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Research report

Talker-specific learning in amnesia: Insight into mechanisms of adaptive speech perception

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ABSTRACT

A hallmark of human speech perception is the ability to comprehend speech quickly and effortlessly despite enormous variability across talkers. However, current theories of speech perception do not make specific claims about the memory mechanisms involved in this process. To examine whether declarative memory is necessary for talker-specific learning, we tested the ability of amnesic patients with severe declarative memory deficits to learn and distinguish the accents of two unfamiliar talkers by monitoring their eye-gaze as they followed spoken instructions. Analyses of the time-course of eye fixations showed that amnesic patients rapidly learned to distinguish these accents and tailored perceptual processes to the voice of each talker. These results demonstrate that declarative memory is not necessary for this ability and points to the involvement of non-declarative memory mechanisms. These results are consistent with findings that other social and accommodative behaviors are preserved in amnesia and contribute to our understanding of the interactions of multiple memory systems in the use and understanding of spoken language.

1. Introduction

Human speech perception is remarkable in that it extracts meaning from a highly variable signal with speed and precision that defy even the most advanced speech recognition software. The variability inherent in speech is a classic example of a many-to-many mapping problem: Depending on the talker and context, different acoustic signals can map onto the same linguistic category; likewise, a particular acoustic signal can map onto different linguistic categories (Liberman, Cooper, Shankweiler, & Studdert-Kennedy, 1967; Peterson & Barney, 1952). For example, native English speakers would consider the vowels in *tab* and *tack* to fall under the same linguistic category (e.g., the */æ/* sound), but when spoken, these vowels have different acoustic signatures because they precede different consonants. Conversely, a particular acoustic pattern might be categorized as either an *a* or an *eh* sound, depending on the speaker's identity and the way he or she pronounces these vowels. In principle, this many-to-many mapping should render the speech perception process

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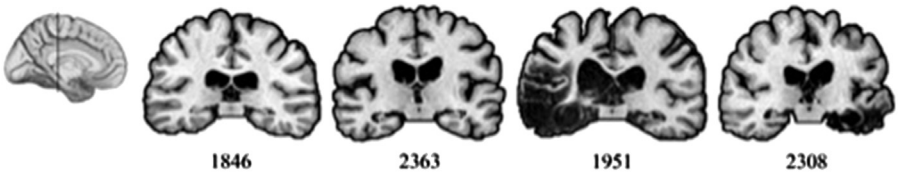

Fig. 1 – Magnetic resonance scans of amnesic patients. Images are coronal slices through the midportion of the hippocampus from T1-weighed scans. Volume changes can be noted in the region of the hippocampus bilaterally.

impossible *unless* listeners learn how sound-to-meaning mappings change across talkers and contexts. The fact that human listeners rapidly adapt to new talkers suggests we do indeed learn these mappings. The key unanswered question is: *How?*

Although multiple theories of talker adaptation during speech perception have been proposed, their relationship to various memory systems has yet to be fully explored. Specifically, the respective roles of the declarative and non-declarative memory systems are not specified in these theories. One prominent theory of speech perception is the episodic theory, which proposes that every instance of speech is stored as a separate memory trace. These traces provide a record of how a particular acoustic signal was used by a particular talker in a particular context. When a new instance of speech is heard, contextually similar traces are activated proportionate to their similarity to the new sound, guiding comprehension of the unfolding speech sounds (Goldinger, 1998; Goldinger & Azuma, 2003). Although the name of this theory – and its proposal that "episodic memory traces" (Goldinger, 1996, 1998) of speech events are created– may lead one to believe that episodic memory, a form of declarative memory for autobiographical events and experiences (e.g., time-, place-, and person-specific information), underlies the storage of talker-specific information, this is not specified. One could imagine a version of this theory in which low-level, non-declarative associations accumulated with each new episode support this ability.

A second class of theories, broadly referred to as normalization theories, proposes that listeners compute talker-specific mappings or algorithms that support the ability to match the variable input received from multiple talkers onto invariant mental representations of phonological categories (Magnuson & Nusbaum, 2007). This class of theories posits reliance upon learned mappings or routines, which, to a first approximation, implicates procedural, non-declarative memory as the underlying mechanism. However, no specific memory mechanism has been proposed, and a version of these theories in which declarative memory subserves the learning of these mappings could also be imagined.

Currently, there is no direct evidence linking the learning of talker-specific mappings to either the declarative or non-declarative memory system, and evidence from healthy individuals is equivocal, as both systems may support learning. Here, we provide a test of the role of declarative memory by examining speech perception in amnesic patients who have severe declarative memory impairment following medial temporal lobe damage that prevents them from learning new episodic information while leaving non-declarative forms of memory intact.

In the present study, five amnesic and five healthy, demographically-matched comparison participants heard the speech of two unfamiliar talkers with different regional accents of American English. Crucially, the male talker pronounced words like *tack* and *tag* with different vowels, whereas the female talker used the same vowel. After a brief exposure to the two talkers' voices, each participant followed a series of instructions such as *Click on tack* while viewing a display containing images of a tack and a same-onset competitor word, such as tag (Dahan, Drucker, & Scarborough, 2008; Trude & Brown-Schmidt, 2012). We assessed participants' ability to distinguish between the initial sounds of the words *tack* and *tag* by monitoring eye-gazes to the corresponding images in the display. Previous research using this paradigm with neurologically intact, college-age participants has shown that listeners are able to learn and apply their knowledge about the male talker's accent and identify the target word more easily when listening to the male talker than the female talker due to the difference in the target and competitor words' vowels (Trude & Brown-Schmidt, 2012). Thus, successful learning predicts more looks to the target on male-talker trials, compared to female-talker trials. If declarative memory is necessary for how human speech perception adapts to variability across talkers, amnesic patients should fail to learn the male talker's accent, and therefore should perform equally with both talkers. However, if declarative memory is *not* necessary for this adaptation process, amnesic participants should perform like healthy participants.

2. Methods

2.1. Participants

Participants included five amnesic participants (1 female; mean age = 51.8) with bilateral hippocampal damage (Fig. 1)[1] due to anoxia ($n = 3$), resulting in damage that was hippocampal circumscribed, or herpes simplex encephalitis ($n = 2$), resulting in more extensive bilateral medial temporal lobe damage affecting hippocampus, amygdala, and surrounding cortices (Table 1). Neuropsychological testing confirmed a severe and selective declarative memory impairment (mean Wechsler memory scale – WMS = III general memory index – GMI = 61.4) in the context of preserved intelligence

[1] Patient 2563 wears a pacemaker and was unable to undergo the structural magnetic resonance imaging examination. Anatomical analyses from a computerized tomography scan revealed damage only to the hippocampal region bilaterally.