

Preserved Cross-modal Priming and Aging: A Summary of Current Thoughts

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Abstract: Research on within-modal repetition priming suggests that this form of implicit memory is preserved in older adults not only for visual stimuli but also for stimuli presented to other perceptual modalities (e.g., touch, audition, and olfaction). Fewer studies, however, have examined whether priming is modality specific. Studies conducted with young adults have shown that cross-modal (vision-to-touch and touch-to-vision) transfer was similar in magnitude than within-modal transfer (vision-to-vision and touch-to-touch). A recent study further investigated whether cross-modal priming between these perceptual modalities is preserved in older adults. The results suggest that cross-modal priming between vision and touch is preserved and symmetric in both, young adults and older adults. Moreover, within-modal and cross-modal priming for ecological sounds and pictures is preserved with age. These behavioural findings and other recent neuroscience results suggest that cross-modal priming occurs in posterior extrastriate occipital areas that are preserved in aging. Future directions for research in this area include the performance of well designed cross-modal priming studies conducted in normal elderly and Alzheimer's disease patients using different perceptual modalities, familiar and novel stimuli combining behavioural and brain imaging measures, and the inclusion of well designed priming tasks in programs directed to improving memory functions in the elderly.

Key words: aging; cross-modal priming; explicit memory; implicit memory; lateral occipital complex (LOC); within-modal priming

Introduction

Cognitive ageing has been considered as a process of progressive cognitive decline but new and rapidly growing brain imaging data combined with behavioural measures suggest a more positive view. Behavioural studies of cognitive performance with age have been based on response time recordings and accuracy data. These studies have consistently shown a pattern of losses and gains in different cognitive functions. For example, some mental functions such as speed of processing, executive control, working memory, and episodic

memory have all shown consistently age-related declines. In contrast, other cognitive functions such as world knowledge, semantic memory, vocabulary and implicit memory have shown invariance or even growth with age.

Recent advances on neuroimaging have allowed the examination of neural activation while participants performed different cognitive tasks as well as the study of the relations between behavioural measures and neural activity. In this paper, we selectively review some age-related studies on within-modal and cross-modal priming mostly from our laboratory. First, we comment briefly on some within-modal priming findings involving different perceptual modalities. As a whole, the findings from these studies suggest that within-modal repetition priming for stimuli presented to a number of perceptual modalities

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such as vision, touch, audition, and olfaction is preserved with age. Second, we present some recent cross-modal priming findings showing that this ability is spared in older adults. An interesting question is whether the preserved priming effects in older adults are related to the brain structural and functional factors.

Aging affects cognitive processing as well as brain activity and function of all individuals. Until quite recently, the neural and cognitive mechanisms of age-related gains and losses in cognitive function were studied separately. In recent years, however, the cognitive neuroscience of ageing emerged with studies focusing on the relationships between the effects of ageing on cognitive processes and the brain areas involved in these processes (e.g., Cabeza, Nysbett & Park, 2005; Dennis & Cabeza, 2008; Park & Reuther-Lorenz, 2009).

Many behavioural and cognitive neuroscience studies have shown significant declines in certain cognitive processes with ageing (e.g., Baltes & Lindenberger, 1997; Nilsson, 2003; Park, Polk, Mikels, Taylor, & Marshuetz, 2001; Salthouse, 1996). These declines, however, differ across cognitive functions and individuals showing different patterns of decline, stability or even gains across the ageing process (e.g., Hedden & Gabrieli, 2004; Mitchell, 1989; Nilsson, 2003; Park et al., 2001, 2002; Rönnlund & Nilsson, 2006; for reviews see Hedden & Gabrieli, 2004; Park & Reuter-Lorenz, 2009). Ageing theorists agreed that substantial deficits appear with age in declarative memory related to the conscious and intentional retrieval of facts and episodes (see Cabeza et al., 2005; Fleischman & Gabrieli, 1998). Cross-sectional (e.g., Nilsson, 2003; Park et al., 2002) as well as longitudinal studies (e.g., Rönnlund, Lövdén, & Nilsson, 2008; Schaie, 1996) have shown different patterns of cognitive ageing that vary across the lifespan. It is important to note that although the type of experimental design is important when evaluating ageing, the specific cognitive domain that is assessed is vital

