgments for each famous name, performed in separate events: an initial forced-choice occupation judgment (4s) and a subsequent confidence judgment that pertained to the preceding occupation judgment (4s). Judgments were separated by intervening jitter (2-12s) filled with fixation (see Figure 1B). For the forced-choice trials, participants were presented with a famous name and five occupation options (i.e. 'actor', 'author', 'musician', 'politician', and 'athlete) that were presented below the name. Participants were instructed to choose the occupation most clearly associated with the famous name, regardless of whether they thought they recognized the name confidently or found it to be unfamiliar and were guessing. After the subsequent jitter period, participants were presented again with the famous name, the occupation they had chosen, and four confidence options. Participants were asked to rate their confidence that their response was correct on a scale of one ('completely guess') to four ('completely confident'). 'Two' and 'three' responses were reserved for intermediate degrees of confidence. As in the name-recognition phase, participants were required to complete a practice phase at the beginning of
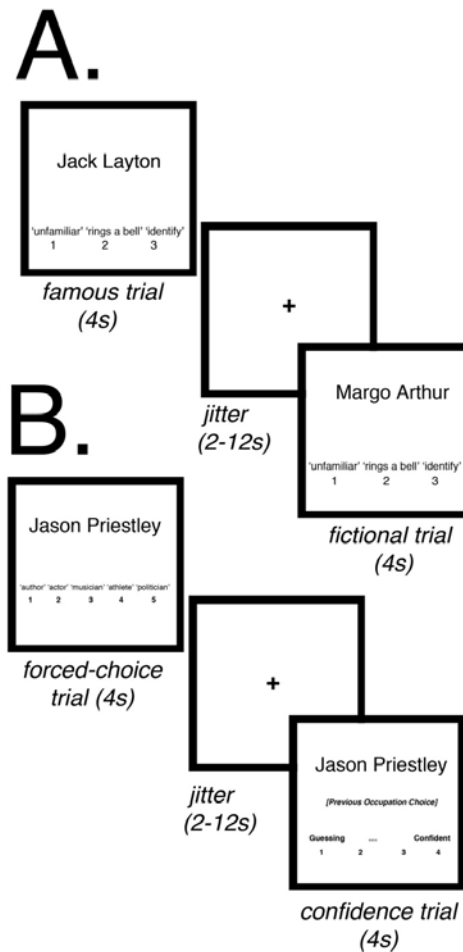
Figure 4-1: Experimental design

A) For each of the five name-recognition runs, participants were presented with 30 famous and 10 fictional names, and were asked to indicate whether each one 1) was unfamiliar, 2) rang a bell, or 3) could be identified based on recall of a discrete piece of semantic information. B) For each of the five occupation runs, participants were presented with 30 famous names one at a time. For each name, participants made an occupation forced-choice judgment in an initial event, followed by a confidence judgment in a separate event.

Table 4-1: Examples of famous name stimuli used

Authors	Actors	Athletes	Musicians	Politicians
Timothy Findley	Jason Priestley	Ross Rebagliati	Jay Sean	Paul Wolfowitz
Yann Martel	Daniel Craig	Andre Agassi	Roger Waters	Jack Layton
Margaret Atwood	Christina Cox	Tessa Virtue	Rita MacNeil	Rona Ambrose
Eudora Welty	Megan Follows	Maria Sharapova	Sarah Harmer	Belinda Stronach
Janet Evanovich	Sandra Oh	Lennox Lewis	Sean Kingston	Carolyn Parrish

the experiment to ensure that they were comfortable with task demands and timing constraints.

After participants exited the scanner, they were asked to complete an additional behavioral task that probed occupation knowledge for the same famous names that were previously encountered in the name-recognition phase runs of the fMRI session. For each name, presented one at a time, they made forced-choice occupation judgments and corresponding confidence judgments in a similar way as they had for the other set of famous names presented under scanning. Unlike during scanning, however, presentation of names and response delivery were self-paced with a maximum duration of four seconds and an inter-stimulus interval of one second.

4.6 fMRI data acquisition and image analysis.

Image acquisition was completed on a 3-Tesla Siemens MAGNETOM Tim Trio MRI scanner (Siemens, Erlangen, Germany) using a 32-channel head coil. An oblique axial orientation was selected so as to prevent artifacts related to inclusion of the eyes in the functional volumes. For each volume, 42 contiguous 3 mm slices were obtained with a field of view of 19.2 X 19.2 cm (sampled with a 64 x 64 matrix) and an in-plane resolution of 3 x 3 mm. A T2* weighted single shot EPI acquisition was used for all functional scans (echo time (TE) = 25 ms; repetition time (TR) = 2000 ms; flip angle, 70°) with 176 volumes per run for name-recognition phase runs and 260 volumes per run for the occupation-phase runs. In between the name-recognition and occupation phases, a T1-weighted high-resolution anatomical scan was acquired in the sagittal plane (192 slices; TR

= 2300 ms; TE = 4.25 ms; 240 x 256 matrix, in-plane resolution of 1 mm x 1 mm

with 1 mm slice thickness). fMRI data were analyzed using Brain Voyager QX

2.3 software (Brain Innovation, Maastricht, The Netherlands). Functional images

were resampled into 3 mm isotropic voxels, high-pass filtered, co-registered with

the anatomical image, and transformed into standardized Talairach space

(Talairach & Tournoux, 1988). To account for anatomical variability between

subjects, resulting images were smoothed using a three-dimensional Gaussian

kernel with a full-width at half maximum value of 8 mm. Predictors for all

conditions in all analyses were convolved with a standard Boynton response

function and examined in a random-effects general linear model (GLM). Mean

intensity of the volume, as well as the six motion predictors generated during

motion correction, were included as a covariates-of-no-interest for each separate

run. Unless indicated otherwise, a significance level of $p < 0.001$ (uncorrected)

was used as a statistical threshold for all activation maps. In addition, each

activation map was thresholded at the cluster level of $p < 0.05$, which was

determined based on Monte Carlo estimation using the BrainVoyager plugin. As

the minimum cluster size threshold differed for each map, we report them

separately in the table that pertains to each contrast we report.

4.7 Results

Behavioral data for the two experimental phases were examined

separately. These data was examined at the level of response proportions, forced-

Table 4-3: Behavioral data for name-recognition phase [Mean (SEM)]

	Recognition Response		
	unfamiliar'	rings a bell'	identify'
famous trials - response proportions	0.55 (0.03)	0.17 (0.02)	0.28 (0.03)
fictional trials - response proportions	0.87 (0.03)	0.13 (0.03)	0.01 (0.00)
famous trials – RT (ms)	1903.63 (87.45)	2296.32 (101.98)	1578.97 (74.46)
fictional trials – RT (ms)	1897.59 (88.34)	2391.51 (123.57)	N / A

Table 4-3: Behavioral data for occupation phase [Mean (SEM)]

	Confidence Level			
	1 (Completely Guessing)	2	3	4 (Completely Confident)
response proportions	0.48 (0.13)	0.19 (0.13)	0.08 (0.05)	0.25 (0.10)
forced-choice trials – RT (ms)	2572.77 (270.34)	2670.80 (291.54)	2549.51 (333.31)	2132.67 (220.77)
confidence trials – RT (ms)	962.38 (301.70)	943.50 (345.02)	1039.67 (355.31)	894.34 (200.90)
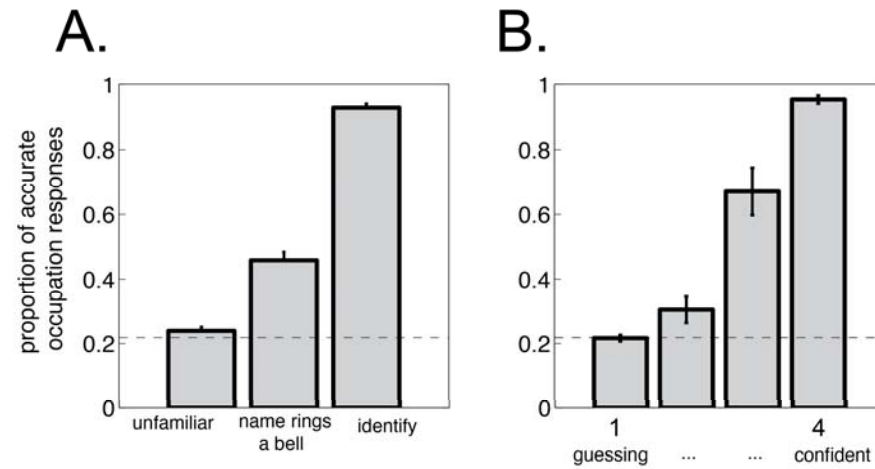
Figure 4-2: Occupation forced-choice accuracy

A) proportion of accurate post-scanning occupation forced-choice responses associated with each of the three recognition responses from the five name-recognition phase runs. B) proportion of accurate occupation forced-choice responses associated with the four confidence levels from the five occupation phase runs. Black dashed line indicates chance occupation accuracy. Error bars represent SEM

choice occupation response accuracy, and reaction times (RT). Unless indicated otherwise, a two-tailed *t*-test was used for all pairwise statistical comparisons.

