On the Adaptative Reliance on Fuzzy Memory Representations in Adult Aging

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Abstract

According to fuzzy-trace theory, human cognition is driven by evolutionary and ontogenetic pressures to rely on less precise gist representations rather than retaining verbatim representations, especially in older adulthood, where declines in episodic memory are well-documented. Older adults' reliance on gist representations is often viewed through a negative lens, as such representations can contribute to false memories. However, their ability to remember gist details of past episodes may also confer advantages, especially in situations where memory is most deficient, as in remembering where someone was encountered. Remembering the gist of past experiences may lead to "well-enough" performance in some situations, enabling older adults to remember just enough details to avoid catastrophic memory errors. Thus, in contrast to the many negative views about adult age-related changes in memory, the preservation of gist in older adulthood can have a positive impact and may speak to the evolutionary benefit of gist representations in situations in which human memory is severely limited.

Keywords. Aging, gist, verbatim, episodic memory, fuzzy-trace theory

On the Adaptative Reliance on Fuzzy Representations in Adult Aging

As we age into older adulthood, many aspects of our cognitive functioning change, some for the better (e.g., vocabulary, general knowledge; Nyberg et al., 1996), others for the worse (e.g., episodic memory; Light, 1991; Naveh-Benjamin & Old, 2008; Zacks et al., 2000). One of the more ubiquitous features of adult age-related cognitive decline is a marked deficit in episodic memory, or memory for past events bounded in a specific time and place (Tulving, 1983). In standard laboratory tests of episodic memory, older adults in normal cognitive health (i.e., older adults with no history of cognitive impairment such as dementia) are less accurate and slower to respond than younger adults on tests of recognition and recall (for meta-analyses, see Fraundorf et al., 2019; Old & Naveh-Benjamin, 2008; Rhodes et al., 2019). Numerous longitudinal studies have similarly documented declines in standardized tests of episodic memory from about age 65 (e.g., Salthouse, 2014). These deficits have implications for everyday life of older adults, by resulting in more omissions (e.g., forgetting where one parked the car when visiting the mall, or forgetting the name of a familiar person one meets at a social occasions) and commissions (e.g., as an eyewitness, misidentifying a person was in a crime scene as the one who actually committed the crime).

As the population of adults aged 65 and older is accelerating in many countries (U.S. Census Bureau, 2018), concerns about negative adult age-related effects on episodic memory are likely to grow, prompting more research on the topic in the hopes of understanding the causes of these deficits and possibly finding solutions to combat them. To that end, we must consider not only what aspects of episodic memory are most vulnerable to adult age-related declines, but also what aspects are most resistant. In the present chapter, we review the state of the literature on one important aspect of episodic memory – representations of past episodes that retain the core

meaning or essence of those episodes (i.e., *gist representations*) – that mostly appears resistant to adult age-related loss. In considering how gist representations are well-preserved in older adulthood, we can also gain a deeper understanding of the evolutionary benefits of what fuzzy-trace theory calls a "fuzzy processing preference" (Brainerd & Reyna, 1990), especially in situations in which episodic memory is limited.

We begin our review with an overview of fuzzy-trace theory (Brainerd & Reyna, 1990, 2004) and alternative theories that differentiate between specific and gist memory representations. We then consider empirical evidence highlighting the essential nature of gist representations as a core component of episodic memory that can be adaptively relied upon in situations in which memory is severely limited. Here, we concentrate on developmental changes in gist memory representations, with a particular focus on older adults' ability to remember the gist of an aspect of episodic memory – the binding between components of an episode – that is especially susceptible to age-related losses. Next, we consider potential reasons why older adults can remember the gist of past episodes as well as younger adults, despite pronounced losses in memory for the specific details, by appealing to (1) the resource-demanding nature of specific and gist representations, and (2) the speed with which both types of representations can be encoded or retrieved. To this end, we review recent literature employing divided attention paradigms in young adults to model the attentional-demanding properties of specific/verbatim and gist memory representations and studies attempting to map out the time course under which these representations can be formed in young adults, and we consider what these findings may tell us about adult age-related shifts toward gist representations. In the last section, we consider how a reliance on gist representations can be advantageous to older adults, especially given their limitations in episodic memory in general.

Theoretical Perspectives on Specific and Gist Representations

The distinction between specific (or verbatim) and gist memory representations is core to fuzzy-trace theory (Brainerd & Reyna, 1990, 2004, 2015; Reyna & Brainerd, 1995), though other theories also distinguish between specific and more general memory representations (e.g., *hierarchical representation theory* – Craik, 2002, 2020; *discourse/reading theories of situation models* – Kintsch, 1988; van Dijk & Kintsch, 1983)[1]. According to fuzzy-trace theory, during encoding, two parallel traces of information about the contents of an episode are created independently, with one trace (dubbed the *verbatim memory trace*) capturing the specific, instantiating details of the episode (i.e., the specifics of what transpired, such as the precise way in which a sentence appeared in text; cf., Kintsch, 1988). A *gist memory trace* captures the core content of the episode, that is, *what* the episode was about. In other words, the gist of an episode represents the central meaning of what transpired and has elsewhere been referred to as a *situation model* of an episode (e.g., Kintsch, 1988; Radvansky & Dijkstra, 2007; van Dijk & Kintsch, 1983).

Fuzzy-trace theory is not the only cognitive theory to predict different levels of memory representation, though it may be the most well-known. For example, Craik's (2002) *hierarchical representation theory* also describes different levels of representation. In this theory, there is no categorical break between episodic and semantic memory that traditional systems theories describe (e.g., Sherry & Schacter, 1987), but stored knowledge is theorized to reside on a continuum of specificity. In essence, any memory can hypothetically be accessed at different

[1] These theories all have in common that they originated in the cognitive psychology literature without attempting to pinpoint the neural correlates of different levels of representation, and thus are formulated on a common scale. However, there are also theories that did originate in the neuroscientific literature and which point to distinct levels of representation in episodic memory that are reliant upon different regions of the hippocampus and prefrontal cortex (for a recent review of this literature, see Robin & Moscovitch, 2017).

levels of specificity. For instance, an individual may access the semantic level for knowing that September 11, 2001 was a major historical moment of the 21st century, or that individual may access an episodic level of representation that incorporates more specific information about what he or she was doing on September 11. Even this episodic level of representation may be accessible at various nodes according to Craik's theory, such as remembering very specific details (e.g., "I was in the deli aisle at the local supermarket when I first heard about the events of 9-11") or more general details (e.g., "I was not at my house when I first heard about the events of 9-11").