(Ballesteros, Nilsson, & Lammaire, 2009b). The last two decades of aging research has shown that not all cognitive processes deteriorate equally with age. Furthermore, not all the individuals follow the same trend of cognitive decline. Cognitive processes like verbal abilities and world knowledge are spared with age or even improve across the lifespan (see Park et al., 2002). Moreover, well educated older adults obtain statistically higher scores on the Mill-Hill test (a vocabulary test assessing general cultural level) and higher levels of repetition priming than young adults with the same educational level (Osorio, Pouthas, Fay, & Ballesteros, in press). Importantly, repetition priming as a measure of implicit memory (better performance for previously encoded stimuli compared to new ones) assessed with a wide variety of implicit memory tests and stimuli presented to different perceptual modalities (e.g., vision, audition, touch, and olfaction) is another cognitive ability that appears stable with age (e.g., Ballesteros & Reales, 2004; Ballesteros, Reales, & Mayas, 2007; Ballesteros, Gonzalez, Mayas, Reales, & García, 2009a; Ballesteros, Reales, Mayas, & Heller, 2008; Fusari & Ballesteros, 2006; LaVoie & Light, 1994; Mitchell, 1989). The enormous corpus of published studies in aging has also showed some contradictory findings although most often implicit memory was age-invariant (for reviews, Fleischman, 2007; Fleischman & Gabrieli, 1998; Light, 1991; Mitchell & Bruss, 2003). Inconsistent findings were mostly due to differences across studies in the type of tasks used to assess implicit memory and in the selection of participants (discussed in Fleischman, 2007, but see also Mitchell & Bruss, 2003).

Implicit memory in normal and pathological ageing

Implicit memory is assessed by showing repetition priming, which refers to better performance in terms of accuracy and/or response time with previously experienced stimuli that do not require conscious or intended retrieval of

previously encountered information (Graf & Schacter, 1985; Schacter, 1987; Squire, 2004). That is, the repeated exposure to stimuli produced facilitation in cognitive processing when the same stimuli are repeated later on time.

Repetition priming as a form of nonconscious, unintended manifestation of memory was first investigated in a series of studies conducted in the United Kingdom by Warrington and Weizkrantz (1968, 1970, 1974) with amnesic patients. These patients were not able to remember words presented previously for study. However, they completed words in word-stem and word-fragment completion tasks more frequently with previously studied words than with new words. These studies showed dissociation between two types of memory retrieval, one conscious lost and the other intact in amnesic patients. Since these early studies this type of nonconscious memory has attracted a great interest among human memory researchers. The dissociation between spare repetition priming and impaired explicit memory occurred in amnesic patients with bilateral lesions in the mesial temporal lobe and has been replicated in other studies (e.g., Levy, Stark, & Squire, 2004; Schacter, 1987). It has also been reported that occipital neocortical lesions impaired repetition priming with intact explicit memory, showing a double dissociation (Fleischman et al., 1995; Keane, Gabrieli, Mapstone, & Corkins, 1995; see Fleischman, 2007). Research on implicit memory has interested cognitive psychologists and neuroscientists for decades because empirical findings have shown consistently that this type of memory is dissociable of explicit memory measures such a recognition or recall (e.g., Henson, 2003; Schacter, Wig, & Stevens, 2007).

An interesting question is whether implicit memory is maintained with age. Most of the information on the stability of repetition priming as a form of implicit memory with age proceeds from cross-sectional studies (e.g., Ballesteros & Reales, 2004; Ballesteros et al., 2007; Ballesteros et al., 2008; LaVoie & Light, 1994; Mitchell,

1989). However, the question of whether implicit memory is stable during aging can only be answered throughout well designed longitudinal studies. Just a few of these studies have been so far reported in the literature. The common finding is that priming did not decline with age (Christensen, Henderson, Griffiths & Levings, 1997; Davis, Trussell, & Klebe, 2001; Fleischman, Wilson, Gabrieli, Bienias, & Bennett, 2004).

