Brain and Cognition 87 (2014) 122–133

Contents lists available at ScienceDirect

Brain and Cognition

journal homepage: www.elsevier.com/locate/b&c

Expert athletes activate somatosensory and motor planning regions of the brain when passively listening to familiar sports sounds

Elizabeth A. Woods [a,*], Arturo E. Hernandez [a], Victoria E. Wagner [a], Sian L. Beilock [b]

[a] The University of Houston, Department of Psychology, 126 Heyne Building, Houston, TX 77204, USA
[b] The University of Chicago, Department of Psychology, 5848 South University Avenue, Chicago, IL 60637, USA

ARTICLE INFO

Article history:
Accepted 16 March 2014
Available online 14 April 2014

Keywords:
Action perception
Athlete expertise
Auditory processing
Embodied cognition
Motor planning
Passive listening

ABSTRACT

The present functional magnetic resonance imaging study examined the neural response to familiar and unfamiliar, sport and non-sport environmental sounds in expert and novice athletes. Results revealed differential neural responses dependent on sports expertise. Experts had greater neural activation than novices in focal sensorimotor areas such as the supplementary motor area, and pre- and postcentral gyri. Novices showed greater activation than experts in widespread areas involved in perception (i.e. supramarginal, middle occipital, and calcarine gyri; precuneus; inferior and superior parietal lobules), and motor planning and processing (i.e. inferior frontal, middle frontal, and middle temporal gyri). These between-group neural differences also appeared as an expertise effect within specific conditions. Experts showed greater activation than novices during the sport familiar condition in regions responsible for auditory and motor planning, including the inferior frontal gyrus and the parietal operculum. Novices only showed greater activation than experts in the supramarginal gyrus and pons during the non-sport unfamiliar condition, and in the middle frontal gyrus during the sport unfamiliar condition. These results are consistent with the view that expert athletes are attuned to only the most familiar, highly relevant sounds and tune out unfamiliar, irrelevant sounds. Furthermore, these findings that athletes show activation in areas known to be involved in action planning when passively listening to sounds suggests that auditory perception of action can lead to the re-instantiation of neural areas involved in producing these actions, especially if someone has expertise performing the actions.

1. Introduction

When thinking of top athletes in the world, Michael Jordan and Serena Williams quickly come to mind as prototypes for basketball and tennis respectively. But what sets these expert athletes above other athletes who never make it to the professional level? Basketball and tennis are both fast-paced, interactive sports that require an athlete to perform a number of perceptual, cognitive, and motor skills in very brief periods of time. In order to succeed in these sports, an athlete must locate and identify the relevant perceptual cues, make a decision about what these cues mean, and plan and execute the appropriate motor response accordingly. Oftentimes all of this happens so quickly that movements must be initiated with very limited perceptual information. Research has shown that this ability to quickly and accurately process domain-specific information is one of the defining features of expertise; experts are consistently faster and more accurate than novices on a number of perceptual–cognitive paradigms (Hodges, Starkes, & MacMahon, 2006; Mann, Williams, Ward, & Janelle, 2007; Starkes & Ericsson, 2003). Furthermore, this expert advantage in sport may be associated with increased activity in sensory and motor regions of the brain during visual processing tasks (Beilock, Lyons, Mattarella-Micke, Nusbaum, & Small, 2008; Calvo-Merino, Glaser, Grezes, Passingham, & Haggard, 2005; Calvo-Merino, Grezes, Glaser, Passingham, & Haggard, 2006). However, despite widespread global participation in sports and its influence on society, there have been relatively few neuroimaging studies to analyze the expert advantage in sport, especially in the auditory domain.

1.1. Behavioral evidence of an expert advantage in sport

There is considerable behavioral evidence for an expert advantage in sport. This advantage has been observed across numerous sports and a variety of perceptual–cognitive paradigms. Experts tend to perform better than novices on sport-specific attention allocation, object recognition and recall, temporal and spatial occlusion, visual search, anticipation, and decision-making

* Corresponding author. Fax: +1 713 743 8588.
E-mail address: ewoods@uh.edu (E.A. Woods).

http://dx.doi.org/10.1016/j.bandc.2014.03.007
0278-2626/© 2014 Published by Elsevier Inc.

(Abernethy, 1990, 1991; Abernethy, Gill, Parks, & Packer, 2001; Abernethy, Neal, & Koning, 1994; Abernethy & Russell, 1987; Abernethy, Zawi, & Jackson, 2008; Hodges et al., 2006; Jackson, Warren, & Abernethy, 2006; Starkes & Ericsson, 2003; Voss, Kramer, Basak, Prakash, & Roberts, 2010; Williams & Ford, 2008; Williams, Ward, & Smeeton, 2004; Wright, Bishop, Jackson, & Abernethy, 2010). A concrete example of this expert advantage in sport is that tennis experts are able to use early visual cues to anticipate the manner and direction in which the ball will come off the racquet, whereas novices are not (Goulet, Bard, & Fleury, 1989; Overney, Blanke, & Herzog, 2008; Shim, Carlton, Chow, & Chae, 2005; Williams, Ford, Eccles, & Ward, 2011). Although action execution is obviously necessary as well, these perceptual and cognitive skills are at least as important, if not more, for successful athletic performance (Ward, Williams, & Bennett, 2002).

