Practice effects in healthy older adults: Implications for treatment-induced neuroplasticity in Aphasia

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ABSTRACT

In treating aphasic individuals with anomia, practice naming pictures leads to better performance as measured by accuracy and reaction time. The neurocognitive mechanisms supporting such improvements remain elusive, in part due to gaps in understanding the influence of practice on neurotypical older adults. The current study investigated the influence of practice naming one set of low frequency pictures of actions and objects in 18 healthy older adults, ten of whom were tested twice approximately one month apart. Both item and task practice effects were observed in improved accuracy and response latencies naming pictures in the scanner. This same facilitation effect was observed in neuroimaging results. For example, a significant main effect of practice was observed in bilateral precuneus and left inferior parietal lobule, characterized by greater activity for naming practiced vs. unpracticed pictures. This difference was significantly diminished in subsequent runs after exposure to unpracticed pictures. Whole brain analyses across two sessions showed that practice effects were specific to practice, i.e., there were not similar observable changes in contrasts examining actions vs. objects over time. These findings have important implications for understanding treatment-induced neuroplasticity in anomia treatment.

1. Introduction

Many treatment programs aimed at strengthening word retrieval in aphasia rely on the widely believed notion that ‘practice makes perfect’. Psychological validity for this truism regarding the repeated performance of some sequence of actions is usually found in more accurate performance and faster reaction times. Although there is an extensive literature investigating the neurobiology of memory, learning, and priming over the last two decades, most studies of practice effects have focused on motor learning or other visuomotor or visuospatial tasks (Karni et al., 1995; Poldrack et al., 1998; Sakai et al., 1998; Seidler et al., 2002). While there may be some generalizability from these studies to examining the effects of practice on other cognitive functions, there is also reason to believe that task domain influences neuroplasticity. In their extensive review of the neuroimaging literature on practice effects, Kelly and Garavan (2005) note that task domain may be one of the main contributing factors to the incongruous results that have included patterns of increased activity, decreased activity, and spatial redistribution of activity. These authors suggest that the mechanisms of neural plasticity are likely to differ in sensorimotor compared to more cognitive domains, with connectivity changes seen in primary cortex or between primary sensory and motor cortex in the former, as contrasted with connectivity changes among more spatially distributed brain regions in the latter.

Only a small fraction of the literature has examined practice in the context of language tasks. This is surprising given that Raichle and colleagues demonstrated over two decades ago changes in activity patterns in healthy controls after less than 15 min of verb generation practice in which participants passively viewed, repeated, and generated appropriate verbs for one experimental set of nouns. The authors noted a change in cognitive strategy with the practiced nouns. Whereas novel nouns require selection of a verb from an array of appropriate verbs, practiced verbs elicited stereotyped responses in most participants, thus effectively changing the task from one of pure verb generation to that of a paired-associates task in which semantic processing and response selection were minimal. Given a change in cognitive processes underlying the task between practiced and novel nouns, it is not surprising that functional reorganization was observed. As Raichle et al. (1994) suggested, what participants learned via practice was “…not the ability to say the word per se, but rather the selection of a specific word on the basis of stimulus response associations” (p. 19).

Response selection during picture naming is more constrained than
in verb generation where nouns may elicit many different verbs related to an object's function (what it does), alone or in relation to another object or agent (what you do with it, or to it), etc. Thus practice in the context of picture naming, where response selection is more limited, seems less likely to evoke a change in cognitive processing in healthy adults, and thus might be less likely to involve experience-dependent functional reorganization. As Kelly and Garavan (2005) suggest, functional reorganization – as opposed to redistribution or change in level of activity – is most likely to occur following practice-dependent changes in cognitive processes. Some degree of functional reorganization is likely taking place following anomia treatment, where practice-related changes in functional activity during picture naming have been observed and assumed to present evidence of treatment-induced neuroplasticity in aphasic patients (see e.g., Meinzer and Breitenstein, 2008). Still, given the variability observed in the nascent study of treatment-induced neuroplasticity in aphasia, it is surprising that there have not been more investigations into practice effects of repeated naming in healthy, non-brain damaged individuals.

Some repetition priming studies have demonstrated changes in performance and neural activity following repeated exposure to naming targets (van Turennout et al., 2000, 2003). For example, van Turennout et al. (2000) showed long lasting, differing effects in time course and regional specificity in eight participants who silently named pictures following brief exposure to one set of pictures. While the authors referred to the changes as ‘practice-induced’, neuroplasticity following brief exposure may not offer the best comparison to treatment-induced neuroplasticity following longer periods of practice or training. In a recent study of naming practice, both task-specific and item-specific improvements in performance and correlated BOLD signal changes were observed in a healthy group of young adult volunteers after repeated exposure to a picture naming task (Basso et al., 2013). While their study provides a more ecologically valid comparison to treatment-induced neuroplasticity following naming practice, the participants were all young adults, which might not reflect the same mechanisms of neuroplasticity observed in healthy older adults.