In our laboratory, we have investigated repetition priming in normal and pathological aging using pictures (Ballesteros et al., 2007), objects explored haptically (Ballesteros & Reales, 2004; Reales & Ballesteros, 1999) and familiar sounds (Ballesteros et al., 2009a). We have also investigated olfactory repetition priming using a wide set of familiar substances (Fusari & Ballesteros, 2006, Fusari & Ballesteros, 2008). Olfactory repetition priming was assessed twice using a speeded odor naming test, the first time shortly after encoding and the second time after a month from the encoding episode. Explicit memory for odors was also assessed after the implicit memory task. Latencies from the immediate implicit task revealed intact odor priming for older as well as for young adults. Importantly, olfactory priming was still significant after a month interval in older adults, while for young adults this effect was enhanced. In contrast, explicit memory in older adults was impaired when compared to young adults. These results indicated that primed odors are identified quicker than new odors and this result is not age-dependent. In contrast, the results showed that explicit memory was impaired in the elderly when compared to young adults. As far as we know, this study is the first to report intact odor priming in healthy older adults, and that the priming effect is long-lasting in the olfactory modality. A four-year longitudinal study (Fleischman et al., 2004) showed dissociation between implicit and explicit memory functions over this period in older healthy adults. Priming remained stable while explicit memory declined significantly over this period of time.

The sparing of this type of non-declarative (non-intentional) memory suggests that the underlying brain structures remain relatively intact in old age (Daselaar, Veltman, Rombouts, Raaijmakers, & Jonker, 2005; Gabrieli et al., 1994) and even during the first stages of Alzheimer's disease (Ballesteros & Reales, 2004; Fleischman et al., 2004). In contrast, the episodic memory system that relies on the hippocampus and the related medial-temporal lobe system deteriorates (e.g., Fay, Isingrini, & Claris, 2005a; La Voie & Light, 1994; Nilsson, 2003; Park et al., 2002; for reviews see Hedden & Gabrieli, 2004; Park & Rueter-Lorenz, 2009).

At the neural level, recent structural imaging studies suggest substantial age-related grey and white matter shrinkage with age, with anterior regions showing greater decline than posterior regions. The greatest reduction in brain structures with ageing occurs in the caudate nucleus, the lateral prefrontal cortex, the cerebellum and the hippocampus, with minimal or no reduction in volume in the occipital cortex and the entorhinal cortex (Raz et al., 2005; for a review, see Dennis & Cabeza, 2008; Park & Reuther-Lorenz, 2009). These structural brain changes correlate with behavioural data showing larger performance declines in tasks mediated by the frontal lobes (Park et al., 2002; West, 1996). Moreover, functional imaging studies suggest a posterior-anterior shift in older adults and a reduction in the asymmetry of brain activity with age (Dennis & Cabeza, 2008). Interestingly these functional imaging results suggest that the increase in activation in the prefrontal cortex may play a compensatory role for age-related deficits occurring in other more posterior brain regions. Older adults may use different strategies than young adults (Friedman, 2003; Park & Gutchess, 2005; Park and Reuter-Lorenz, 2009; Reuter-Lorenz, 2002).

Cross-modal priming and aging

Repetition priming was assumed modality specific (Schacter, Chiu & Ochsner, 1993).

However, the effects of modality shifts from study to test on repetition priming were investigated presenting verbal stimuli at study to vision and new and old stimuli to audition at test, or vice versa. These type of studies showed that priming was reduced and rarely eliminated with modality change from the study phase of the experiment to the test phase (e.g., Jacoby & Dallas, 1981; Roediger & Blaxton, 1987; McClelland & Pring, 1991) and pointed that priming is modality specific. Based on these results, we (Reales & Ballesteros, 1999) suggested that the reduction in verbal priming observed in some previous verbal studies was the results of the lack of overlap between auditory stimuli (sounds) and visual stimuli (letters). In contrast, we proposed that priming is not modality specific when familiar objects were presented to vision and touch.