1.2. Neural correlates of auditory and action perception

Given that the mastery of a sport typically involves perceptual and cognitive processing of auditory and visuo-motor cues, it is important to note the patterns of neural activation that sub-serve these processes. Several neuroimaging studies have found that environmental sound recognition activates bilateral brain regions including the IFG,[1] MTG,[2] STG[3] (Binder et al., 2000; Demonet et al., 1992; Dick et al., 2007; Lewis, Brefczynski, Phinney, Janik, & DeYoe, 2005; Lewis et al., 2004; Wright et al., 2010), SMG,[4] and posterior cingulate gyrus (Lewis et al., 2004).

IFG has been implicated in motor planning across a number of domains (Hillis et al., 2004; Iseki, Hanakawa, Shinozaki, Nankaku, & Fukuyama, 2008; Liakakis, Nickel, & Seitz, 2011; Ozdemir, Norton, & Schlaug, 2006; Parks et al., 2011; Tettamanti et al., 2005; Wadsworth & Kana, 2011) and may be involved when listening to action-related sounds (Lahav, Saltzman, & Schlaug, 2007), whereas posterior MTG has previously been associated with the recognition of tools and with high-level visual processing of complex biological motion (Beauchamp, Lee, Haxby, & Martin, 2003; Safford, Hussey, Parasuraman, & Thompson, 2011). In addition, it has been suggested that posterior MTG may be particularly important for processing multimodal information and may embody some type of action knowledge that is recruited for the recognition of familiar environmental sounds (Leech & Saygin, 2011; Murray, Camen, Spierer, & Clarke, 2008). Similarly, the left SMG may play a role in audio-tactile associations that emerge for sounds that are often manipulated by the right hand (Lewis et al., 2004). Embodied theories of cognition have explained a similar phenomenon in linguistic processing by proposing that perceptual and motor regions work together with language areas to enable comprehension and production of complex, meaningful sounds. It may be that environmental sounds have similar sensorimotor demands. In fact, studies have found neural activation specific to action-related sounds in left premotor areas (Galati et al., 2008; Pizzamiglio et al., 2005) as well as temporal areas, including MTG (Galati et al., 2008) and posterior STG (Pizzamiglio et al., 2005). Although STG has been shown to be activated when processing environmental sounds, this region may not be activated as selectively as MTG, and may have more to do with lower-level aspects of sound recognition (Lewis et al., 2005). PCC[5] activation during environmental sound processing may be involved in retrieving information from long term memory to determine if the sound is familiar or not (Lewis et al., 2004). Since several studies have demonstrated that participants exhibit a preference or advantage for familiar sounds compared to unfamiliar sounds (Jacobsen, Schroger, Winkler, & Horvath, 2005), the aforementioned neural regions (IFG, MTG, STG, SMG, PCC) may show differential neural activation for familiar and unfamiliar sounds.

1.3. Neural correlates of expertise

There is strong evidence that training and skill acquisition may cause changes in neural activation, especially in the case of expert skill performance (Hill & Schneider, 2006; Wright, Bishop, Jackson, & Abernethy, 2011). These neural changes as a result of training are particularly clear for primary motor areas in the brain. For instance, expert musicians have enlarged representations of their fingers in the primary motor cortex (Elbert, Pantev, Wienbruch, Rockstroh, & Taub, 1995). There is also evidence that this expertise effect may carry over into the perception of action. Calvo-Merino et al. (2005) found motor expertise effects in bilateral premotor cortex and intraparietal sulcus, right superior parietal lobe, and left posterior superior temporal sulcus for two different types of dancers (ballet and capoeira martial artists) when passively viewing an action being performed by someone else. Interestingly, the neural response differed depending on the viewers' own expertise with executing the specific action; expert dancers had stronger BOLD[6] activation in motor areas of the brain when they observed actions from their own type of dance than when they observed kinematically similar actions in the other type of dance. Similarly, when ballet dancers viewed gender-specific dance moves, greater activation was observed in premotor, parietal, and cerebellar regions when viewing moves with which the observer had personal experience (Calvo-Merino et al., 2006). In short, these studies reveal that there may be expertise effects in action perception, and that these effects may appear as an increased neural response in motor regions of the brain.

Beilock et al. (2008) also found motor expertise effects in a fMRI experiment with three varying levels of hockey expertise: player, fan, and novice. Results revealed a positive correlation between hockey experience and neural activity in left dorsal premotor cortex, a region usually implemented in higher-level action selection and implementation (Haslinger et al., 2002), and a negative correlation between hockey experience and activity in right sensory-motor cortex, a lower level sensory-motor region implicated in the instantiation of movement (Bedard & Sanes, 2009; Mancini et al., 2009). Taken together these results suggest that experts engage in motor preparation in response to the perception of highly familiar stimuli, and that this has to do with their expertise with executing the specific action (Beilock et al., 2008; Calvo-Merino et al., 2005, 2006). However, the majority of these studies focused on athletic expertise in the visual modality. Auditory expertise has not been examined in the domain of sport, but an effect is likely, especially given that auditory expertise effects have been observed in musicians, specifically in premotor regions of the brain (Dick, Lee, Nusbaum, & Price, 2011; Margulis, Mlsna, Uppunda, Parrish, & Wong, 2009; Ohnishi et al., 2001). Given the high relevance of auditory perceptual cues to successful athletic performance, athletic expertise in the auditory domain merits further investigation (Chartrand, Peretz, & Belin, 2008).

1.4. Present study

The purpose of the present fMRI study was to examine whether athletic expertise influenced the neural correlates of passive sound perception. To accomplish this, a 2 (expertise) × 4 (sound type) experimental design was employed. Participants were either

[1] Inferior frontal gyrus.
[2] Middle temporal gyrus.
[3] Superior temporal gyrus.
[4] Supramarginal gyrus.
[5] Posterior cingulate cortex.
[6] Blood–oxygen level dependent.