Available online at www.sciencedirect.com

ScienceDirect

Journal homepage: www.elsevier.com/locate/cortex

Research report

This is your brain on Scrabble: Neural correlates of visual word recognition in competitive Scrabble players as measured during task and resting-state

Andrea B. Protzner [a,b,c,], Ian S. Hargreaves [a,b], James A. Campbell [a], Kaia Myers-Stewart [a], Sophia van Hees [a,b], Bradley G. Goodyear [b,c,d,e,f], Peter Sargious [g,h] and Penny M. Pexman [a,b,c]*

[a] *Department of Psychology, University of Calgary, Calgary, Alberta, Canada*
[b] *Hotchkiss Brain Institute, University of Calgary, Calgary, Alberta, Canada*
[c] *Seaman Family MR Research Centre, University of Calgary, Foothills Medical Centre, Calgary, Alberta, Canada*
[d] *Department of Radiology, University of Calgary, Foothills Medical Centre, Calgary, Alberta, Canada*
[e] *Department of Clinical Neurosciences, University of Calgary, Foothills Medical Centre, Calgary, Alberta, Canada*
[f] *Department of Psychiatry, University of Calgary, Foothills Medical Centre, Calgary, Alberta, Canada*
[g] *Department of Medicine, University of Calgary, Foothills Medical Centre, Calgary, Alberta, Canada*
[h] *Institute for Public Health, University of Calgary, Calgary, Alberta, Canada*

ARTICLE INFO

Article history:
Received 9 September 2014
Reviewed 18 October 2014
Revised 16 December 2014
Accepted 23 March 2015
Action editor Sonja Kotz
Published online 1 April 2015

Keywords:
Expertise
fMRI
Language networks
Lexical processing
Resting-state

ABSTRACT

Competitive Scrabble players devote considerable time to studying words and practicing Scrabble-related skills (e.g., anagramming). This training is associated with extraordinary performance in lexical decision, the standard visual word recognition task (Hargreaves, Pexman, Zdrazilova & Sargious, 2012). In the present study we investigated the neural consequences of this lexical expertise. Using both event-related and resting-state fMRI, we compared brain activity and connectivity in 12 competitive Scrabble experts with 12 matched non-expert controls. Results showed that when engaged in the lexical decision task (LDT), Scrabble experts made use of brain regions not generally associated with meaning retrieval in visual word recognition, but rather those associated with working memory and visual perception. The analysis of resting-state data also showed group differences, such that a different network of brain regions was associated with higher levels of Scrabble-related skill in experts than in controls.

Abbreviations: BA, Brodmann's area; COWAT, Controlled Oral Word Association Test; LDT, lexical decision task; LIFG, left inferior frontal gyrus; LV, latent variable; NAART, North American Adult Reading Test; NASPA, North American Scrabble Players Association; PLS, partial least squares analysis; RART, Revised Author Recognition Test; WAIS, Weschler Adult Intelligence Scale.

* *Corresponding author.* Department of Psychology, University of Calgary, 2500 University Drive NW, Calgary, T2N 1N4, Alberta, Canada.
E-mail addresses: protzner@ucalgary.ca (A.B. Protzner), ishargre@ucalgary.ca (I.S. Hargreaves), jacyippee@yahoo.com (J.A. Campbell), kmyersstewart@gmail.com (K. Myers-Stewart), goodyear@ucalgary.ca (B.G. Goodyear), Peter.Sargious@albertahealthservices.ca (P. Sargious), pexman@ucalgary.ca (P.M. Pexman).
http://dx.doi.org/10.1016/j.cortex.2015.03.015

A large body of research is dedicated to providing a theory for the surprising observation that very high levels of achievement within a domain tend to be domain-specific, and not based upon the general superiority of experts (Chase & Simon, 1973). Though debate continues as to the relative role played by innate factors and dedicated practice in the development of expert performance (Ericsson, 2014; Grabner, 2014; Hambrick et al., 2014), there is agreement that very high levels of achievement are supported by the emergence of unique knowledge structures. Drawing largely from studies contrasting chess experts and non-experts, these unique knowledge structures can be framed in terms of strategic or cognitive differences (e.g., quick perception of board patterns, automatic generation of ‘next move’, etc.) that set experts apart from non-experts (Chase & Simon, 1973; Ferrari, Didierjean, & Marmeche, 2008). The emergence of these knowledge structures has also been associated with changes in the neural substrates that support chess expert versus non-expert performance (Grabner, Neubauer, & Stern, 2006).