The key point to emphasize, whether we adopt fuzzy-trace theory, Craik's hierarchy of stored knowledge, or other theories (e.g., van Dijk & Kintsch,1983), is that these theories predict that more specific representations of past episodes are susceptible to interference or decay across time, whereas gist or more general representations are thought to be more immune to these degradative influences. This idea is also shared by Surprenant and Neath's (2009) *specificity principle of memory*, according to which, when an individual is tasked with remembering specific information, they are more likely to fail to remember that information compared to when they are tasked with remembering more general information. Thus, according to Surprenant and Neath (2009), the reason individuals, especially older adults, do worse on some memory tasks – such as free recall compared to item recognition (Rhodes et al., 2019) – is attributable to the extent to which the task of memory requires an individual to remember specific information that had been presented or learned earlier. Although we have pointed to a couple of different theories that differentiate between specific and gist representations, we will concentrate in the remainder of this review on fuzzy-trace theory, owing to its more detailed set of fundamental principles about the distinctions between specific/verbatim and gist memory representations (see Brainerd

& Reyna, 1990, 2004). However, this is not to say that fuzzy-trace theory is the single, correct account of specific and gist representations, and, indeed, other theories (e.g., Craik, 2002; Radvansky & Dijkstra, 2007; Robin & Moscovitch, 2017) also predict that older adults' episodic memory representations are less specific in nature than those of younger adults (cf., Greene & Naveh-Benjamin, 2023a).

Gist Representations as Primitive Features of Human Memory

Fuzzy-trace theory treats gist representations as a core feature of human memory and suggests that these representations may have a deeper, evolutionary basis, as evident in classical animal latent learning studies in which animals appear to store general layouts (or "cognitive maps") of the learning environments (e.g., Tolman, 1948). The idea that gist/general representations are an evolutionally-ingrained feature of memory, extending beyond humans and into animals, leads naturally to one of fuzzy-trace theory's central arguments – gist traces are created and can be accessed independently of verbatim traces.

Unlike earlier serial processing theories, like those of Kintsch (1988), which proposed that gist representations were created on the basis of interpreting verbatim streams of information (i.e., gist representations formed after verbatim representations had been at least partially established and their meaning could be extracted; cf., Reder, 1982), fuzzy-trace theory assumes an alternative position – verbatim and gist traces are stored independently, and in some situations, gist representations appear to be formed more rapidly than verbatim representations. For instance, Draine and Greenwald (1998) showed that semantic priming effects occurred for primes presented for as little as 50ms, in which participants were not aware of the prime's verbatim appearance yet nevertheless responded more accurately and more quickly in a lexical decision task (e.g., more accurately and rapidly categorizing "Sarah" as a typically female name

after being presented with “Jane” as a semantically-related prime versus “Mark” as a semantically-unrelated prime). More recently, Greene and Naveh-Benjamin (2023b) have shown that gist representations for complex episodes involving remembering what scene had been paired with a face (e.g., whether it was an indoor or outdoor scene) can be established more rapidly than corresponding verbatim representations (e.g., whether it was a specific park scene), supporting fuzzy-trace theory’s position of rapid formation of gist representations that is not dependent on interpreting verbatim representations (cf., Ahmad et al., 2017; Potter, 1976; Tatler et al., 2003).

These empirical findings of rapid gist formation that can occur on quick timescales and appear to occur more rapidly than verbatim formation speak to the primitive nature of gist representations as a core architectural component of human memory, an idea earlier captured in connectionist models in which learning occurs at least in part by connecting incoming streams of information to higher-order content nodes that capture the general meaning (e.g., McClelland & Rumelhart, 1985). What makes gist representations such a core feature of memory is their connection to stored knowledge, or semantic memory in the traditional systems perspective. That is, gist representations create a “semantic tag” of an episode, linking what transpired in an episode to knowledge held in long-term memory. Supporting this idea, there are surprising developmental patterns in which, among young children who have a more limited knowledge base, there is less reliance on semantic gist representations compared to adolescents and young adults, such that young children exhibit fewer spontaneous false memories that share a semantic overlap with true memories (Brainerd & Reyna, 2015). For example, in the classic Deese-Roediger-McDermott (DRM) paradigm (Deese, 1959; Roediger & McDermott, 1995), the tendency to falsely recall or recognize an unpresented lure (e.g., “sleep”) that is semantically

related to the presented items on the list (e.g., “bed,” “dream,” and “pillow”) surprisingly increases with age across childhood to young adulthood (Brainerd et al., 2002). Indeed, the DRM illusion appears to be strongest in older adults, who have a much more extensive knowledge base (Koutstaal & Schacter, 1997; Norman & Schacter, 1997).

It may seem counterintuitive that gist representations could be seen as a primitive feature of human memory when such representations are not as readily relied upon in young children, who have more limited knowledge, but it is precisely this connection to stored knowledge that highlights the essential nature of gist representations as a fundamental aspect of memory. Specifically, the developmental shift toward an increased reliance on gist representations highlights the importance of these representations as episodic memories become more unreliable, especially in old age. Even in situations in which episodic memory may still be quite optimal (i.e., in young adulthood), an increased reliance on gist representations can be advantageous due to the ease with which such representations can be maintained or accessed from memory (see Brainerd & Reyna, 1990, 2015), a point we return to shortly.