A recent study has shown that cross-modal object priming between vision and touch is preserved in older healthy adults (Ballesteros et al., 2009a, Exp. 1). Both, young and older adults showed similar magnitudes of priming, both within-modal (vision to vision; touch to touch) and cross-modal (vision to audition, vision to touch, and vice versa), suggesting that not only within-modal but also cross-modal priming is preserved with age.

Just a few behavioral studies have investigated cross-modal implicit memory effects between vision and touch in young adults (Easton, Greene, & Srinivas, 1997; Easton, Srinivas, & Greene, 1997; Reales & Ballesteros, 1999). In their study conducted with young adults, Reales & Ballesteros (1999) investigated whether the perceptual representations of visual and haptically explored objects were modality specific and whether there were dissociations between implicit and explicit memory tasks. We suggested that visual and haptic representation of objects could be shared. The cross-modal priming paradigm is a good method for studying the extent to which visual and haptic representations of 3D objects overlapped (Ballesteros, 2008; Reales &

Ballesteros, 1999). The results showed that within-modal priming (vision to vision; touch to touch) was equivalent to cross-modal priming (touch to vision; vision to touch). Furthermore, the same perceptual facilitation was obtained under two encoding condition (shallow and deep encoding). So, the manipulation of levels of encoding at the study-phase of the experiment neither affected within-modal priming nor influenced cross-modal priming. The results suggested that implicit memory for familiar three-dimensional (3D) objects assessed by a

speeded object naming test was equivalent in conditions in which the objects were presented to the same modality at study and test to conditions in which the exploration modality changed from study to test (see Figure 1).

The absence of levels-of-processing effects suggests the pre-semantic nature of the mental representations that support implicit memory for objects. We proposed that the repetition priming effects arise from an abstract structural description of the objects and that these structural descriptions are equally accessed by vision and touch.

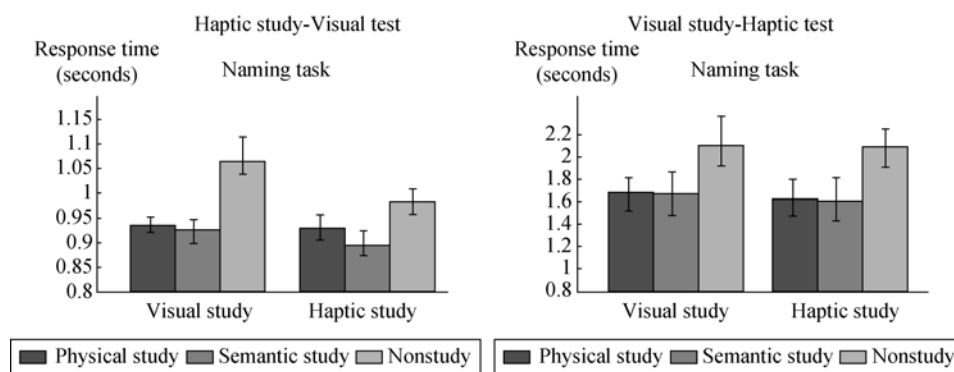


Figure 1. Response time (in seconds) in the haptic and visual object naming test performed by young adults as a function of level of encoding (physical encoding, semantic encoding, and nonstudied). Modified from Reales and Ballesteros (1999), *Experimental Journal of Experimental Psychology: Learning, Memory, and Cognition*, Exp. 1, p. 649. Copyright American Psychological Association.