4.7.1 Behavioral results: name-recognition phase

A chi-squared test initially verified that participants applied the three recognition responses in different proportions to famous names as compared to fictional names ($\chi^2 = 10779.72$, $p < 0.001$), thus confirming successful discrimination between these two types of names. Critical for the focus of the current investigation, we found that the NRB response was given with higher proportion to famous than to fictional names ($t(15) = 2.67$, p < 0.05), indicating that this response conveyed a meaningful memory signal (see Table 2 for all response proportions). Next, we examined each recognition response type ('unfamilar', NRB, 'identify') with respect to the accuracy of associated post-scanning occupation judgments (see Figure 2A). Critically, we found that for famous names that received NRB responses, participants were above-chance in their later forced-choice occupation judgments ($t(15) = 9.40$, p < 0.001, one sided). Next we used a one factor repeated-measures ANOVA, with planned comparisons, to compare forced-choice occupation accuracy for the three types of recognition responses. Overall, there were differences in forced-choice occupation accuracy depending on what recognition response had been given in the scanner ($F(2, 30) = 590.31$, $p < 0.001$). Planned comparisons revealed that occupation accuracy for famous names with NRB responses was higher than that for famous names classified as 'unfamiliar' ($F(1, 15) = 89.25$, $p < 0.001$); in turn, occupation

accuracy associated with 'identify' response was higher than that associated with the NRB response ($F(1, 15) = 440.84$, $p < 0.001$). These results are consistent with previous findings from our lab, specifically, that NRB responses discriminate between famous and fictional names and that, for famous names, they are associated with a meaningful semantic signal, as reflected in above-chance forced-choice occupation accuracy.

Next, we examined RTs for the three recognition responses (see Table 2). As there were insufficient 'identify' responses for fictional names to include stimulus type (famous versus fictional) as a separate factor, we collapsed data across both stimulus types for these RT analyses. We revealed significant differences overall between the RTs for the three recognition responses ($F(2, 30)$ $= 31.44$, $p < 0.001$). Planned comparisons revealed that participants took longer to give NRB responses as compared to 'unfamiliar' responses ($F(1, 15) = 25.26$, $p <$ 0.001); they also took longer to give NRB responses than to give 'identify' responses ($F(1, 15) = 68.28$, $p < 0.001$). Thus, NRB responses were associated with the longest reaction times. This pattern is similar to what has been reported in studies on recognition memory, where the 'Know' response, taken to reflect a state of familiarity in study-test paradigms, is generally associated with longer RTs than 'unfamiliar' and 'remember' responses (e.g., Wheeler & Buckner, 2004).

4.7.2 Behavioral results: occupation phase

The accuracy of the forced-choice occupation judgments that participants made while under scanning was assessed separately for each of the four confidence levels (i.e., from one to four; Figure 2B). For choices associated with the lowest confidence level (i.e., 'one - completely guessing'), forced-choice occupation accuracy was at chance ($t(15) = -0.17$, $p = 0.57$, one sided). Accuracy for decisions associated with all other confidence levels was above chance (all $p > 0.05$). A one-factor repeated measures ANOVA revealed differences in forced-choice occupation accuracy between the four confidence levels ($F(3, 45) = 67.32$, $p < 0.001$). Planned comparisons using the pooled error term within this model revealed no significant difference between the forced-choice occupation accuracy associated with confidence levels 'one' and 'two', respectively *($F(1, 15) = 67.32$, $p < 0.001$)*; however, confidence level 'three' was associated with higher forced-choice occupation accuracy than was confidence level 'two' ($F(1, 15) = 21.79$, $p < 0.001$); a similar pattern was also observed when confidence levels 'three' and 'four' were compared ($F(1, 15) = 17.79$, $p < 0.001$).

Next, we examined RT for forced-choice events, separated based on confidence level for the decision (see Table 3 for RT data for both forced-choice and confidence events). A one-factor repeated measures ANOVA revealed that overall, the time taken to make forced-choice judgments was affected by the level of confidence participants expressed ($F(3, 45) = 67.32$, $p < 0.001$). Planned comparisons revealed no significant difference in RT between forced-choice occupation trials associated with confidence levels 'one' and 'two' *($F(1, 15) =$*

1.07, $p = 0.32$) nor between those associated with confidence levels 'two' and 'three' $(F(1, 15) = 2.00 \ p = 0.29)$. However, RTs for forced-choice trials associated with confidence level 'four' were less than those associated with confidence level 'three' $(F(1, 15) = 35.18, p < 0.001)$. Thus, the differences observed appear to be related primarily to faster responding for forced-choice trials associated with highest confidence.

4.7.3 fMRI analyses – Semantic access

In our initial brain imaging analyses we aimed to define a network of brain regions that supports the ability to access semantic knowledge about famous names. In a second step, we then aimed to examine the extent to which NRB responses engage that same network. To define the semantic access network, we used the conjunction of two contrasts from the name-recognition phase and the occupation phase, respectively (Nichols, Brett, Andersson, Wager, & Poline, 2005). For this purpose, data from both phases were combined into a single General Linear Model (GLM).

To define semantic access in the first phase of the experiment, we compared brain activity for famous names given 'identify' responses, which were presumably associated with recall of a distinct piece of semantic information, with that associated with famous names given 'unfamiliar' responses. To define semantic access in the second phase of the experiment, we focused specifically on the forced-choice occupation trials, as they explicitly required access to semantic knowledge about the presented famous names. We designated each forced-choice

occupation trial as either reflecting or not reflecting successful semantic access, and we contrasted brain activity for these two types of trials. Our inferences about the success of semantic access in trial assignments took into account both the objectively scored response accuracy of the forced-choice judgments as well as the associated confidence expressed. Specifically, we defined our semantic-access contrast using a comparison between accurate forced-choice trials that were associated with confidence levels two through four, and all (i.e., accurate and inaccurate) forced-choice trials associated with the lowest confidence level. Notably, accurate and inaccurate forced-choice trials associated with the lowest confidence level were assumed to reflect chance guessing given that our behavioral analyses revealed that accuracy was not different from chance for such trials.

Our first random-effects GLM thus included 6 predictors of interest. Separate predictors were created to model four types of trials associated with the three types of recognition response: famous identify (Fam_Iden), famous NRB (Fam_Nrb), famous unfamiliar (Fam_Unf), and fictional unfamiliar (Fict_Unf). Separate predictors were also created to model the two types of forced-choice occupation responses (i.e., those with and without semantic access; Fc_Sem and Fc_Nosem, respectively), and a corresponding predictor for confidence judgments was also included but was not examined. Finally, a confound predictor was included to model inaccurate forced-choice trials associated with two, three, and four confidence levels, as well as corresponding confidence trials. The confound predictor also included trials for fictional names associated with NRB and
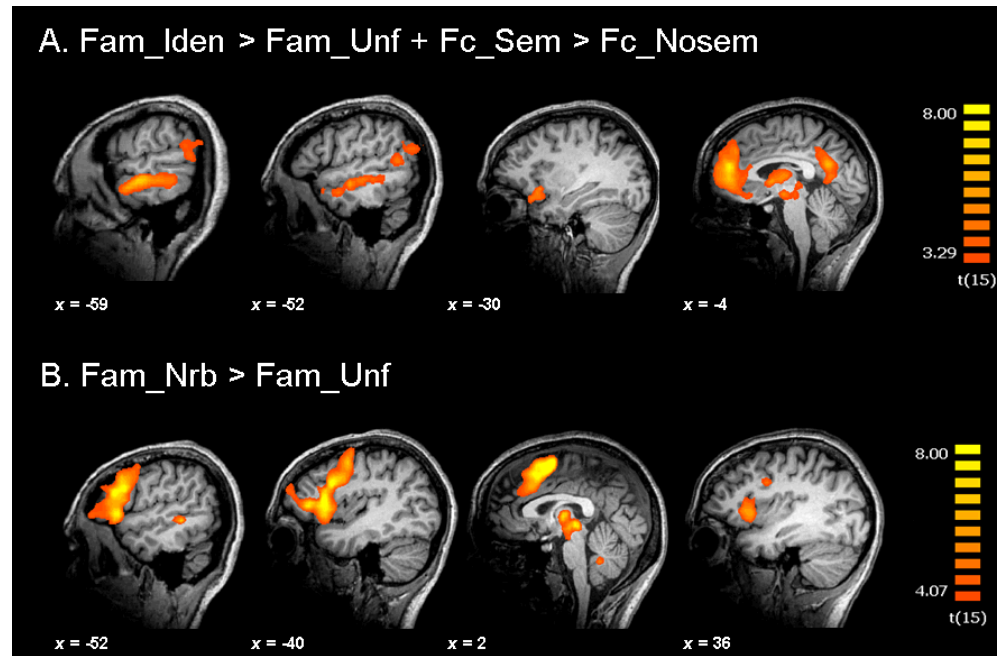
Figure 4-3: Brain regions implicated in semantic access, and in NRB responses