Gist Representations in Older Adults

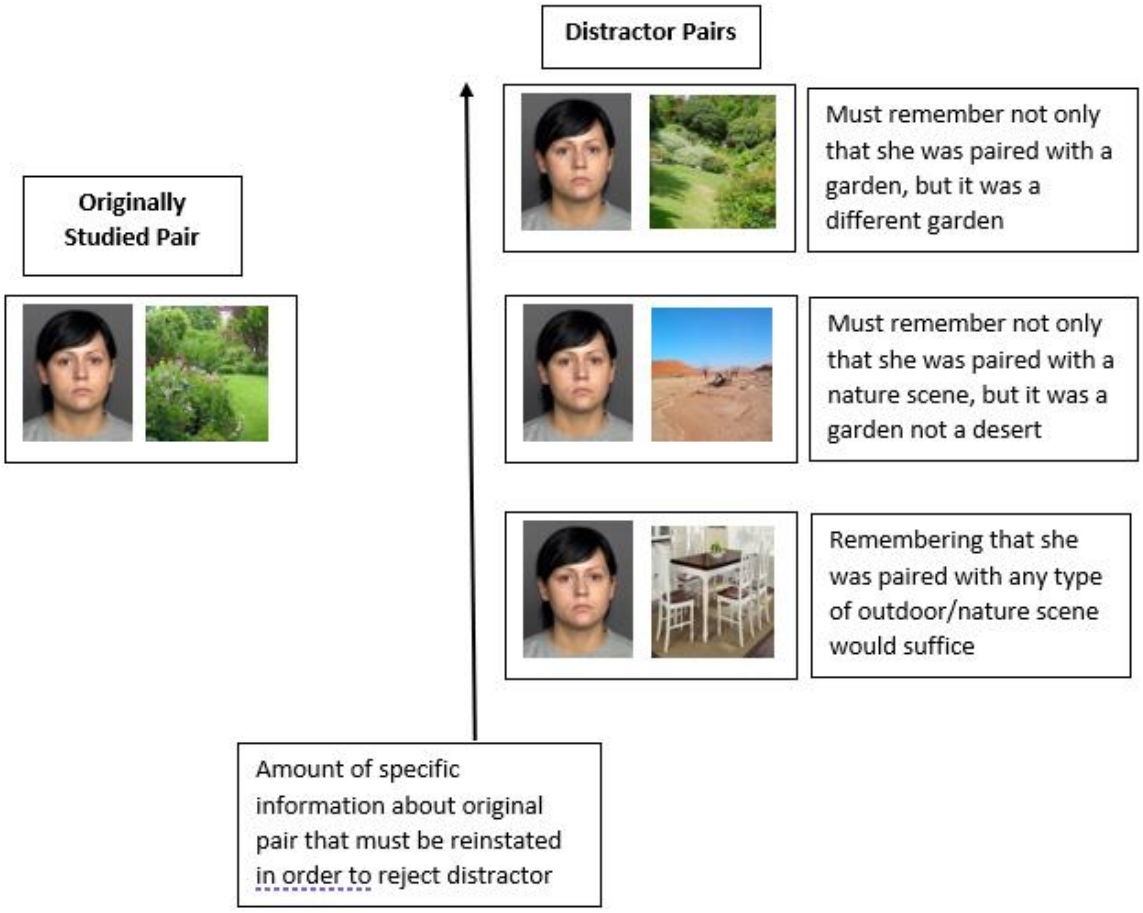
In situations in which episodic memory is more severely limited, such as in older adulthood, a reliance on gist representations may help individuals avoid catastrophic memory errors. For instance, it has been widely shown that older adults’ deficits in episodic memory may be related to their inability to bind together different components of an episode, such as a person and a location (see Old & Naveh-Benjamin, 2008; Naveh-Benjamin, 2000). However, when older adults can rely on pre-existing knowledge, they can successfully remember episodes at more general levels. For example, in a study by Castel (2005), young (age: M = 20.3 years) and older adults (age: M = 70.3 years) were tasked with remembering novel item-price associations

(e.g., a gallon of milk priced at $13.15, or a loaf of bread at $3.50). Although older adults performed worse than younger adults at remembering the specific price associated with a given item, they were able to remember the general price level (i.e., whether an item was priced fairly or was over- or underpriced). What these findings highlight is a *beneficial* role of relying on gist memory to help remember at least the core essence of what transpired in an event in a situation in which older adults are notoriously limited in their memory, which is in contrast to the more often held negative views about older adults' reliance on gist representations, owing to such representations contributing to more spontaneous false memories (e.g., Koutstaal & Schacter, 1997) and diminished survival processing effects on memory (e.g., Otgaar et al., 2014; Stillman et al., 2014). But can older adults also rely upon gist representations in situations in which their ability to use pre-existing knowledge as an aid may be more limited? To address this question, we turn now to describing a more recent set of results that suggests that gist representations are readily accessible among older adults even when pre-existing knowledge is likely to be of less use.

The basic task used in these studies is an associative recognition task in which participants study pictures of faces paired with pictures of scenes (Greene & Naveh-Benjamin, 2020), simulating remembering meeting people in different places (Gruppuso et al., 2007), a hallmark of episodic memory. During the study phase of the procedure, participants view unique face-scene pairs, such as a young woman paired with a garden. At test, which typically occurs in long-term memory in these studies (i.e., after several study pairs have been presented and following a brief retention interval), participants must distinguish between intact pairs (e.g., the young woman with the same garden scene) from distractor pairs that vary in how similar they are to originally studied pairs. A highly similar pair may feature the young woman paired with a

different garden scene, a less similar pair may feature the young woman paired with a desert (a different type of nature scene), and a dissimilar pair may feature the young woman paired with a dining room (a type of non-nature, indoor scene). As illustrated in Figure 1, the amount of specific information about the original episode that a participant would need to remember in order to reject the distractor pairs depends on the similarity of those pairs to the originally encoded pair.