The interactions between vision and touch have been investigated in young adults using functional magnetic resonance imaging (fMRI) as a way to assess the effects of cross-modal priming between these two modalities on brain activation (James et al., 2002). The results showed that haptic exploration of unfamiliar three-dimensional objects (3D) produced activation (instead of deactivation, see Henson, 2003) not only in the somatosensory cortex but in other areas as well of the occipital cortex previously associated with visual object processing. This cross-modal priming effect on brain activation was observed in areas that are part of the lateral occipital complex (LOC), including the middle and lateral occipital areas (MO and LO) and the fusiform gyrus (FG). Although these researchers did not collect themselves behavioral data, the brain imaging

activation data parallel findings of previous behavioral studies. Based on behavioral (Easton, Greene, & Srinivas 1997; Easton, Srinivas, & Greene, 1997; Reales & Ballesteros, 1999) as well as on fMRI findings (Amedi, Malach, Hendler, Peled, & Zahory, 2001, Amedi, Kriegstein, van Atteveldt, & Beauchamp, 2005; James et al., 2002) it seems plausible that priming uses a common haptic and visual representation which neural substrate might well be LOC.

More recently, we (Ballesteros et al., 2009a) examine whether cross-modal priming between vision and touch is preserved in older adults. The study conducted to investigate cross-modal priming between vision and touch showed that cross-modal repetition priming between these two modalities does not deteriorate with age as both groups showed the same level of priming between

these two modalities (see Figure 2). The finding that cross-modal (vision-to-touch and touch-to-vision) priming is preserved in the old age,

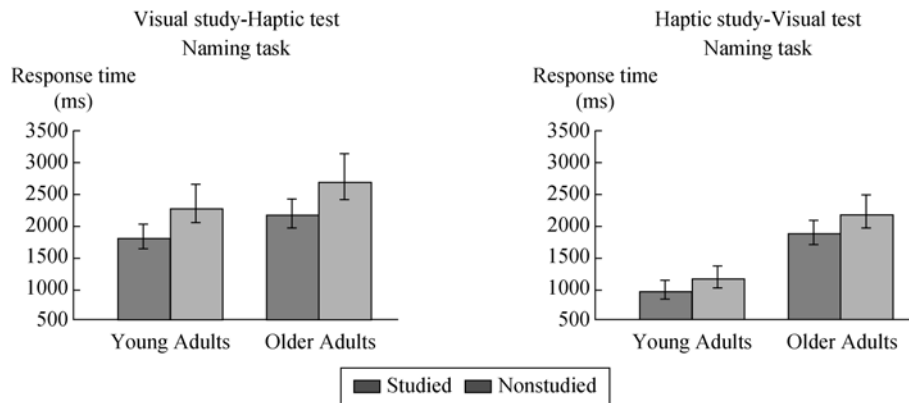


Figure 2. Response time in (ms) in the two cross-modal conditions (visual study/haptic tests and haptic study/visual test) in young and healthy older adults for studied and nonstudied objects. Error bars indicate the standard error of the mean. Modified from Ballesteros et al. (2009), *European Journal of Cognitive Psychology*, Exp. 1. Copyright Psychology Press.

We (Ballesteros et al., 2009a, Exp. 2) have also investigated whether within-modal and cross-modal priming for ecological sounds and their corresponding pictures is preserved in the old age

suggests that the neural machinery involved in repetition object priming does not deteriorate with age.

by comparing performance of younger and older adults. The results (see Figure 3) showed that the repetition priming exhibited by young adults was similar to that shown by the older participants.