Sagittal views displaying brain areas involved in (A) conjunction analysis for successful semantic access ($p < 0.005$ for each contrast, effective $p < 0.000025$, minimum cluster size = 13 voxels) and (B) contrast of NRB responses minus 'unfamiliar' responses, for famous names only ($p < 0.001$, minimum cluster size = 11 voxels). Main effects for each analysis superimposed on representative participant's structural MRI within the range of *t*-values shown for each analysis separately. Fam_Iden - famous names given 'identify' response, Fam_Nrb -famous names given NRB response, Fam_Unf –famous names given 'unfamiliar' response, Fict_Unf – fictional names given 'unfamiliar' response, Fc_Sem – occupation forced choice trials associated with semantic access (see main text for details), Fc_Nosem – occupation forced choice trials associated with no semantic access.
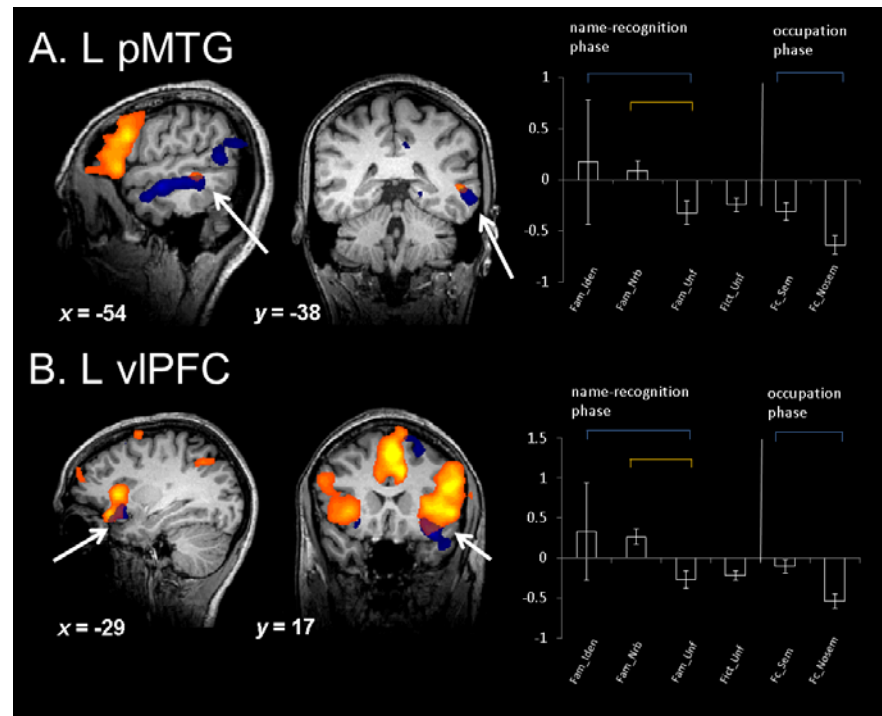
Figure 4-4: Areas of overlap between semantic access and NRB responses

Separate analyses from Figure 4-3 overlaid on anatomical images of a representative participant's brain, demonstrating regions of overlap. Activation map in blue reflects conjunction analysis for successful semantic access and that in orange reflects the Fam_Nrb > Fam_Unf contrast. Arrows highlight regions of overlap in (*A*) left middle posterior temporal gyrus and (*B*) an inferior aspect of left ventrolateral prefrontal cortex. Beta weights for these two regions of overlap are presented for descriptive purposes, for all conditions of the name-recognition phase runs and the two occupation forced-choice conditions of the occupation-phase runs. Blue and orange lines indicate contrasts used to isolate brain regions in the two separate analyses. Images shown in radiological convention (left equals right). Error bars represent SEM.

Table 4-4: Brain areas isolated in semantic access conjunction [Fam_Iden > Fam_Unf + Fc_Sem > Fc_Nosem]

Brain Regions		x	y	z	t-value
Cerebellum	R	26	-68	-36	4.96
Brain stem	M	8	7	6	7.82
Anterior cingulate	M	-4	46	18	8.31
Precuneus	M	-4	-56	21	6.74
Middle temporal gyrus	L	-61	-17	-9	7.83
Angular gyrus	L	-43	-65	18	6.54
Anterior temporal lobe	L	-44	16	-23	4.00
Ventrolateral prefrontal cortex	L	-30	12	-9	3.40

Threshold set at $p < 0.005$, effective $p < 0.000025$, minimum cluster size $= 13$. L, left; R, right, M, midline. Coordinates are expressed in millimeters in the Talairach and Tournoux brain atlas: x, medial–lateral axis (negative, left); y, anterior–posterior axis (negative, posterior); z, dorsal–ventral axis (negative, ventral). Fam_Iden - famous names given 'identify' response, Fam_Nrb -famous names given NRB response, Fam_Unf –famous names given 'unfamiliar' response, Fict_Unf – fictional names given 'unfamiliar' response, Fc_Sem –forced choice trials associated with semantic access (see main text for details), Fc_Nosem – forced choice trials associated with no semantic access.

**Table 4-5: Brain areas isolated in contrast of NRB responses minus 'unfamiliar' responses [Fam_Nrb > Fam_Unf]**

Brain Regions		x	y	z	t-value
Caudate	L	-14	1	14	7.37
	R	8	5	12	9.90
Ventrolateral prefrontal gyrus	L	-40	20	11	9.02
	R	-31	22	4	7.30
Dorsolateral prefrontal gyrus	L	-41	13	27	10.31
	R	-22	37	33	6.50
Superior parietal lobe	L	-34	-65	33	5.53
Middle temporal gyrus	L	-52	-38	-3	7.37
Brain stem	M	-3	-24	-2	8.04
SMA / cingulate	M	0	2	57	12.83
Cerebellum	M	5	-49	-39	5.71

Threshold set at $p < 0.001$, minimum cluster size $= 11$ voxels.

'identify' responses from the name-recognition stage.

4.7.4 Brain regions engaged by NRB responses and by semantic access

As outlined above, to define the brain network supporting successful

semantic access, we used the conjunction of the aforementioned contrast from the

name-recognition phase (i.e., Fam_Iden > Fam_Unf) and that from the occupation

phase (i.e., Fc_Sem > Fc_Nosem; $t(15) = 3.29$, $p < 0.005$ for each contrast,

effective $p < 0.000025$; see Figure 3, Table 4, Table 5). We observed an extensive

swath of activation that included large aspects of the left MTG from posterior to

anterior sections, the left ATL, an area of left vlPFC, the left angular gyrus, the

precuneus, a midline area at the border of the supplementary motor area (SMA)

and the anterior cingulate (ACC). In general, this network resembles both the

network of brain regions recently implicated in making familiarity judgments for

highly famous names (Sugiura, et al., 2009), and that proposed to support

semantic-memory retrieval more generally, as revealed in a recent meta-analysis

(Binder, et al., 2009). In the next step, we contrasted brain activity associated with

famous names given the NRB response with that associated with famous names

that were given the 'unfamiliar' response (i.e., Fam_Nrb > Fam_Unf; $t(15) =$

4.07, $p < 0.001$; see Figure 3B, Table 4). We observed particularly robust

activation bilaterally in the ventrolateral as well as the dorsolateral prefrontal

cortex, the bilateral caudate, and in midline structures such as the precuneus.

Next, we directly investigated the extent to which NRB responses engaged

brain regions in the semantic access network by examining overlap in the two

previously described activation maps [i.e., 1) Fam_Nrb > Fam_Unf), 2) Fam_Iden > Fam_Unf + Fc_Sem > Fc_Nosem]. In comparing these two activation maps, we observed two areas of overlap, which included an inferior region of the left vlPFC (see Figure 4A) and a posterior region of the left MTG (see Figure 4B). Thus, as we predicted, one aspect of what separates NRB responses from 'unfamiliar' responses is the recruitment of some brain areas that also support the successful retrieval of semantic knowledge about famous names.

4.7.5 Brain regions differentially involved in NRB responses

To further understand the neural basis of NRB responses, we next examined whether any brain regions were more engaged when participants provided NRB responses than when they gave 'identify' responses for famous names. This analysis revealed robust activation in bilateral prefrontal areas, including the dorsolateral prefrontal cortex, a region at the border of the vlPFC and the anterior insula (AI), as well as an area of the right rostrolateral prefrontal cortex (see Figure 5, Table 6). In interpreting this contrast, it is worth noting that RTs for NRB responses were overall longer than those for 'identify' responses. Thus, it is important to ask whether some of the differences in brain activation that we observed between these two subjective recognition states might be related to more extensive processing that is reflected in the difference in RTs between them. Indeed, in the case of NRB responses, participants may spend more time conducting semantic search processes with respect to the occupation that pertains to the presented famous name. This would be consistent with the idea that NRB

responses are characterized by repeated or extended attempts to retrieve a discrete piece of semantic information (Young, et al., 1985). To address this issue, we also support semantic search processes, as has previously been suggested (Anderson, Anderson, Ferris, Fincham, & Jung, 2009).