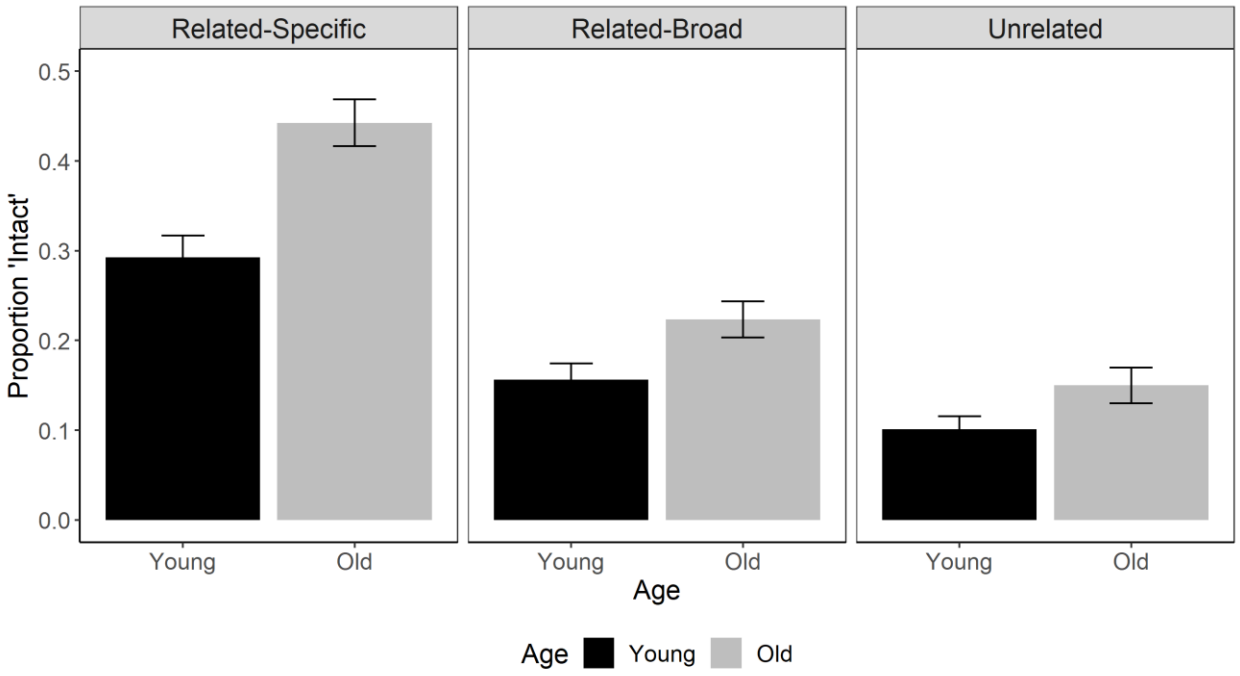
Figure 1. *Depiction of Levels of Specificity in Greene and Naveh-Benjamin's (2020) Associative Specificity Task*



Note. Face depicted in figure is adapted from the FACES database (Ebner et al., 2010) and has been approved for display purposes to illustrate research methodology per Clause 7 of the FACES Platform Release Agreement. Scenes are from Konkle et al. (2010).

Greene and Naveh-Benjamin (2020) found that, compared with younger adults (age: M ~ 19.5 across both experiments), older adults (age: M ~ 73.0 across both experiments) were less accurate in rejecting the most similar distractor pairs (Related-Specific pairs), but age differences were smaller for rejecting less similar pairs (Related-Broad pairs; see Figure 2). Importantly, there were null effects of age on rejecting the dissimilar (Unrelated) pairs, which do not resemble an original pair at either a specific or a gist level of representation (cf., Greene et al., 2022). Such findings suggest that older adults were able to remember the gist of what transpired in a given pairing (e.g., "the young woman had been paired with an outdoor scene, not an indoor scene") but were less capable of remembering more specific information (e.g., "the young woman had been paired with the first garden scene, not the second one"). Indeed, these conclusions were supported by a model-based analysis from the simplified conjoint recognition multinomial processing tree (or MPT) model applied to the data (Stahl & Klauer, 2008), which provides independent indices of verbatim and gist memory, separate from response biases. The MPT results showed that estimates of *gist memory* were comparable between young and older adults, whereas estimates of *verbatim memory* were smaller in older adults.

Figure 2. *Proportion of Erroneous "Old/Intact" Responses to Distractor Pairs for Young and Older Adults in Experiment 1 of Greene et al. (2022)*



Note. Figure is a re-adaptation of the data from Experiment 1 of Greene et al. (2022), available on the Open Science Framework at https://osf.io/vkcgh/.

These findings are important in establishing that older adults can remember the gist of complex episodic associations, even in situations in which pre-existing knowledge may not be very beneficial. For instance, for the pair featuring a young woman paired with a garden, it is conceivable that an older adult could have relied upon pre-existing knowledge of encountering young women near gardens to aid with rapidly forming a gist representation, as in the study by Castel (2005) in which older adults could make use of pre-existing knowledge about the real-world price of grocery items to aid in their memory for the general price range of novel item-price pairings. However, such pre-existing knowledge of encountering young women near

gardens may be less useful in the study by Greene and Naveh-Benjamin (2020) because alternative types of pre-existing knowledge may interfere, such as having encountered old men near gardens. Importantly, the finding that older adults could remember the gist of these novel face-scene pairs, even in a situation in which pre-existing knowledge may offer limited aid, speaks to the benefit of gist representations as they can be relied upon both when pre-existing knowledge can be useful (e.g., Castel, 2005) and when such knowledge may not be as useful.

Potential Reasons Why Older Adults Rely Upon Gist Representations

Decades of empirical research converge on the theoretical ideas of fuzzy-trace theory of developmental increases in gist processing and decreases in verbatim processing that are especially notable in older adulthood (Greene & Naveh-Benjamin, 2020; Greene et al., 2022; Koutstaal, 2003; Koutstal & Schacter, 1997; Pidgeon & Morcom, 2014; Radvansky et al., 2001; Stine-Morrow et al., 2002; Tun et al., 1998), leading to a potential principle of cognitive aging – older adults' preferentially rely upon gist representations. But why is this the case? To get some insight on why these age-related shifts toward gist (or fuzzier) processing and away from specific processing occur, we consider in depth two aspects about the nature of verbatim/specific and gist representations. In the first, we concentrate on the resource-demanding nature of verbatim and gist memory representations, and in the second, we concentrate on the time course under which verbatim and gist representations can be established during encoding or accessed at retrieval. These two aspects (resource demands, and speed of formation and access), and the extent to which they differ between verbatim and gist levels of representation, are likely critical in accounting for adult age-related deficiencies in verbatim representations but preservations in gist representations given that adult aging is associated with declines in both cognitive resources (e.g., Craik & Byrd, 1982) and in processing speed (e.g., Salthouse, 1996). As we will show,

many of the earliest principles embodied in fuzzy-trace theory from Brainerd and Reyna (1990), such as the *reduction-to-essence principle* (i.e., independent gist extraction) and the *fuzzy processing preference principle*, still hold considerable merit in light of new empirical evidence, though perhaps some refining of some aspects of these principles may be in order.