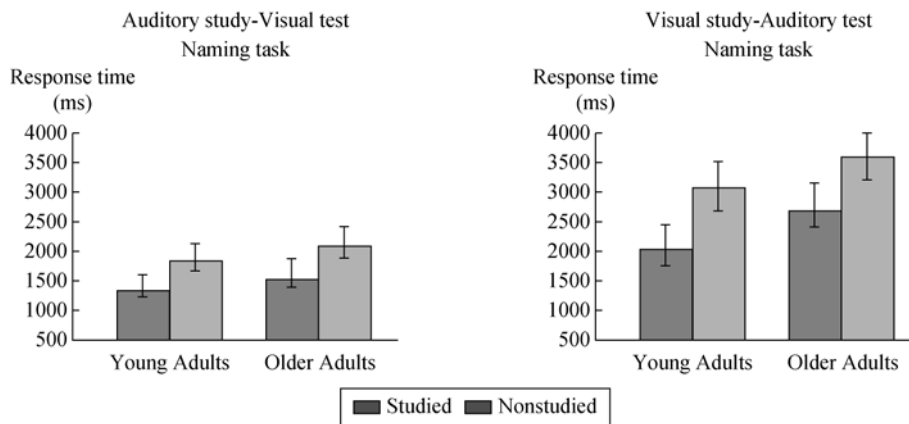


Figure 3. Response time (in ms) in the cross-modal conditions in the implicit memory test as a function of study condition (studied and nonstudied stimuli), test modality (auditory/visual; visual/auditory), and group (young and older adults. Modified from Ballesteros et al. (2009), *European Journal of Cognitive Psychology*, Exp. 2. Copyright Psychology Press.

These behavioural findings on cross-modal visual, auditory, and haptic priming as well as other recent results from neuroimaging studies suggest the implication of areas in the occipital cortex that were previously considered modality-specific. The results from these studies may indicate that cross-modal facilitation might well occur in posterior extrastriate occipital areas that are well preserved not only in normal ageing but also in the first stage of

Alzheimer's disease. These findings extend previous results from our laboratory with young adults (Reales & Ballesteros, 1999) showing that cross-modal priming was of the same magnitude that within-modal priming when familiar objects were presented visually or haptically as well as when auditory events produced by familiar objects and their corresponding pictures are presented at study and test. The cross-modal facilitation observed in our studies suggests that the

representations supporting repetition priming are not modality specific and might depend on high-level structural features that define an object's shape and its spatio-temporal structure.

Other studies have investigated cross-modal priming for visual and auditory events in undergraduate students (Greene, Easton, & LaShell, 2001), normal ageing and Alzheimer's disease patients (Balota, Watson, Duchek & Ferraro, 1999; McGeorge, Taylor, Della Sala & Shanks, 2002; Schneider, Engel & Debener, 2008). Greene and colleagues (2001) found that while visual study produced auditory priming, auditory study produced auditory priming (within-modal priming) but not visual priming (cross-modal priming). Similar results were reported by McGeorge et al. (2002) in young adults, older adults and Alzheimer's disease patients. All groups showed similar within modal priming (vision-vision) but not cross-modality priming effect (auditory-visual). In contrast, Balota and colleagues (1999) found comparable cross-modal audition to vision priming using words as stimuli in young adults, healthy elderly and Alzheimer's disease patients. More recently, Schneider et al. (2008) have reported cross modal priming effect in both directions between vision and audition for visually and orally words tested later using a word-stem completion task. The findings of these studies are in consonance with our results (Ballesteros et al., 2009a) using a different paradigm and show that the object identification in one modality (vision or audition) is influenced by input from another modality. These mixed results may be accounted for a number of experimental differences, including the smaller number of trials, the type of stimuli (filmed events versus pictures), the experimental design (within-subjects versus between-subject) and the selection of the dependent variable (accuracy versus response time).

Taken together, these cross-modal findings support the idea that vision, touch, and audition share common object representations. Moreover, young adults and older adults showed similar magnitudes of cross-modal priming, suggesting that not only within-modal priming, but also cross-modal priming is

preserved in normal aging. The findings also support the multiple memory systems proposal (Tulving & Schacter, 1990) and have implications for theories of adult memory and cognitive ageing. While the structural perceptual object system is spared with age, the episodic memory system that relies on the medial-temporal lobe is impaired. In contrast to the age-related decline on a number of cognitive functions, within-modal and cross-modal repetition priming (as a measure of implicit memory) is spared in older adults.