4.7.6 Subjective evaluation of semantic knowledge

To better understand the contributions of partial knowledge in NRB responses, we also examined NRB responses in relation to the level of confidence that participants had on the post-scanner forced-choice occupation task for the same famous names. As noted previously, these names were different from those that were presented for occupation judgments under scanning. In doing so, we aimed to reveal brain regions that could support the subjective sense of the availability of some semantic knowledge in NRB responses, which we documented in our previous behavioral investigations (i.e., Chapter 3). In that line of research, we showed that participants expressed higher levels of confidence in their occupation judgments for famous names that were previously judged to be familiar-only (i.e., as indicated with an NRB response), than for those that were judged to be 'unfamiliar'. Thus, despite the lack of success in recalling a discrete piece of semantic knowledge for famous names that receive NRB responses, participants may still have a vague sense of the availability of such knowledge in association with these responses. Indeed, in the current data, we observed such a pattern with respect to the confidence for occupation
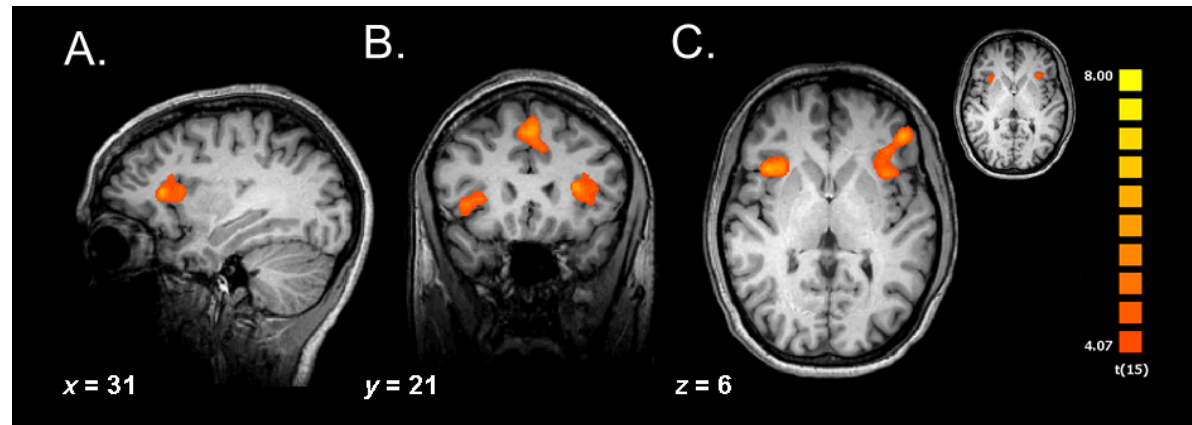
Figure 4-5: Areas engaged more by NRB than by 'identify' responses

Areas engaged more by NRB responses than by 'identify' responses for famous names only ($p < 0.001$, cluster threshold = 14 voxels). Sagittal (A), coronal (B), and transverse (C) views show bilateral prefrontal activation and midline anterior cingulate activation. Transverse slice in inset (C; also $z = 6$) shows that activity in the same area of bilateral ventrolateral prefrontal cortex also correlated with RT in famous name trials associated with NRB responses ($p < 0.005$, cluster threshold = 5 voxels). Images shown in radiological convention (left equals right).

**Table 4-6: Brain areas isolated in contrast of NRB responses minus 'identify'
responses [Fam_Nrb > Fam_Iden]**

Brain Regions		x	y	z	t-value
Dorsolateral prefrontal cortex	L	-52	13	24	6.09
	R	44	4	30	5.01
Ventrolateral prefrontal cortex	L	-28	25	12	7.28
	R	38	16	6	6.5
Rostrolateral prefrontal	R	32	55	18	5.06
Intraparietal gyrus	L	-49	-20	48	4.98
SMA / cingulate	M	-1	13	45	6.88

Threshold set at $p < 0.001$, minimum cluster size = 14 voxels.

Table 4-7: Brain areas for which BOLD activity correlated significantly with RT in NRB responses

Brain Region		x	y	z	t-value
ACC (dorsal)	M	0	5	49	4.16
	L	-6	20	31	3.60
Brain stem	M	6	-10	4	4.07
vlPFC	R	33	-1	34	4.26
	R	48	14	31	3.59
Cerebellum	R	21	-49	-23	3.83
Intraparietal lobule	R	33	-70	40	3.74
	L	-24	-67	40	3.86
Ventrolateral prefrontal cortex	R	33	17	7	3.72
	L	-33	23	10	3.69
Middle frontal gyrus	R	30	38	40	3.59

Threshold set at $p < 0.005$, minimum cluster size = 5 voxels.

judgments as well (for NRB responses, mean occupation confidence = 2.13; for

'unfamiliar' responses, mean confidence = 1.32; $t(15)$ =10.01, $p < 001$). To isolate

the neural mechanisms of those processes that allow for the assessment of the

potential availability of semantic knowledge, and that may contribute to the

subjective experience of availability, we compared brain activity associated with

two distinct types of NRB responses in a separate GLM. Specifically, we

compared NRB responses that were associated with subsequent high confidence

in forced-choice occupation responding (i.e., confidence responses 3 and 4) with

NRB responses associated with subsequent low confidence (confidence responses

1 and 2)[5]. All other recognition trial types were included with separate predictors.

In this analysis, we observed brain activation in bilateral perirhinal cortex and, to

a lesser extent, in other structures including the cuneus and left hippocampus

($t(14) = 4.07$, p < 0.001; see Figure 8, Table 8). The observed activity in bilateral

perirhinal cortex is of specific interest, given that this structure has been

implicated in familiarity assessment in a large body of research on recognition

memory (i.e., conducted with the study-test paradigm and discrete study episodes;

see Eichenbaum et al., 2007, for review).

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[5] Notably, there were less NRB responses that were later associated with high confidence forced-choice responding (mean = 7.63, range 1 - 17) than NRB responses associated with later low confidence forced-choice responding (mean number of trials = 17.68, range 5 - 49). One subject, who exhibited only one high confidence NRB trial, was not included in this analysis.
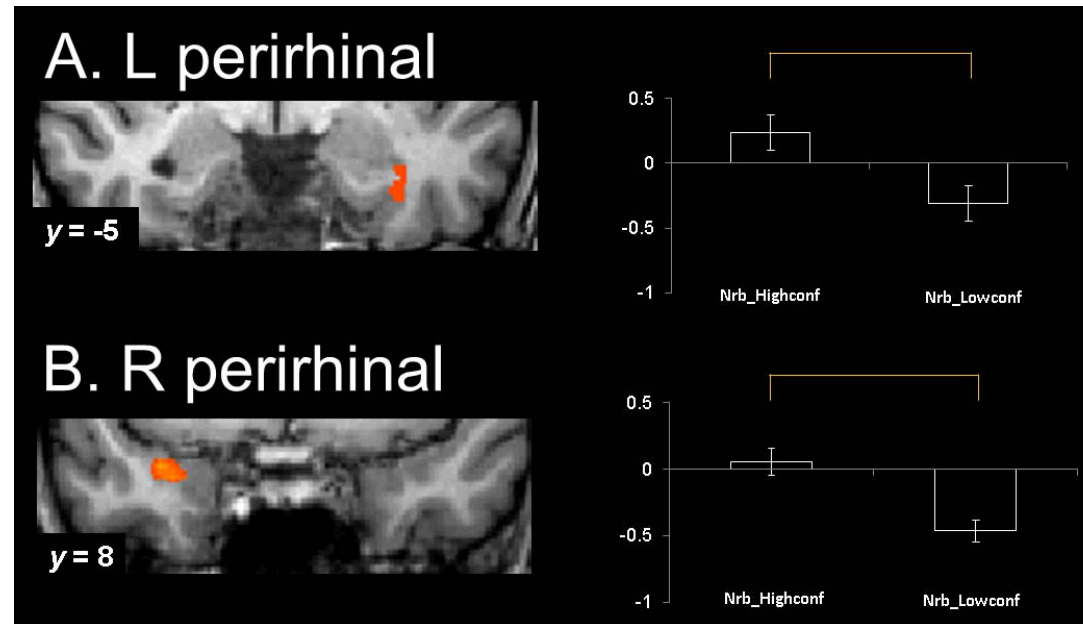
Figure 4-6: The role of the perirhinal cortex in NRB responses

Illustration of bilateral perirhinal cortex activation, as revealed in contrast of NRB responses for famous names associated with later high occupation forced-choice confidence (i.e., 3 and 4) minus corresponding NRB responses associated with later low occupation confidence (i.e., 1 and 2; $p < 0.001$, minimum cluster size = 3 voxels). Nrb_Highconf – NRB responses associated with later high confidence, Nrb_Lowconf – NRB responses associated with later low confidence. Images shown in radiological convention. Error bars represent SEM.

