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Auditory temporal processing, reading, and phonological awareness among aging adults

Michal Ronen[a], Adi Lifshitz-Ben-Basat[b], Riki Taitelbaum-Swead[b], Leah Fostick[b,*]

[a] Department of Psychology, Ariel University, Israel
[b] Department of Communication Disorders, Ariel University, Israel

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ABSTRACT

Auditory temporal processing (ATP) has been related in the literature to both speech perception as well as reading and phonological awareness. In aging adults, it is known to be related to difficulties in speech perception. In the present study, we aimed to test whether an age-related deficit in ATP would also be accompanied by poor reading and phonological awareness. Thirty-eight aging adults were compared to 55 readers with dyslexia and 42 young normal readers on temporal order judgment (TOJ), speech perception, reading, and phonological awareness tests. Aging adults had longer TOJ thresholds than young normal readers, but shorter than readers with dyslexia; however, they had lower speech perception accuracy than both groups. Phonological awareness of the aging adults was better than readers with dyslexia, but poorer than young normal readers, although their reading accuracy was similar to that of the young controls. This is the first report on poor phonological awareness among aging adults. Suprisingly, it was not accompanied by difficulties in reading ability, and might instead be related to aging adults' difficulties in speech perception. This newly discovered relationship between ATP and phonological awareness among aging adults appears to extend the existing understanding of this relationship, and suggests it should be explored in other groups with ATP deficits.

1. Introduction

Auditory temporal processing (ATP) reflects the individual's ability to correctly perceive brief auditory stimuli, presented rapidly. It is important in daily life for functions that depend on perceiving temporal information presented briefly, such as speech, music, and sound localization. ATP is studied extensively using different tasks, including gap detection (e.g., Fostick & Babkoff, 2013a; Fostick, Bar-El, & Ram-Tsur, 2012a; Harris, Eckert, Ahlstrom, & Dubno, 2010; Palmer & Musiek, 2014), duration discrimination (e.g., Kumar, 2011; Nowak et al., 2016), and temporal order judgment (the ability to perceive the order of the tone presented, reflecting the participants' temporal resolution necessary for perceiving temporal information) (Fink, Churan, & Wittmann, 2005; Fink, Ulbrich, Churan, & Wittmann, 2006; Fostick, 2017; Fostick et al., 2012a; Fostick & Babkoff, 2013a, 2013b, 2017; Fostick, Babkoff, & Zukerman, 2014; Fostick, Bar-El, & Ram-Tsur, 2012b; Fostick & Revah, 2018; Reed, 1989; Szymaszek, Sereda, Pöppel, & Szelag, 2009; Szymaszek, Szelag, & Sliwowska, 2006; Tallal, 1980; Wittmann & Szelag, 2003). Studies of ATP usually test the human capacity for temporal perception (Babkoff & Fostick, 2013; Fink et al., 2006; Fostick & Babkoff, 2013a, 2013b, 2017; Wittmann & Szelag, 2003), and focus on different subpopulations, such as aging adults (Babkoff & Fostick, 2017; Fink et al., 2005; Fostick & Babkoff, 2013a; Schneider, Daneman, & Pichora-Fuller, 2002; Schneider & Pichora-Fuller, 2001; Schneider, Speranza, & Pichora-Fuller, 1998; Szymaszek et al., 2009), readers with dyslexia (Ben-Artzi, Fostick, & Babkoff, 2005; Fostick et al., 2012a, 2012b; Fostick, Babkoff, & Zukerman, 2014; Fostick, Eshcoli, Shtibelman, Nechemya, & Levi, 2014; Reed, 1989; Tallal, 1980), students with attention deficit hyperactivity disorder (ADHD) (Fostick, 2017), sleep deprived young adults (Babkoff, Zukerman, Fostick, & Ben-Artzi, 2005; Fostick, Eshcoli, et al., 2014), aphasic patients (Fink et al., 2005; von Steinbuchel, Wittmann, Strasburger, & Szelag, 1999; Wittmann & Szelag, 2003), and those on the autism spectrum (de Boer-Schellekens, Eussen, & Vroomen, 2013; Kwakye, Foss-Feig, Cascio, Stone, & Wallace, 2011). For most of these subpopulations, ATP is considered an addition to their primary deficit. However, aging adults and readers with dyslexia are theorized to have an ATP deficit as the origin of their linguistic difficulty, and this has been studied extensively.