We argue that the different perceptual modalities do not work in isolation. In contrast, they provide complementary and redundant information about objects in the environment, which facilitate recognition accuracy and identification speed (Amedi et al., 2005; Millar, 1994). Multisensory integration is a crucial characteristic of human perception (Fort, Delpuech, Pernier, & Guiard, 2002). Numerous recent studies in intersensory integration and cross-modal associations have shown cross-modal links in information processing between auditory and somatosensory modalities (e.g., Soto-Faraco, Spence, & Kingstone, 2004; Spence, Rawson, & Kingstone, 2000), olfaction and touch (Dematté, Sanabria, Sugeran, & Spence, 2006), olfaction and vision (Dematté, Sanabria & Spence, 2009) or touch and vision (Auvray, Gallace, Tan, & Spence, 2006). This suggests that the information extracted by different sense modalities is combined in certain ways to facilitate perception and action (Zampini, Torresan, Spence, & Murray, 2007).

Electrophysiological studies have further demonstrated the links between the neural processing of auditory and somatosensory information (e.g., Eimer, Val Valzen, & Driver, 2002; Murray et al., 2005) and that vision can modulate somatosensory cortical processing (Taylor-Clarke, Kennet, & Haggard, 2002). Moreover, single unit recording studies have shown that neurons in the monkey's anterior parietal cortex respond to auditory and visual stimuli, provided that these stimuli in other modalities are associated with tactile information needed for performing the task. So, it has been inferred that these cells, in addition to facilitate or priming the task, form

part of a network that maintains the tactile stimulus within the focus of attention during the delay (e.g., Zhou & Fuster, 2000, 2004). Repetitive transcranial magnetic stimulation (rTMS) has also shown the importance of the anterior intraparietal sulcus (IPS) in the integration of information from tactile and visual object manipulation (Buelte et al., 2008). Moreover, a recent EEG study suggests that auditory-visual binding might be achieved by transient synchronization of neurons from different modalities in the Gamma-frequency (N30 Hz) range supporting the hypothesis that oscillatory activity in the Gamma band reflects cross-modal semantic-matching processes in multisensory convergence sites as left middle temporal gyrus, an area related to the processing of both complex auditory stimuli and multisensory processing (Schneider, Debener, Oostenveld, & Engel, 2008)

Interestingly, the posterior lateral temporal cortex is considered today as a multisensory region that is activated under multisensory processing (see Beauchamp, Lee, Argall, & Martin, 2004; Wallace, Ramachandran, & Stein 2004). Regions in the ventral occipitotemporal cortex (VOT) located ventral to lateral occipital cortex (LOC) process abstract stimulus properties such as the object category that is accessible via touch and vision (three-dimensional object structure). Within superior temporal sulcus, a patchy organization of regions is activated in response to auditory, visual and multisensory stimuli and it suggests that it is an anatomical substrate for multisensory integration (Beauchamp, 2005). Recent fMRI results suggest that higher-order temporal and occipital areas respond to coincident sounds and pictures regardless of their semantic relationship; whereas, the right claustrum/insula region is differentially activated in association with multisensory integration of conceptually related common objects (Naghavi, Eriksson, Larsson, & Nyberg, 2007). Furthermore, repeated versus nonrepeated environmental sounds (Bergerbest, Ghahremani, & Gabrieli, 2004) produced faster responses (behavioural repetition priming) as well as neural priming (reduced activation in the right

superior temporal gyrus, bilateral superior temporal sulci, and right inferior prefrontal cortex). Behavioral priming correlated positively with reduced activations, not only in modality specific auditory cortex but also in multimodal areas.

The cross-modal findings for objects presented to vision and touch replicated previous results with young adults (Reales & Ballesteros, 1999) and extended previous visual (Ballesteros et al., 2007) and haptic findings (Ballesteros & Reales, 2004) with elderly participants to cross-modal priming. They also extend cross-modal priming to the auditory modality, the third modality involved in object recognition. It could be argued that the effects might be due to lexical, semantic or strategic processes as participants named the stimuli. Note, however, that Reales and Ballesteros (1999; Exp.1) manipulated level of encoding at study and did not find any effect of this variable in within-modal or in cross-modal priming. The lexical-semantic explanation conflicts also with results in the verbal domain showing that cross-modal priming in normal adults presents no advantage of deep over shallow processing when the shallow encoding task requires lexical access (Richardson-Klavehn, & Gardiner, 1996). Moreover, another experiment (Reales & Ballesteros, 1999; see Footnote 2) did not support the lexical hypothesis. In that study, participants named familiar objects presented haptically followed by incidental speeded word-fragment completion. Even though participants at study directed their attention to the stimuli as lexical units, priming was not found when they were presented with the corresponding fragmented words. To completely rule out the lexical effect, additional studies are worth pursuing in which words would be included to see if presenting words produces the same cross-modal results.