Are Gist Representations Less Resource-Demanding?

Perhaps one of the most appealing reasons why older adults can successfully remember gist representations but have pronounced deficiencies in memory for verbatim representations of past episodes is because gist representations may be less costly, in terms of cognitive resources, than verbatim representations to encode, maintain, or retrieve. Before addressing the evidence bearing on this hypothesis, we must consider what a cognitive resource is. The idea of cognitive resources has a long-standing history in cognitive psychology, and cognitive resources are often synonymous with attention, which is theorized to be more limited in older adulthood (e.g., Craik & Byrd, 1982; Hasher & Zacks, 1988; Rabinowitz et al., 1982), or working memory capacity, which is also limited in older adulthood (Wingfield et al., 1988). One of the most straightforward ways to address the nature of a cognitive resource is by appealing to Cowan's (1988, 2019) *embedded processes* framework.

According to Cowan (1988, 2019), there is a fundamental link between attention and memory, in that attention directs the mind to focus on features of the environment to be processed into a current state of memory – working memory – that serves, essentially, as the "portal" to long-term memory (cf., Forsberg et al., 2021; Fukuda & Vogel, 2019). At any given time, the number of possible inputs from the environment may be impossibly large for the mind to concentrate on all of them, so attention can be guided to focus on task-relevant information. At the same time, knowledge from long-term memory can be recruited into working memory to

help refine where attention is directed. As an example, in a study by Henderson et al. (1999), participants spent considerably less time focusing on items that were consistent with a scene (e.g., a stethoscope appearing in a doctor's office) than those that were inconsistent with a scene (e.g., a frying pan in a doctor's office), thus implicating a role of long-term memory in selectively guiding attention toward salient and unexpected features of the environment. Critically, according to Cowan (2001), the capacity of working memory is severely limited to about three to five units of information in younger adults, and even fewer units in older adults (e.g., Greene et al., 2020; Light & Anderson, 1985; Wingfield et al., 1988).

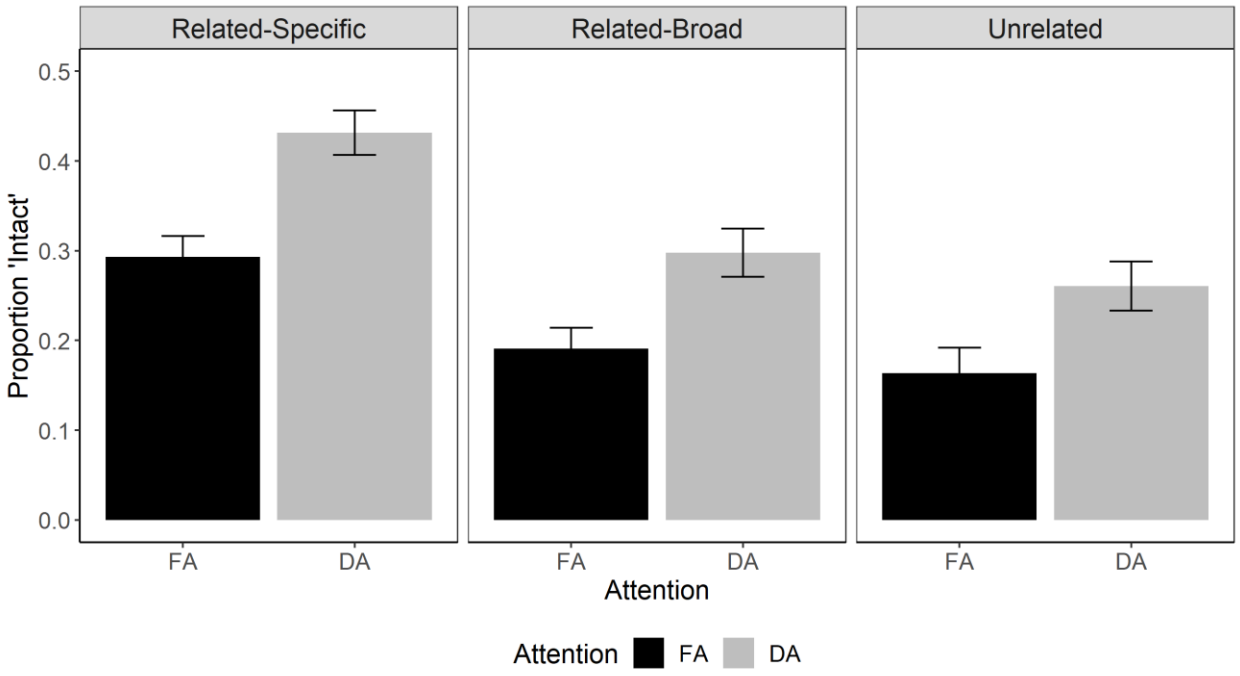
Having now belabored what we mean by a "cognitive resource" – namely, as a limited capacity to focus attention on some inputs during encoding, to maintain these inputs briefly in working memory and to allow their consolidation into long-term memory, and to later retrieve these inputs from long-term memory – we now return to the hypothesis that gist representations are less resource-demanding than verbatim representations. This hypothesis falls naturally out of fuzzy-trace theory's *fuzzy processing preference principle*, which states that humans naturally prefer to process information in a fuzzier manner (i.e., more consistent with the gist of what transpired, rather than the specifics) because gist traces are, among other things, more accessible and require less processing complexity than verbatim traces (Brainerd & Reyna, 1990). It is also related to fuzzy-trace theory's *reduction-to-essence principle*, the idea that there is a natural tendency to extract the essence (gist) of information in large part because it is easier to maintain such information and because gist traces are highly malleable, allowing an easy updating as new information becomes available. Both principles are also related to the "principle of least effort" (Zipf, 1949). Let us consider now the evidence from studies of cognitive aging and those of divided attention about whether this hypothesis holds merit. To do so, we will concentrate on the

associative specificity task of Greene and Naveh-Benjamin (2020) described earlier (see Figure 1), as it also has been applied to investigate the effects of divided attention on specific and gist memory representations.