Another approach to the study of expertise eschews direct comparisons between experts and non-experts in favor of an approach that tracks the emergence of domain-specific ability though extensive training. These studies focus mostly on training in the domains of perception, attention, and working memory (and not chess), and show with functional magnetic resonance imaging (fMRI) that domain-specific training can result in both reductions *and* increases in activation (e.g., Basso et al., 2013; Olesen, Westerberg, & Klingberg, 2004). For example, in a study by Olesen et al. (2004), working memory training led to increased activity in areas associated with working memory and selective attention (lateral frontal and parietal cortices), and simultaneous decreases in areas associated with task effort (anterior cingulate cortex). The key finding, as summarized by Jonides (2004), is that after training, the neural substrates that support performance remain unchanged, but show different levels of activation (increases or decreases). This stands in contrast to studies comparing experts to non-experts, which reveal that experts (though relying on similar networks as controls) tend to recruit additional areas when solving domain-specific tasks (e.g., Gauthier, Skudlarski, Gore, & Anderson, 2000). In a review of numerous studies, Guida and colleagues argued that these two seemingly contradictory findings actually represent two stages in the development of expertise (Guida, Gobet, Tardieu, & Nicolas, 2012). As learners gain experience in a domain, increasing efficiency can lead to increases or decreases in activation; but as learners become experts, new knowledge structures begin to emerge and are supported by functional reorganization.

Numerous lines of evidence converge on the idea that the emergence of unique knowledge structures relies on a corresponding change in the functional architecture that underlies behavior. Our ability to read words, for instance, has been tied to the reshaping of a network of regions that are normally recruited in visual pattern recognition (Behrmann & Plaut, 2013; Dehaene et al. 2010). Dehaene and colleagues used fMRI to compare cortical activation in illiterate (−school, −literacy), formerly-illiterate (−school, +literacy) and literate adults (+school, +literacy). They concluded that literacy not only changes language networks (involving networks that are normally associated with the processing of spoken language) but also changes the organization of the visual cortex (specifically, the so-called Visual Word Form Area develops in the fusiform gyrus), and reinforces white matter (WM) tracts that are associated with left temporo-parietal language networks (i.e., the arcuate fasciculus; Thiebaut de Schotten, Cohen, Amemiya, Braga, & Dehaene, 2012).

Reading is a multidimensional skill that can be framed as the dynamic construction of information involving shape (i.e., orthography), sound (i.e., phonology) and meaning (i.e., semantics; Seidenberg & McClelland, 1989). Interestingly, the relative contribution to reading made by any of these dimensions varies as a function of task demands (Balota, Paul, & Spieler, 1999), the information elicited by the stimulus (e.g., words vary in terms of the amount of semantic information they evoke; Yap, Pexman, Wellsby, Hargreaves, & Huff, 2012), and even the relative availability of all three types of information over time (Holcomb & Grainger, 2006). Recent research suggests that visual word recognition also is shaped by our experience using written words for different purposes. For example, competitive Scrabble players have extraordinary word recognition experience in that they dedicate vast amounts of time to studying word lists to improve their game performance (Halpern & Wai, 2007; Hargreaves, Pexman, Zdrazilova, & Sargious, 2012; Tuffiash, Roring, & Ericsson, 2007).

Scrabble is a popular board game in which two players alternate strategically forming words out of seven randomly drawn lettered tiles. Tiles are placed within squares on a standard 15 × 15 square game board. After the first word has been played, all subsequent words must attach to at least one tile already played, and form a word when read left to right or top to bottom. If one's opponent believes that a newly created word would not be found in a designated dictionary, he or she may challenge the play, and if correct, all tiles played on that turn are returned to the offending player and no points are awarded. Conversely, if a challenged word is acceptable, the player issuing the challenge may lose his or her turn. As such, word recognition is equally important in responding to an opponent's play as in making one's own. The purpose of the game is to maximize your cumulative score, as compared with your opponent's, by forming multiple words, taking advantage of premium squares, or securing a bonus for playing all seven tiles. Recent research suggests that the degree of Scrabble expertise (as captured through an official rating system) can be attributed to time spent in practice and not to other factors, such as working memory or perceptual processing (Tuffiash et al., 2007). Hargreaves et al. (2012) demonstrated that this extended, deliberate practice is associated with exceptional performance in the standard word recognition task, the lexical decision task (LDT; i.e., “*is it a word?*”). Specifically, Scrabble experts are faster than non-experts in making word/nonword decisions, especially for vertically presented words, and show a decreased reliance on word meaning. Accessing word meaning is viewed as a reliable cue that a stimulus is a word, and the presence of meaning is thought to facilitate responding in the LDT (Pexman, Lupker, & Hino, 2002). Scrabble experts show less of a reliance on meaning, which is congruent with anecdotal reports suggesting that many Scrabble players do not learn the meanings of the words they study (Fatsis, 2002), and that experts were able to judge