Table 4-8: Contrast of high versus low confidence NRB responses

Brain Regions		*x*	*y*	*z*	*t*-value
Perirhinal cortex	L	-31	-5	-28	5.08
	R	32	7	-19	4.12
Hippocampus	L	-22	-45	1	3.78
Cuneus	L	-61	-38	-12	5.62

Areas engaged more by NRB responses associated with later high occupation confidence (i.e. 3 and 4) as compared to those associated with later low occupation confidence (i.e. 1 and 2) for famous names ($p < 0.001$, minimum cluster size = 3 voxels).

4.8 Discussion

Here, we examined the neural correlates of the NRB recognition response for famous names, with a focus on the extent to which this subjective state involves recruitment of brain areas that support the successful access of relevant semantic knowledge. We first established that successful semantic access engaged a mostly left-lateralized network of brain regions that included a large section of the left MTG, the left ATL, the left angular gyrus, and an inferior aspect of the left vlPFC. Critically, we observed that NRB responses also engaged two brain areas in common within this network, specifically an inferior aspect of left vlPFC and a posterior portion of the left MTG. Furthermore, we revealed that a separate set of bilateral ventrolateral and dorsolateral prefrontal regions were engaged more so by NRB responses than by successful identification. Follow up analyses revealed that activity in two areas within this network, an area in the left vlPFC and a bilateral area at the border of the vlPFC and AI, also correlated with RT in NRB responses. In a separate analysis, we also revealed significant brain activity in the perirhinal cortex when we contrasted NRB responses associated with subsequent high confidence in later forced-choice occupation judgments, with those associated with later subsequent low confidence.

The study was motivated by the hypothesis that some type of semantic knowledge is accessed at the time NRB responses are being made. This hypothesis was based on findings from the neuropsychological literature, which suggested that patients with preserved familiarity for famous names and impairments in semantic knowledge frequently exhibit some partially preserved

semantic knowledge for the stimuli in question (Giovanello, et al., 2003;

McCarthy, et al., 2005; Verstichel, et al., 1996; Warrington & McCarthy, 1988;

Westmacott & Moscovitch, 2001). It was also motivated by our previous findings

in healthy individuals that suggested above-chance performance on semantic

judgments can be observed for famous names associated with NRB responses

(i.e., Chapter 3). Here, we observed overlap in the brain network that we

implicated in semantic access, and brain regions that showed increased activity

for NRB as compared to 'unfamiliar' responses, specifically in the left posterior

MTG and the left vlPFC. As reviewed in a recent meta-analysis of the semantic

memory literature (e.g., Binder, et al., 2009), the left MTG and the left inferior

frontal gyrus have been shown to contribute to semantic-memory retrieval in

many situations, and have been suggested to play specific roles in the storage of

semantic representations and in executive control processes, respectively (but see

Whitney, Jefferies, & Kircher, 2011). Interestingly, these two regions have also

been suggested to interact in coordinating retrieval functions related to the

processing of word stimuli. One study showed that the left vlPFC is functionally

connected with the left posterior MTG during the recognition of words, but not

pseudowords or meaningless letter strings (Bokde, Tagamets, Friedman, &

Horwitz, 2001), suggesting differential contributions to the recognition of word

forms that are associated with semantic meaning. The left vlPFC and left MTG

have also been found to co-activate in support of verbal working memory

processes that specifically involve maintenance of semantic, as compared to

phonological, word information (Shivde & Thompson-Schill, 2004). This

research is consistent with our assertion that activation of these two areas reflects

access of some degree of semantic knowledge.

Given that the MTG has generally been implicated in the storage of

semantic representations, it is important to ask what type of representation this

could be. In the language literature, the left posterior MTG has been proposed,

along with some other structures, to support the lexicon of known words (Howard

et al., 1992; for similar suggestions, see Fiebach, Friederici, Müller, & von

Cramon, 2002; Price et al., 1994; Pugh et al., 1996; Vinckier et al., 2007). Thus,

one possibility is that the engagement of this structure that we revealed here is

related specifically to lexical representations of known famous names and not to

related semantic knowledge about them. Given that we observed that this area

was recruited both by NRB responses as well as by responses that conveyed

successful semantic access, such activation may allow for familiarity processing

in both situations. By contrast, as the anterior MTG was only found to be engaged

by successful semantic access and not by NRB responses, this area may be

specifically involved in the successful retrieval of semantic knowledge for names.

This account would be in keeping with general assumptions underlying IAC

models of person recognition, namely, that the registration of familiarity for

names is dissociable from the access of related semantic knowledge about them.

A problem with this account is that it would not explain the availability of

semantic knowledge during NRB responses that we previously reported (i.e., in

Chapter 4) and also document in the current study. At the neural level, another

possibility is that the left posterior MTG may not only support lexical

representations of known words, but also some degree of related (perhaps partial) knowledge about them; in this scenario, more anterior areas of left MTG and left ATL could be required for accessing the type of fully formed semantic knowledge that is required for full identification. That some partial knowledge is stored in the relatively circumscribed area of the left posterior MTG that we isolated might explain why some patients with diffuse brain damage, such as patients KC and RFR, have been shown to exhibit partial knowledge for famous names despite widespread brain damage. Interestingly, one recent study of functional and structural connectivity showed that anterior aspects of the left MTG are substantially better connected than posterior aspects of this structure with the larger network of brain areas that support language processing, which includes left superior temporal gyrus and left inferior prefrontal cortex (Turken & Dronkers, 2011). Thus, this greater connectivity for anterior aspects of the left MTG might be necessary for the retrieval of more detailed or better-specified semantic information. While this hypothesis clearly requires further testing, the idea that more anterior aspects of the left temporal lobe are required for retrieving specific semantic knowledge is broadly consistent with other research. For example, in one recent fMRI study, the left ATL was found to be more engaged during the recall of specific as opposed to more general semantic knowledge about faces (Brambati, et al., 2010). This notion would also be consistent with the finding that patients with semantic dementia, who exhibit a breakdown in semantic knowledge representations as a result of damage to the ATL. Such patients generally demonstrate more impairment in tasks that require access to

specific as compared to general semantic information (e.g., an impaired ability to identify an apple, with a preserved ability to confirm it's edibility; Patterson, Nestor, & Rogers, 2007).

Overall, the current findings lend support to the notion, also suggested by past work, that different aspects of the vlPFC have dissociable functions in their contributions to semantic-memory retrieval (for a review, see Race, et al., 2009). Although activity in the vlPFC has frequently been observed in studies of person recognition (e.g., Nielson, et al., 2010; Sergent, et al., 1994; Sugiura, et al., 2009), it is not well understood at what stage in the process of identification this structure plays a critical role. In the current study, NRB responses for famous names tended to activate a large swath of bilateral prefrontal regions, with a bias towards more activation in the left hemisphere, as compared to corresponding 'unfamiliar' responses. This activation may reflect many different processes related to cognitive control; however, the follow-up analyses we performed provide evidence that may help constrain this interpretation. Given the overlap of this activation map with that implicated in semantic access was found only in left inferior aspects of this large swath of prefrontal activation, it could be argued that only these aspects are related to semantic retrieval. Importantly, the notion that only an inferior area of the left vlPFC contributes to semantic retrieval is consistent with some prior work. After examining brain activity elicited by four different semantic retrieval tasks, Badre et al. (2005) argued that an inferior and anterior area of left vlPFC supports the retrieval of semantic knowledge representations stored in the lateral temporal lobe, whereas a more dorsal area of

left vlPFC supports the ability to select which currently activated semantic

representations are most relevant to the task at hand (see Badre & Wagner, 2007;

Race, et al., 2009, for further discussion; see Gold et al., 2006 for similar

evidence).

　　While the current data cannot provide any evidence that directly speaks to

semantic selection, we contend that the more dorsal aspects of the vlPFC that we

linked to NRB responses may be related to semantic search processes and / or

response uncertainty more generally. In our contrast of brain activity for NRB

responses and 'identify' responses, we observed activation that centered on an

area of left mid-vlPFC as well as a bilateral area at the border of the vlPFC and

the AI. Interestingly, this differential involvement of these structures in this

contrast may not be reflective of differences between these two subjective states

but rather to differences in RT. In a separate analysis, we demonstrated that

activity in these brain areas also correlated with RT when NRB responses were

considered independently. Thus, these areas are likely to support processes related

to conducting search efforts for pertinent semantic knowledge. Anderson et al.