To understand the divided attention paradigm, we must entertain the theoretical ideas that older adults possess more limited attentional resources (Craik & Bryd, 1982; Rabinowitz et al., 1982), which may manifest in the form of a diminished ability to allocate attention to relevant features of the environment in an embedded-processes conception (and, possibly, away from irrelevant features; e.g., Hasher & Zacks, 1988) or in terms of *fewer* units to be allocated to encoding, maintaining, and retrieving information from memory. If these ideas hold merit, then we should expect that we can model similar deficits in episodic memory typically observed in older adults by dividing attention in young adults between a primary memory task and a secondary task, which leaves them with fewer resources to process the primary task features. Indeed, divided attention, especially during encoding, has been shown to markedly reduce young adults' recognition and recall (Craik, 1983; Craik et al., 1996; Naveh-Benjamin et al., 1998, 2003), making their performance resemble that of older adults, though the patterns do not perfectly match what is obtained with older adults. For instance, Naveh-Benjamin et al. (2003) showed that divided attention at encoding in young adults resulted in relatively equal deficits in item and associative recognition, whereas adult aging is associated with a more robust deficit in associative than item recognition. Nevertheless, in DRM-type procedures, young adults under divided attention at encoding show similar rates of false recollection of unpresented critical lures to older adults (Skinner & Fernandes, 2009), suggesting that attention plays a critical role in accounting for adult age-related deficits in item-specific memory.

Greene and Naveh-Benjamin (2022c) used the associative specificity recognition task, described earlier, to examine whether divided attention during encoding would disrupt only specific or also gist representations of face-scene pairs. They found that, compared with young adults who encoded face-scene pairs under typical full-attention conditions (i.e., without simultaneously carrying out a secondary task), young adults who encoded those pairs while simultaneously responding to an auditory choice reaction time task were worse at rejecting distractor pairs at all levels of similarity (see Figure 3). That is, not only were these participants worse at correctly rejecting the similar distractor pairs that retain the gist of the originally encoded pair, but also they were worse at correctly rejecting the dissimilar pairs (such as the young woman appearing with a dining room in Figure 1, when at study she had been presented with a garden). In addition, the MPT results showed deficits in both verbatim and gist memory parameters, showing that the effects of divided attention were more robust than those of aging reported in Greene and Naveh-Benjamin (2020).

Figure 3. *Proportion of Erroneous "Old/Intact" Responses to Distractor Pairs for Young Adults Under Full or Divided Attention in Experiment 2 of Greene et al. (2022)*



Note. FA = full attention, DA = divided attention. Figure is a re-adaptation of the data from Experiment 2 of Greene et al. (2022), available on the Open Science Framework at https://osf.io/vkcgh/.

On the one hand, the divided attention results in Greene and Naveh-Benjamin (2022c) do not serve as a perfect model of the aging results from Greene and Naveh-Benjamin (2020). On the other hand, they may tell us something about whether gist representations, in addition to verbatim representations, are resource demanding. Indeed, the fact that a division of attention during encoding results in deficits in gist memory suggests that some commitment of attention is necessary to establish a gist representation in the first place (cf., Greene & Naveh-Benjamin,

2022b). Thus, it seems likely that gist representations are not automatically extracted, but rather, some cognitive resources must be devoted to processing the gist of an episode during encoding.

Nevertheless, the idea that gist traces are less resource demanding than verbatim traces may still hold merit. That is, although older adults have fewer resources than younger adults, they may have enough resources to encode the gist of a complex episode, but not enough resources either to encode, maintain, or retrieve the verbatim representation. To get more traction on this hypothesis, it would be useful to use a divided attention paradigm in which the difficulty of the secondary task is manipulated. It may be that the auditory choice reaction time task employed in Greene and Naveh-Benjamin (2022b, 2022c), in which participants must discriminate between three types of tones of different pitch, is a somewhat difficult task that results in a diminished ability to encode both verbatim and gist representations. However, a simpler task – for example, one requiring discrimination of only two types of tones, or one using a simple reaction time task – may more closely mirror the aging results by showing deficits in verbatim but not in gist representations. If, under easier divided attention conditions, deficits in only verbatim but not gist representations occurred, this would support the notion that verbatim representations are *more* resource-demanding than gist representations insomuch as verbatim representations are disrupted even under simpler task constraints. [2]

Whether it is an encoding failure, a maintenance failure, or a retrieval failure that results in older adults' deficits in verbatim memory remains to be determined. Indeed, the maintenance of information, at least temporarily in working memory, may require attentional refreshing (Barrouillet et al., 2004) or other resources to overcome decay or interference (e.g., Oberauer et

[2] At the time this chapter was accepted, the authors had not yet followed up on this, but they have done so now in Greene and Naveh-Benjamin (2023c), showing that, indeed, under less demanding levels of the concurrent task, divided-attention induced deficits emerge only for specific/verbatim but not gist representations.

al., 2012). Moreover, attention appears to be involved during retrieval, as evident in studies of divided attention at retrieval in young adults showing that response latency is slower under divided attention conditions (Naveh-Benjamin et al., 1998). Older adults are less likely to deeply elaborate upon the contents of retrieved episodes (Jacoby et al., 2005), and it is conceivable that a deep elaboration at retrieval may be needed to reintegrate a verbatim representation (Brainerd & Reyna, 1990), such that it is more effortful and resource-demanding to retrieve a verbatim than a gist representation. Also supporting this idea is a study by Luo and Craik (2009), in which young adults tested under divided attention at retrieval in an item-context memory task showed deficiencies in remembering the specific context in which an item had been presented earlier but could remember more general details of the encoding context. Such results are in line with what is typically found in older adults, who have preserved gist but impaired verbatim memory. In addition, in a recent study by Greene and Naveh-Benjamin (2022a), older adults (age: M = 69.2 years) could sometimes remember specific representations of face-scene pairs in the associative specificity task described earlier when the tests occurred *immediately* after encoding but not when the tests occurred in long-term memory. These results suggest that older adults may initially partially establish verbatim representations but are later less capable than younger adults of maintaining and retrieving these representations. Still, more work is needed in this area, but at least tentatively, the emerging picture suggests that there are resource-demanding properties (such as a commitment of attention) that are involved, at the time of encoding, for both specific and gist representations, whereas during retrieval, it appears that the reintegration of a specific representation is resource-demanding, whereas that of a gist representation is less resource demanding (see Dodson et al., 1998; Luo & Craik, 2009).