In a recent fMRI study of the influence of repeated picture naming in healthy older adults, MacDonald et al. (2015) investigated the effects of short-term (minutes) vs. long-term (days) between repeated exposure to one set of pictures compared to unprimed pictures. They found different repetition suppression effects in distinct regions of left inferior frontal and bilateral inferior temporal gyri, depending on the time course of exposure to pictures. In addition to an exploratory whole brain analysis, they examined mean percent signal change in seven spherical left-hemisphere regions of interest (ROIs) selected from language-related fMRI meta-analyses and their own studies of semantic and auditory repetition facilitation tasks. ROI analysis showed significant differences in activity in distinct regions in inferior frontal cortex, depending on the time course of practice, which they suggest supports different neuro-cognitive mechanisms underlying short-term vs. long-term facilitation effects.

In the current investigation, we expand on the topic of practice effects in healthy older adults by examining changes in brain activity in 18 older participants on a picture naming protocol following repeated exposure to one set of pictures just prior to the scan session. Ten of these participants were tested twice approximately four weeks apart, which is the timeframe for fMRI testing pre-/post- intensive anomia treatment in our aphasia treatment studies (Kurland et al., 2016). In addition, we expand on the ROIs investigated by MacDonald et al. (2015), for example to include right hemisphere (RH) homologues, given the known hemispheric asymmetry reduction in older individuals (HAROLD; Cabeza, 2002). We also include an ROI in posterior inferior temporal cortex that was suggested to be a “vital” LH region for anomia recovery (Fridriksson, 2010).

Another unique aspect of the current study regards the stimuli. Whereas prior studies limited naming to pictures of objects, half of the stimuli in the current study were objects, half actions. Thus stimuli elicit different grammatical classes (nouns vs. verbs), which are known to engage partially distinct neural systems, and speakers tend to name actions more slowly than objects (Vigliocco et al., 2011). In addition, actions have been shown to evoke stronger activation than objects in bilateral posterior middle temporal cortex, left temporo-parietal junction, and left frontal cortex, a network previously identified in representation and processing of action knowledge (Liljeström et al., 2008). Apart from the advantages of being able to test aphasic participants for dissociations in action/object naming, we utilized the difference in action/object neural processing in the current study to test the specificity of the practice effect.

The current study aimed to address three experimental questions regarding item and task specificity on repeated practice in healthy older adults: 1) Is an item practice effect robust in healthy older participants following brief practice naming one set of pictures? We expected to see differences in regional activity between two sets of low frequency pictures, after participants repeatedly practiced naming one set just prior to the first MRI session; 2) What are the effects of time and additional practice (between runs and between sessions) on picture naming? Based on the findings of Raichle and others, additional practice was expected to continue to influence task-specific activity for naming practiced vs. unpracticed pictures; and 3) How specific are practice-induced changes over time? Based on our pilot studies, participants were expected to demonstrate high intra-subject reliability with respect to naming the full set of pictures, i.e., without respect to practice condition. Thus, for example, changes observed across sessions for naming practiced vs. unpracticed pictures would not be observed for naming actions vs. objects. It was hoped that a practice effect on one set of pictures might shed new light on practice-related changes observed in studies of treatment-induced neuroplasticity in aphasia.

2. Material and methods

2.1. Participants

Participants were recruited from a local stroke support group, including healthy spouses, siblings, and friends of stroke survivors. The Institutional Review Board of the University of Massachusetts Amherst approved the study, and signed informed consent was obtained. The eighteen participants (7 male) were 48–76 years old. All were first language English speakers and completed at least high school (highest grade: 12–22). None had a history of neurological disease. Scores on the Mini Mental State Examination (MMSE; Folstein et al., 1975) were all within normal limits (range: 28–30). All but one were strongly right-handed according to self-report on the Edinburgh Handedness Inventory (Oldfield, 1971). Demographic data are reported in Table 1.

2.2. Stimuli

Stimuli consisted of blocks of black and white line drawings of common objects and picturable actions. Three sets of 40 pictures (half objects; half actions) were selected from a subset (n = 218 objects) of the Snodgrass and Vanderwart (1980) normed set of objects and from An Object and Action Naming Battery (Masterson and Druks, 1998; n = 100 actions). One set was made up of images of high frequency words (e.g., “hand”, “house”, “walk”, “sit”, etc.). The other two sets were comprised from low frequency words that were matched on psycholinguistic variables known to affect word retrieval (word length, number of syllables, word frequency, age of acquisition, concept familiarity, etc.). One of the matched sets of low frequency pictures was randomly assigned to be practiced (PR), while the other set was not practiced (UNPR).

2.3. MRI protocol

MRI data were acquired in two sessions, either once (n = 8) or...
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