(2009) found that the lateral prefrontal cortex was active in a sustained manner

while participants tried to find answers to semantic insight problems, but not past

the point at which a solution was provided. These authors argued that this

structure plays an important role in executive processes related to searching for a

relevant representation in semantic memory. Notably, the AI, the other structure

that showed differential activity in the contrast of Fam_Iden > Fam_Unf, has been

linked to response uncertainty in a range of different contexts, including risky

decision making in gambling tasks (Paulus, Rogalsky, Simmons, Feinstein, &

Stein, 2003), and ambiguous responding in target detection tasks (Hampshire,

Thompson, Duncan, & Owen, 2008). In one recent study, the structure was linked

to representing psychophysical uncertainty in a vertical line classification task,

which did not require any semantic processing, based on an RT analysis similar to

the one employed here (Grinband, Hirsch, & Ferrera, 2006). In that study, it was

proposed that the AI plays a general role in categorical decision making when

neural evidence relevant to the currently necessary decision is limited. Regardless

of the precise functional role of dorsal ventrolateral prefrontal regions and the AI

in NRB responses, our study converges with prior work in suggesting different

roles for anterior versus more dorsal aspects of vlPFC.

In our analyses to examine the neural correlates of subjective components

of NRB experiences, we revealed the bilateral perirhinal cortex as a structure that

may contribute to a sense of meta-cognitive awareness regarding available

semantic knowledge in relation to NRB responses. Perirhinal cortex was engaged

more by NRB responses that were later associated with high confidence forced-

choice occupation decisions than by NRB responses associated with low

confidence occupation decisions. Perirhinal cortex has been widely implicated in

assessing familiarity in the context of research on recognition memory with the

study-test paradigm, where its role has been contrasted with the role of the

hippocampus in the recollection of episodic detail (for reviews, see Aggleton &

Brown, 1999; Brown, Warburton, & Aggleton, 2010; Eichenbaum, et al., 2007).

Recent evidence suggests that this structure may contribute to assessment of

familiarity outside of study-test paradigms as well. Some evidence from research in patients with temporal-lobe epilepsy, for example, point to a role of perirhinal in the experience of deja-vu, which refers to a subjectively inappropriate sense of familiarity based on life-time experience (for reviews, see Spatt, 2002; Wild, 2005). Furthermore, two studies have provided evidence for a role of perirhinal cortex in recognizing object stimuli in rhesus monkeys (Holscher, Rolls, & Xiang, 2003; Rolls, Franco, & S. Stringer, 2005). Critically, these studies showed that neurons in this structure became increasingly active as these stimuli were presented hundreds of times over the course of a period of 7-13 days. Notably, no study, to our knowledge, has investigated whether the perirhinal cortex also contributes to isolated states of familiarity in situations where recognition is linked to semantic representations acquired through life experience (i.e., familiarity-only experiences). The results of the present study suggest that, within the context of famous name recognition, this structure may be specifically be engaged in processes related to subjectively appreciating the availability of semantic knowledge in NRB responses.

Our findings have relevance to research that has examined the neural basis of other similar phenomenological memory states, such as 'feeling of knowing' (Hart, 1965) and 'tip of the tongue' (TOT) states (R. Brown & McNeill, 1966; Schwartz & Metcalfe, 2011). In a classic study, R. Brown & McNeil (1966) presented participants with definitions of rare words, and asked participants if they knew the corresponding words that fitted the definitions. A 'familiarity-only' experience for a famous name can be taken to reflect the flip side of the TOT

state, as participants are provided with a lexical item (i.e., a famous name in this case), and they must search for related defining information that would allow for identification. Interestingly, similar to NRB experiences, the TOT state has also been shown to be associated with the availability of some degree of fragmentary but meaningful semantic knowledge (e.g., Koriat & Lieblich, 1974; for a review, see Schwartz & Metcalfe, 2011). Further, some of the same brain regions that were differentially involved in NRB as compared to 'unfamiliar' responses in the current study have also been found to be differentially engaged in the TOT state. These regions include the anterior cingulate cortex and the right dorsolateral cortex (Kikyo, Ohki, & Sekihara, 2001; Maril, Simons, Weaver, & Schacter, 2005; Maril, Wagner, & Schacter, 2001). The involvement of the anterior cingulate in the TOT state has been considered consistent with the widely accepted notion that this structure contributes to monitoring cognitive conflict (Maril, et al., 2001). In the current experiment, the role of this structure may reflect a conflict between a subjective sense of the availability of some semantic knowledge, and a lack of the ability to retrieve information that would allow for full identification.

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5 General Discussion

The broad goal of my thesis was to take initial steps towards understanding how recognition memory relates to recognition based on lifetime experience, by investigating in detail the cognitive and neural processes that support famous name recognition. In three separate experimental investigations, I applied paradigms that have traditionally been used exclusively in the field of recognition memory, to the study of fame judgments. An important aspect of the experimental approach I employed is that I exclusively used moderately famous names that are unlikely to be identified confidently by everyone, but at the same time, are sufficiently common so as to provoke feelings of familiarity and identifications in some participants. One advantage of using moderately famous names, rather than highly famous names such as Bill Clinton, is that I was able to explore the signal-detection mechanisms that support participants' ability to discriminate them from fictional names. Specifically, this approach allowed me to ensure participants' discrimination performance was to some degree inaccurate, which is necessary to examine the signal-detection mechanisms that underlie any type of discrimination (Macmillan & Creelman, 2005). Notably, a particular concern with asking participants to recognize moderately famous names is a lack of ability to ensure participants have had any exposure at all to them. In Chapter 2, I incorporated this potentially confounding factor into the signal-detection model I developed by implementing finite mixture distributions to separately represent famous names with and without exposure. The main conclusion of my modeling was that the memory evidence that underlies the ability to discriminate between famous and fictional names is graded and can be well described with

Gaussian distributions. Considerations of exposure aside, I also observed other important differences between the memory evidence that supports fame recognition judgments and that typically implicated in recognition memory. Specifically, I found that once exposure was accounted for in the signal-detection model, other statistical parameters that have previously been deemed important in accounting for recognition memory decisions were unnecessary. Statistically, I found that there was no need to incorporate a parameter for unequal variances, nor one to represent any high-threshold process. This suggests that the processes at work when recognizing stimuli based on past experience may be different in critical ways from recognizing stimuli based on one temporally constrained event.

In Chapters 3 and 4, I examined the role of available semantic knowledge in supporting feelings of familiarity for famous names, with a specific focus on the 'name rings a bell' recognition experience. Notably, isolation of the 'name rings a bell' experience also hinged on the use of moderately famous names; names of highly famous individuals such as Bill Clinton would only very rarely provoke this type of experience in most participants. In Chapter 3, I established that this recognition state is associated with the availability of a meaningful semantic signal. This link was reflected both in above-chance occupation forced-choice accuracy as well as corresponding confidence judgments for 'name rings a bell' responses. Importantly, it was observed regardless of whether the name recognition judgments were made before or after the occupation forced-choice judgments. Thus, this pattern is unlikely to be dependent on some type of priming between the name recognition and the occupation forced-choice stages, respectively. Importantly, our finding that 'name rings a bell' responses are

associated with the availability of some semantic knowledge runs counter to the

intuition of participants when they have this type of recognition experience;

namely, they perceive that no discrete piece of semantic knowledge can be

recalled. Despite this, the pattern we documented in Chapter 3 is consistent with

the neuropsychological literature, which suggests that patients who exhibit

preserved familiarity for famous names often show evidence of some related

knowledge about them, even if they cannot recall this knowledge in free recall

tasks (Verstichel, et al., 1996; Warrington & McCarthy, 1988; Westmacott &

Moscovitch, 2001). In light of this patient-based literature, I hypothesized that

'name rings a bell' experiences might engage the same brain networks that

support successful access of pertinent semantic knowledge to some extent. In

Chapter 4, I addressed this issue by examining brain activity both while

participants made fame recognition responses that allowed for isolation of a

'name rings a bell' state, and also while they made occupation forced-choice

judgments for a separate set of famous names. I identified two brain regions that

were involved both in the successful access of semantic knowledge for famous

names, and also in 'name rings a bell' experiences more so than 'unfamiliar'

responses. These two regions included the left posterior middle temporal gyrus

and an inferior area of the left ventrolateral prefrontal cortex. Thus, I indeed

found evidence that part of what separates 'name rings a bell' responses from

corresponding 'unfamiliar' responses is the access of a meaningful semantic

signal. In our extended analysis of 'name rings a bell' responses, we found

evidence to suggest that the perirhinal cortex may play a critical role in the

subjective evaluation of semantic knowledge in the context of familiarity

assessment for famous names. In line with previous work (Dietl, et al., 2005; Plailly, et al., 2007), this finding suggests that this structure may contribute to familiarity assessment in recognition memory as well as that based on lifetime experience.