Can Gist Representations Be Established More Rapidly Than Verbatim Representations?

We noted earlier that, unlike serial processing theories like those of Kintsch (1988), fuzzy-trace theory assumes independence between verbatim and gist representations. In verbatim-gist serial dependency theories, the gist of a stream of information is extracted only after the verbatim, surface-level representation has been established. For example, to extract the gist of a passage of text, such as the current sentence, one must first process the specific words in the sentence and, only at natural pauses (e.g., at the end of clauses), is the gist interpreted. In order for the gist to be extracted from the verbatim representation, knowledge structures, referred to as "gist macroprocessors," must be in place to connect the verbatim stream of information with existing knowledge held in long-term memory to aid with the interpretation of the meaning of the verbatim representation. Essentially, this implies that the time to establish a gist representation would be longer than the time necessary to initially establish a verbatim representation. Although the earlier evidence on this point was mixed, with some research showing evidence of slower gist extraction (e.g., Gerrig & Healy, 1983; Reder, 1982) and others favoring the rapid gist extraction that is independent of verbatim memory (e.g., Reyna & Kiernan, 1994), the later evidence more firmly favored fuzzy-trace theory's independence assumption, as in the semantic priming procedure of Draine and Greenwald (1998) described previously.

Indeed, in a recent series of experiments using the associative specificity task, Greene and Naveh-Benjamin (2023b) examined, among young adults, the rates at which specific and gist representations of face-scene pairs could be established. To do so, they presented face-scene pairs for either 0.75 seconds, 1.5 seconds, or 4 seconds at encoding (note that the typical presentation rate in the associative specificity task is 4 seconds). With increases in the presentation rate (from 0.75 seconds to 1.5 seconds to 4 seconds), there were consistent increases

in accuracy on the task that were manifest by improvements, in the MPT model, in the verbatim memory parameters. That is, verbatim memory consistently improved from 0.75 seconds to 1.5 seconds to 4 seconds. Regarding the gist memory parameters, there were initial increases in these parameters between the 0.75 second and 1.5 second presentation rates, but no further increases from 1.5 seconds to 4 seconds of presentation rate in Experiment 1, which suggested that gist representations established within 1.5 seconds of encoding time were comparable to those established within 4 seconds of encoding time. Notably, this finding suggests that gist representations for complex episodic associations could be established more rapidly than corresponding verbatim representations, given that there were continued increases in verbatim memory between the 1.5 seconds and 4 seconds presentation rates. However, there was a potential confound in Experiment 1, which was related to differences in the average length of time between encoding and retrieval, which were always larger in the 4 second than 1.5 second and 0.75 second conditions. After equating the retention intervals across the encoding time conditions in Experiment 2, Greene and Naveh-Benjamin (2023b) reported increases in gist memory between the 1.5 second and 4 second conditions that mirrored the increases in verbatim memory. Nevertheless, these findings were still opposed to the slower gist extraction predictions of verbatim-gist serial dependency models, which would predict verbatim representations to be established more rapidly than gist representations (e.g., verbatim memory would be on par between the 1.5 second and 4 second conditions, whereas gist memory would continue to improve from 1.5 seconds to 4 seconds).

Thus far, the existing literature examining the rates at which verbatim and gist representations can be established has primarily focused on these rates in young adults. However, it is well established that adult aging is associated with slower processing speed

(Salthouse, 1996), such that the speed with which older adults can carry out cognitive tasks is slower, though this slowing may be related more to response bias differences between young and older adults in simple yes-no decision tasks rather than to slowed cognitive processing, per se (Ratcliff et al., 2001). Nevertheless, there may be age-related slowing of some cognitive processes, such as the ability to encode or retrieve detailed representations (for a computationally explicit account, see Healey & Kahana, 2016).

If we accept fuzzy-trace theory's principle of rapid gist extraction at encoding that can occur independently of verbatim extraction, and the evidence suggests that at least in young adults there is some merit to this principle, then it is reasonable to conjecture that this principle may also hold among older adults. There is evidence from semantic priming tasks showing that older adults respond as accurately as young adults in lexical decision tasks when primes are semantically congruent with targets (Howard, 1983; Laver, 2009). However, more research is needed to determine how rapidly older adults can establish a gist representation of an episode. One promising direction is currently in the works by the present authors, using the basic paradigm detailed in Greene and Naveh-Benjamin (2023b) to map out the time course under which verbatim and gist representations of complex episodic associations are formed among older adults. Given that older adults' gist representations formed within 4 seconds of encoding time in these procedures (e.g., Greene & Naveh-Benjamin, 2020) are already on par with those of younger adults formed within the same rate of presentation, but older adults' verbatim representations are inferior to those of younger adults, it is conceivable that the rate of formation of a stable verbatim representation is more protracted than that of a stable gist representation for complex episodic associations in old age.

Moreover, fuzzy-trace theory predicts that the speed with which gist representations can be accessed at retrieval is faster than the speed with which verbatim representations can be accessed (Brainerd & Reyna, 1990). To our knowledge, there are no studies assessing the time to retrieve verbatim or gist memory in older adults. Recent advances in MPT modeling, using reaction time data (Heck & Erdfelder, 2016), may make it possible to map out the time course under which verbatim and gist memory are accessed at retrieval (e.g., Brainerd et al., 2019). For now, we will have to wait and see what these analyses may tell us about how quickly older adults can retrieve gist and verbatim representations.

Advantages of Gist Representations in Old Age

We began this chapter by noting that one of the most ubiquitous cognitive declines observed in older adulthood, even among older adults with no pathological impairments, is in episodic memory (Light, 1991, Naveh-Benjamin & Old, 2008; Zacks et al., 2000). Such declines are usually cast in a negative light, with journal articles often describing "age-related episodic memory deficits" (e.g., "inhibitory deficit" – Hasher & Zacks, 1988; "associative deficit" – Naveh-Benjamin, 2000). Indeed, losses in episodic memory that can lead to increased forgetfulness are certainly far from a positive feature of aging, given episodic memory's important role in everyday functions like remembering where you parked your car, or whether you have taken your morning medicine, and in autobiographical recall (Levine et al., 2002) and prospective memory (Brewer & Marsh, 2010).