In summary, a number of studies have reported repetition facilitation within and between vision, touch and audition. Moreover, cross-modal as well as within-modal facilitation is preserved in older adults supporting the idea that these perceptual modalities are well adapted to deal with 3D objects (Reales & Ballesteros, 1999). Vision and touch are finely tuned

to extract precise information about an object's shape and structure. The findings extend the structural hypothesis to audition by showing that cross-modal repetition priming was similar to within-modal repetition priming.

Conclusions and Future Directions

The results reviewed here suggest that repetition priming for objects presented to vision or touch, and the sounds produced by them, is not modality specific. Stimuli presented to a modality at study were identified faster and more accurately when the same stimuli were presented later at test to the other modality compared to new stimuli. These results from our laboratory as well as results from other studies reviewed here suggest that cross-modal repetition priming is not modality specific and support the structural description hypothesis not only in younger adults but also in older adults. Older adults, although slower and more error prone than younger adults, did not differ in the magnitude of cross-modal priming for objects presented to three different perceptual modalities: vision, touch and audition. Visual, tactile, and auditory object information activate cortical association areas that were previously believed to be modality specific. As noted earlier, there is an increased emphasis on the relationship between the senses, and a very interesting blurring of the lines between psychology and neuroscience (Heller & Ballesteros, 2006). The multimodal stimulus set may be instrumental for future research addressing on how multiple senses interact in concert to provide complex functions such as perception and memory.

There remains a lot to learn about cross-modal priming and aging. Further research is needed to clarify whether the observed cross-modal priming is preserved in the very old age and during the first stages of the Alzheimer's disease using different sensory modalities in well designed experimental studies that combine behavioral and fMRI data using familiar as well as unfamiliar stimuli (Henson, 2003; James et al., 2002; van Turenout, Ellmore, & Martin, 2000). Results from these studies might help to clarifying the increase and decrease brain activation

findings reported in the imaging repetition priming literature. Another important avenue in the field of memory and cognitive training would be the inclusion of repetition priming tasks in programs directed to improving memory functions in the elderly.

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保留的跨通道启动与老化：对于近期观点的总结

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摘 要 通道内重复启动的研究提示老年人内隐记忆未受损，这不只体现在视觉通道上还包括其他感觉通道(例如触觉、听觉和嗅觉)。然而很少有研究考察启动任务是否具有通道特异性。在以年轻人为被试的研究中发现跨通道迁移(视觉到触觉和触觉到视觉)和通道内迁移(视觉到视觉, 触觉到触觉)具有相似性。一项最近的研究进一步探索老年人在跨通道启动任务上是否受损。结果显示视觉和触觉间的跨通道启动在年轻被试和老年被试上都是保留的且具有对称性。并且, 对于自然声响、图片的通道内和跨通道启动任务随着老化发展仍旧保留。这些行为结果和其它最近神经科学结果显示跨通道启动发生于枕叶后纹状皮层区, 而这一区域在老年人中未损坏。这一领域未来的研究方向包括利用不同知觉通道间、利用熟悉的和新异的刺激并结合行为的和脑成像的方法, 通过设计完善的跨通道启动来研究正常老人与阿尔兹海默病人, 还包括将设计得完善的启动任务包括在用于改善老年人记忆功能的项目中。

关键词 老化; 跨通道启动; 外显记忆; 内隐记忆; 侧枕叶(LOC); 通道内启动

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