This thesis was strongly motivated by the idea that similar cognitive mechanisms may support familiarity based on a specific laboratory study episode (as in recognition memory), and familiarity based on lifetime experience. There are numerous reasons why it is challenging to relate these two types of familiarity and why the issue of how they are related may have received limited attention in previous research. For example, one reason is that with respect to familiarity based on lifetime experience, entirely distinct processes are at work depending on the type of stimulus that is recognized (e.g., words, famous celebrities, objects, etc). Indeed, distinct and expanding theoretical literatures exist for each of these types of recognition. The fact that this is the case makes it difficult, in some respects, to feel confident in any general conclusion about how recognizing stimuli based on lifetime experience relates generally to recognition memory. For example, although I established that fame judgments are based on graded underlying memory evidence, I cannot be certain this would also apply to the recognition of other types of stimulus materials without systematically investigating this issue. Towards this end, it may also be worthwhile to examine whether graded memory evidence also comes into play when participants discriminate between rare words versus non-words, real versus fictional musical excepts, or famous versus non-famous faces.

Another way in which the study of recognition memory typically differs from the study of recognition based on lifetime experience is related to the accuracy of recognition discrimination. In general, recognition memory tasks are typically sufficiently challenging that participants cannot accurately ascertain whether every single test item was or was not encountered in the prior study phase. By contrast, when investigators study the recognition processes that support the identification of famous celebrities, objects, or words, recognition performance is generally perfect, given that the goal in this situation is to understand the processes that support *successful* recognition. Thus, very few studies in the literature have employed recognition tasks that both hinge on lifetime experience and that also involve imperfect discrimination (but see Kinder & Assmann, 2000; Paap, et al., 1999). This may partly be due to issues of prior exposure, as described above; if discrimination is imperfect, one cannot dissociate whether the observed imperfect discrimination is related to memory processes that one wants to study or whether it is related to a lack of any prior exposure at all for some stimuli. While this is the case regardless of any specific mathematical model that could be tested, by confronting the issue directly and systematically in Chapter 2, it may allow for future research related to how familiarity based on lifetime experience relates to that based on a specific study event, as in recognition memory.

In Chapters 3 and 4, I isolated 'familiarity-only' experiences for names by asking participants to discern between recognition responses that were accompanied by semantic knowledge retrieval and those that were not. This experimental approach is similar to the 'Remember-Know' (RK) paradigm in

recognition memory, where participants are asked whether or not they can recognize an item based only on an isolated state of familiarity or based on recall of some contextual details surrounding the original encounter (Tulving, 1983). While the approach I applied is similar to the RK paradigm in the sense that both experimental procedures involve isolation of a putative 'familiarity-only' response, they are different in the primary type of relevant memory evidence under consideration. Specifically, 'recall' in the case of the RK paradigm means retrieving a piece of episodic information that pertained to the study event in which the test stimulus was originally presented. By contrast, 'recall' in the famous name recognition paradigm I employed in Chapters 3 and 4 referred to the retrieval of a distinct piece of semantic information about the name. This distinction can be related to another broad difference between recognition memory tasks and tasks that probe recognition based on lifetime experience. In the former case, pertinent memory evidence is linked mainly to knowledge of discrete temporally specific events (i.e., episodic memory), whereas in the latter, it is linked mainly to generic factual details such as occupation in the case of fame judgments (i.e., semantic memory).

Although this distinction merits some consideration, it would clearly be overly simplistic to suggest that one type of recognition is based entirely on episodic memory whereas the other is based on semantic memory. In the case of recognition memory, for example, it is well known that encoding stimuli based on semantic meaning leads to increases in recognition performance as compared to encoding them based on phonology (Craik & Lockhart, 1972). Furthermore, in past work, it has been demonstrated that whether or not a famous name is

associated with a specific episodic memory directly affects the speed that it is

processed (i.e., autobiographical significance; Westmacott & Moscovitch, 2003).

Notably, in the signal-detection model I tested in Chapter 2, I found no evidence

in support of including a high-threshold detection parameter, taken to reflect

recollection of episodic detail in the widely employed dual-process recognition

model (Yonelinas, 1999). As discussed in Chapter 3, one possibility is that the

role of autobiographical significance is generally only relevant in recognition

tasks that employ highly famous names, and not in those that employ moderately

famous names, as in the case of the task I employed in Chapter 2. Another is that

autobiographical significance serves a redundant and therefore less relevant

source of information in tasks that specifically involve discriminating famous

from fictional names. If this is true, autobiographical significance may facilitate

the processing of names that are already recognized, but at the same time would

not represent a meaningful signal-detection process that discriminates between

famous and fictional names.

Additional pilot experiments that I conducted in my PhD can speak

tentatively to this possibility and more generally to how semantic and

autobiographical memory contribute to famous name recognition. In several pilot

studies, I asked participants in an initial stage to make name-recognition

confidence judgments for a series of famous and fictional names; in a subsequent

stage, I presented the same famous names to them again one at a time, and I asked

participants, a) to recall any factual details they possessed in association with each

name, and b) to recall a distinct autobiographical memory that involved each

name if they could. First, I observed that semantic information was sometimes

associated with confident recognition even though no autobiographical memory could be recalled. By contrast, recall of autobiographical memories was generally only present in association with recognized famous names if there was also some accompanying recall of semantic information. Currently, my interpretation of this general pattern is that recall of autobiographical information may be only present for famous names that would already be recognized based on semantic identification. Although this hypothesis requires conceptual refinement in the current context, this idea is similar in spirit to one in recognition memory, namely, that of 'non-criterial' recollection (Toth & Parks, 2006). This term was originally applied in the context of the literature on the process-dissociation procedure (Gruppuso, Lindsay, & Kelley, 1997; Yonelinas & Jacoby, 1996), and it refers to the fact that it is possible to recollect episodic details that pertain to an original study event, even if those recollected details are not specifically relevant for the task at hand.

Our finding that 'name rings a bell' experiences are linked to the availability of a meaningful semantic signal is interesting in light of extant research that pertains to the 'Know' response in recognition memory. It is generally assumed that a 'Know' response for a test item refers to a recognition state that involves no availability of episodic knowledge that pertains to the original encounter. That being said, one relevant RK study used methodology that was in some ways similar to that presented in Chapters 3 and 4, and argued that this recognition state does involve some availability of episodic knowledge (Wais, et al., 2008). In the study phase of this experiment, participants were presented with word stimuli one at a time in either a red or a blue font. In the later test

phase, participants were presented with the old words again; for each test item, they made RK judgments followed by forced-choice judgments regarding what font the word was previously presented in (i.e., in red or blue). The researchers found that 'Know' judgments, which were defined to participants in the same way as in previous studies (i.e., as an isolated state of familiarity with no contextual recall), were in fact associated with above-chance performance on the forced-choice source task. This general pattern was observed regardless of whether participants made the forced-choice source judgments before or after the RK judgments. Analogous to the argument we presented with respect to 'name rings a bell' responses and available semantic knowledge, the authors argued that 'Know' responses are associated with the availability of an episodic memory signal. It is worth noting, however, that in the literature at large, there is strong evidence to suggest that these two processes can be dissociated at the cognitive and neural level (Aggleton & Brown, 1999, 2006; Eichenbaum, et al., 2007).

When considered in light of the observations I documented in Chapter 2, the findings from Wais et al. (2008) raise a broader question regarding whether 'familiarity-only' experiences, in the truest sense of the definition, exist at all in any situation. Alternatively, it may be that feelings of familiarity are always critically linked to some type of underlying episodic or semantic memory signal. At the same time, it seems clear that various factors contribute to familiarity judgments. In the current context, familiarity for names is also affected by whether or not they have been encountered particularly recently (Jacoby, et al., 1989), as well as how common they are in daily life irrespective of fame (Stenberg, et al., 2008). In future work, it will be valuable to examine in more

detail the precise manner in which these various sources of evidence interact with semantic knowledge in their contributions to fame recognition decisions.

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Appendix 1: Revised ethics form for fMRI experiment

REQUEST FOR APPROVAL OF REVISIONS, AMENDMENTS, REVISED BROCHURES TO AN APPROVED PROTOCOL UWO Health Sciences Research Ethics Board (HSREB) **Form 2-F-004** Revised 06-01-13

UWO ETHICS NUMBER	8182	
LOCAL PRINCIPAL INVESTIGATOR	Stefan Köhler	
PROJECT TITLE	The Neural Substrates of Episodic Long-Term Memory for Visually Apprehended Information	
Signature of Principal Investigator:		Date:

1.	Review type required? (Number of copies)	FULL BOARD (Original + 16 copies)	
		EXPEDITED (Original only)	x
		FYI only TO REB, APPROVAL NOT REQUIRED (Original only)	

2.	Do the proposed changes alter the information contained in the UWO protocol submission, Letters of Information and Consent documentation or affect local participants?	YES	x
		NO	

3.	Have you included an updated company protocol or investigator's brochure with this request? *(Do not submit duplicates of information already submitted to the HSREB.)*	YES	
		NO	x
3a.	If YES, what is the date or reference number on these documents?		