At the same time, it appears that the widely reported declines in episodic memory that occur in older adulthood may be, at least in some situations, more nuanced than previously thought. For instance, one of the leading theoretical explanations for episodic memory loss associated with advanced age is that older adults are less capable of binding together different

components of an episode (e.g., a person and a location) that are essential to successfully remembering a past experience (Naveh-Benjamin, 2000; Old & Naveh-Benjamin, 2008). Yet new empirical evidence suggests that these binding deficits may be restricted to specific representations (e.g., remembering the exact location in which a person was encountered), whereas gist representations of associations in episodic memory are well preserved in older adulthood (Greene & Naveh-Benjamin, 2020, 2022a; Greene et al., 2022). We have focused extensively on *why* gist representations may be better preserved than specific/verbatim representations, but it also important to emphasize that older adults' ability to remember gist representations can be advantageous, though of course there are some situations where this is not the case (e.g., in the case of survival processing advantages; Otgaar et al., 2014). That is, although we expect there to be continued focus into the causes of age-related losses in specific representations (perhaps advancing some of the mechanisms described here related to resource costs and speed of formation and access), it is also important to consider the benefits that relatively well-preserved gist representations can have for older adults whose episodic memory in general may be more limited.

One potential benefit is that, by retaining primarily gist representations of past episodes – whether by choice (i.e., as a preference to focus on or retain only the general meaning of a past experience) or by necessity (i.e., because it may be more difficult to encode or retrieve more specific details) – older adults may be able to free up their more severely limited working memory (e.g., Greene et al., 2020; Light & Anderson, 1985; Wingfield et al., 1988) to encode new information. That is, because gist representations appear to require less attentional resources to encode and retrieve than verbatim representations, by primarily remembering episodes at gist levels, older adults may be better equipped to encode additional information that would

otherwise interfere with the more specific representations that are costlier to encode, maintain, and retrieve.

Another potential and related advantage is that, in many situations, remembering specific information may be unimportant as gist/general information may lead to well-enough performance. There are, of course, instances where it is important to remember specific details of a past experience – as, for example, in eyewitness testimony. In other instances, remembering specific details may be unnecessary. For example, in reading and discourse comprehension, remembering the exact wording of a sentence or a statement is usually not important for comprehension, except perhaps during school years where verbatim details (e.g., the exact dates of historical events presented in textbooks) may be tested. A more critical aspect of reading comprehension is to understand *what* the text was about (Kintsch, 1988; van Dijk & Kintsch, 1983), and older adults do quite well, in some cases performing better than younger adults, at encoding and retaining the meaning of a passage of text (Radvansky & Dijkstra, 2007; Radvansky et al., 1990, 2001; Stine & Wingfield, 1988; Stine-Morrow et al., 2002). Related to the previous benefit we described above, if older adults attempt to remember specific details (e.g., the exact wording of a sentence), given their more limited working memory capacity, they may not be able to "hold onto" as many details of the text, potentially worsening their comprehension. Concentrating on the essence (or gist) of the text would be advantageous given that it is likely less resource-demanding and results in better comprehension.

Even in situations in which remembering specific information would be advantageous, remembering gist information can still be an aid when more specific representations are lacking. As we have noted, one of the areas in which older adults have the most pronounced performance deficits in episodic memory is in associative binding between components of an episode (Naveh-

Benjamin, 2000). Given findings like those of Greene and Naveh-Benjamin (2020) that older adults can remember such episodic bindings at less specific levels of representation (cf., Castel, 2005), it is conceivable that their ability to remember the gist of complex associations that form the core of episodic memory can help older adults avoid catastrophic memory failures. For example, if an older adult fails to remember the specific parking spot where they left their car while at the mall, but they can remember the more general location (e.g., "I parked on the east side of the mall toward the front of the lot"), this would help them avoid searching for their car in a completely different location (e.g., on the west side of the mall).

A more clinically relevant benefit of preserved gist memory representations is that changes in the ability to remember such representations may be a useful indicator of the transition to mild cognitive impairment (MCI) or Alzheimer's disease (AD; Brainerd & Reyna, 2015). MCI and AD are neurodegenerative disorders that primarily disrupt episodic memory, and their prevalence increases with advanced age, with some reports suggesting that, by age 90, approximately one-third of individuals have some form of dementia (Assistant Secretary for Planning and Evaluation, 2019). Brainerd and Reyna (2015) showed that, in a nationally representative sample of healthy older adults and those with MCI or AD from the Aging, Demographics, and Memory Study of the National Institute on Aging's Health and Retirement Study (2011), the only distinguishing representational differences in tests of episodic memory between healthy controls and patients with dementia were in terms of deficits among the latter in the ability to reconstruct episodes from gist representations. That is, whereas older adults in good health can reconstruct episodes from gist representations to comparable extents as younger adults (Brainerd et al., 2009), older adults with either MCI or AD were incapable of doing so. Perhaps more strikingly, Brainerd and Reyna (2015) demonstrated that deficits in the ability to retrieve

gist representations, even among healthy controls, were more accurate predictors of future disease progression to MCI or from MCI to AD than were typical genetic biomarkers, such as the presence of the APOE ε4 allele.

Conclusion

The preservation of gist representations in older adulthood, when episodic memory is more severely limited (e.g., Light, 1991; Naveh-Benjamin & Old, 2008; Zacks et al., 2000), may speak to the evolutionary benefits of gist representations in that such representations can still be readily relied upon even when other aspects of memory are lacking or inefficient. Such representations can be formed rapidly, without needing to extract the essence of an experience from the exact details of that experience. Moreover, the encoding and later retrieval of gist representations appears to be less resource-demanding, requiring less attentional resources, especially at retrieval, than those needed to encode or retrieve more specific representations of past experiences. That older adults can remember the gist of past episodes as well as younger adults, despite limitations in their ability to remember more specific details, can be advantageous by helping older adults avoid catastrophic memory errors, by freeing up limited resources to encode or retrieve other episodes, and by ensuring that older adults can do well in situations in which memory for specific details is not necessary for comprehension. In addition, declines in the ability to remember gist representations in older adulthood can serve as strong predictor of the transition to early forms of dementia.

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