4.	Does this revision require Health Canada approval? (This section is for clinical drug trials only.) **If YES, attach a copy of the No Objection letter (NOL) from Health Canada that relates to this revision. N.B. UWO HSREB approval will not be granted until a copy of the No Objection letter is received.**	YES – NOL attached	
		YES – NOL pending	
		NO	
		NA - Not a Clinical Trial	x

5	SUMMARY OF CHANGES IN THIS REQUEST FOR A REVISION	√ IF YES	IF YES TO ANY ITEM IN THIS CHART, PROVIDE ADDITIONAL INFORMATION ON A SEPARATE SHEET AND/OR DOCUMENTATION AS NOTED BELOW. (Put Ethics # on each additional page)
	Study end date?		Provide revised date and detailed explanation/rationale for change.
	Principal and/or Co-Investigators?		If PI changing, include letter signed by both PI who is stepping down **and** the new PI indicating they both agree to the change and that the new PI is prepared to take over all responsibility for the study.
	Administrative changes?	x	On an attached sheet briefly summarize changes and revise relevant sections of the UWO protocol and Letter of Information/Consent documentation with revisions underlined.
	Information/Consent documentation?		Provide revised documentation with changes underlined. Do not use coloured marker unless you are prepared to highlight each copy.
	Study instruments, questionnaires etc?		Provide revised or additional questionnaires, instruments etc. and describe when and how they will be implemented.
	Study design or methods?		On an attached sheet briefly summarize changes and revise relevant sections of the UWO protocol and Letter of Information/Consent documentation with revisions underlined. Address statistical issues if appropriate.
	Participant recruitment?		
	Number of study participants?		
	Eligibility of subjects?		
	Other		Briefly summarize changes and revise relevant sections of the UWO protocol and Letter of Information/Consent documentation with revisions underlined.

LEAVE THIS AREA BLANK

RESEARCH ETHICS - ROOM 00045 DENTAL SCIENCES BUILDING – UWO   Page 1 of 1

Appendix 2: APA Permission form for Chapter Two

AMERICAN PSYCHOLOGICAL ASSOCIATION

Ben Bowles

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Date: August 30, 2011

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Appendix 3: Curriculum Vitae

BEN BOWLES

EDUCATION	**PhD**	**University of Western Ontario**, Neuroscience Program, *2007-2011*

> Dissertation title: "Contributions of signal-detection mechanisms and semantic memory representations to famous name recognition."
> Advisor: Stefan Köhler
> Committee: Mieke Verfaellie, Ken McRae, Marc Joanisse & Chris Viger

MSc   **University of Western Ontario**, Neuroscience Program, *2005-2007*

> Dissertation: "Impaired familiarity with preserved recollection after anterior temporal-lobe resection that spares the hippocampus."
> Advisor: Stefan Köhler
> Committee: David Sherry, Stan Leung & Mary Pat McAndrews

BSc   **University of Toronto**, Neuroscience Specialist, *2001-2005*

> Overall GPA: 3.57/4.0

HONORS AND AWARDS

- CIHR National Health Research Forum 'Silver' poster award, 2010
- CIHR Brain Star Award, 2008
- Natural Sciences and Engineering Research Council PGS-D, 2007-2010
- Ontario Graduate Scholarship, 2006-2007
- UofT International Health Program Research Scholarship, 2005
- Victoria University Regent's Inclass Scholarship, 2004-2005

RESEARCH INTERESTS

- Person recognition
- Functional organization of the medial temporal lobe
- Mathematical modeling of recognition using receiver operating characteristics
- Relationship between familiarity assessment and semantic knowledge

PUBLICATIONS

Journal articles

Bowles B, O'Neil EO, Mirsattari SM, Poppenk J & Köhler S. (2011). Preserved hippocampal novelty responses following anterior temporal-lobe resection that impairs familiarity but spares recollection. *Hippocampus* 21(8):847-54.

Martin CB, **Bowles B,** Mirsattari SM, Köhler S. (2011). Selective familiarity deficits after left anterior temporal-lobe removal with hippocampal sparing are material specific. *Neuropsychologia* 49(7):1870-8.

Bowles B, Crupi C, Pigott S, Parrent AP, Wiebe A, Janzen L & Köhler S. (2010). Double dissociation of selective recollection and familiarity impairments following two different surgical treatments for temporal-lobe epilepsy. *Neuropsychologia* 48:2640-2647.

PUBLICATIONS (CONTINUED)

Bowles B, Crupi C, Mirsattari SM, Pigott SE, Parrent AG, Pruessner JC, Yonelinas AP & Köhler S. (2007). Impaired familiarity with preserved recollection after anterior temporal-lobe resection that spares the hippocampus. *Proceedings of the National Academy of Sciences* 104(41):16382-7.

Borgoño CA, Gavigan JA, Alves J, **Bowles B**, Harris JL, Sotiropoulou G & Diamandis EP. (2007). Defining the extended substrate specificity of kallikrein 1-related peptidases. *Biological Chemistry* 388(11):1215-25.

Bowles B, Ferber S & Pratt J. (2005). Letter processing interferes with inhibition of return (IOR): Evidence for cortical involvement in IOR. *Cognitive Brain Research* 25:1-7.

O'Brien J, **Bowles B**, Kamal KM, Jarvi K & Zini A. (2004). Does the GnRH stimulation test predict clinical outcome after microsurgical varicocelectomy? *Urology* 63:1143-7.

O'Brien J, **Bowles B**, Kamal KM, Jarvi K & Zini A. (2004). Microsurgical varicocelectomy in couples with advanced female age: natural history in the era of ART. *Journal of Andrology* 25: 939-43.

Chawla A, **Bowles B** & Zini A. (2004). Vasectomy follow-up: clinical significance of rare non-motile sperm in the post-op semen analysis. *Urology* 64(6):1212-5.

Journal articles accepted (in press)

Rosenbaum RS, Carson N, Abraham N, **Bowles B**, Kwan D, Köhler S, Svoboda E, Levine B & Richards B. Impaired event memory and recollection in a case of developmental amnesia. *Neurocase*.

Bowles B, Harlow IM, Meeking MM & Köhler S. Discriminating famous from fictional names based on long-term life experience: Evidence in support of a signal detection model based on finite mixture distributions.

Journal articles in preparation

Bowles B, McRae K & Köhler S. A link between familiarity assessments in recognition memory and impairments in familiarity assessment for semantic concepts acquired over the lifetime.

INVITED TALKS

Köhler S & **Bowles B**. Three patterns of recognition-memory impairment following different types of surgical intervention for temporal-lobe epilepsy. *Second Meeting of the Federation of the European Societies of Neuropsychology, Amsterdam,* Sept 22-23, 2010.

Bowles B. Neural substrates and cognitive mechanisms that support recognition experiences. *Stanford University*. Sept 13th, 2011.

Bowles B. Semantic and signal detection processes underlying famous name recognition. *University of California, Davis*. November 9th[th], 2011.

POSTER PRESENTATIONS

Bowles B, McRae K & Köhler S. A link between familiarity assessments in recognition memory and impairments in familiarity assessment for semantic concepts acquired over the lifetime. *Cognitive Neuroscience Society Annual Meeting*, 2010.

Bowles B, Crupi C, Pigott S, Parrent AP, Wiebe A, Janzen L & Köhler S. Double dissociation of selective recollection and familiarity impairments following two different surgical treatments for temporal-lobe epilepsy. *CIHR Health Research Forum*, 2010.

Bowles B, Meeking MM & Köhler S. Using receiver operating characteristics to investigate the recognition processes that discriminate between famous and fictional names. *Cognitive Neuroscience Society Annual Meeting*, 2009.

Bowles B, Meeking MM & Köhler S. Using receiver operating characteristics to investigate the recognition processes that discriminate between famous and fictional names. *Canadian Society for Brain, Behavior and Cognitive Science Annual Meeting*, 2008.

Bowles B, O'Neil EO, Mirsattari SM, Poppenk J & Köhler S. Preserved hippocampal novelty responses following anterior temporal-lobe resection that impairs familiarity but spares recollection. *Cognitive Neuroscience Society Annual Meeting*, 2008.

Bowles B, Crupi C, Mirsattari SM, Pigott SE, Parrent AG, Pruessner JC, Yonelinas AP & Köhler S. Impaired familiarity with preserved recollection after anterior temporal-lobe resection that spares the hippocampus. *Cognitive Neuroscience Society Annual Meeting*, 2007.

Bowles B, Ferber S & Pratt J. Letter processing interferes with inhibition of return (IOR): Evidence for cortical involvement in IOR. *UofT Undergraduate Neuroscience Research Day*, 2005.

TEACHING EXPERIENCE

University of Western Ontario
Teaching Assistant, Cognitive Neuropsychology (3rd yr) and Memory (3rd yr), 2006-2007

University of Western Ontario
Teaching Assistant, Biological Psychology (1st yr), 2005-2006

LANGUAGES

English: Native Language
French: Intermediate Listening / Speaking / Writing

REFERENCES

Dr. Stefan Köhler
The University of Western Ontario

REFERENCES (CONTINUED)

Dr. Ken McRae
The University of Western Ontario

Dr. Shayna Rosenbaum
York University