Aging adults (usually defined as over 60 years of age) are a population that often encounters difficulties in both retrieving and perceiving words. They show a decrease of 2% per decade in the accuracy

* Corresponding author at: Department of Communication Disorders, Ariel University, Ariel, Israel.
E-mail address: leah.fostick@ariel.ac.il (L. Fostick).

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of word retrieval, with a slight acceleration at advanced decades of age, such as above age 80 (Borod, Goodglass, & Kaplan, 1980; Welch, Doineau, Johnson, & King, 1996). Difficulties in understanding spoken speech is a common complaint among aging adults, especially when the speaker talks fast, there is background noise, or there are multiple speakers (e.g., Ben-David et al., 2011; Fostick, Ben-Artzi, & Babkoff, 2013; Heinrich et al., 2016; Heinrich, Henshaw, & Ferguson, 2015; Taitelbaum-Swead & Fostick, 2016a). One of the suggested explanations for this difficulty in the perception of spoken language is an age-related decline in ATP. The rationale underlying this explanation is that the appropriate perception of speech cues relies on the ability to correctly perceive brief sounds. A difficulty in perceiving brief sounds interferes with the ability to process rapid speech and to properly differentiate target speech from among background noise (Ben-Artzi, Babkoff, & Fostick, 2011; Füllgrabe, Moore, & Stone, 2015; Humes, Busey, Craig, & Kewley-Port, 2013; Ostroff, McDonald, Schneider, & Alain, 2003; Schneider et al., 2002; Schneider, Daneman, & Murphy, 2005; Schneider & Pichora-Fuller, 2001). Indeed, studies have shown that aging adults perform poorer than young adults in both speech perception and ATP tests (Anderson, Parbery-Clark, White-Schwoch, Drehobl, & Kraus, 2013; Ezzatian, Li, Pichora-Fuller, & Schneider, 2015; Fitzgibbons & Gordon-Salant, 2010; Fostick et al., 2013; Fostick & Babkoff, 2013a, 2017; Fostick, Eshcoli, et al., 2014; Gordon-Salant, 2005; Kraus & Anderson, 2014; Schneider et al., 1998; Schneider et al., 2002; Schneider & Pichora-Fuller, 2001). Aging adults' poor ATP performance is reflected in longer ATP thresholds, such as longer inter-stimulus intervals, longer gaps, and larger differences between the duration of two tones. Studies have also demonstrated positive correlations of 0.3–0.6 between age and ATP thresholds (Babkoff & Fostick, 2017; Ben-Artzi et al., 2011; Fostick & Babkoff, 2013a; Ozmeral, Eddins, Frisina Sr, & Eddins, 2016), and negative correlations in similar magnitude of -0.3–-0.6 between speech perception and ATP, such that smaller ATP thresholds were associated with better speech perception (Babkoff & Fostick, 2017; Jafari, Omidvar, & Jafarloo, 2013; Jin, Liu, & Sladen, 2014).

ATP is also extensively studied in regard to reading and phonological awareness. One of the leading perceptual deficit theories in dyslexia argues that difficulty in perceiving rapid auditory stimuli disrupts the appropriate encoding of speech sounds necessary for good phonological representations and reading acquisition (Farmer & Klein, 1995; Fostick et al., 2012a; Heim, Freeman, Eulitz, & Elbert, 2001; Keen & Lovegrove, 2000; Meyler & Breznitz, 2005; Reed, 1989; Tallal, 1980). Indeed, readers with dyslexia show poorer performance in all kinds of ATP tasks (Ahissar, Protopapas, Reid, & Merzenich, 2000; Ben-Artzi et al., 2005; Breier et al., 2001; Fostick et al., 2012a; Fostick, Babkoff, & Zukerman, 2014; Fostick, Eshcoli, et al., 2014; Ramus et al., 2003; Reed, 1989; Tallal, 1980). Moreover, training in ATP was found to improve phonological awareness, not only for participants with dyslexia (Cohen et al., 2005; Fostick, Eshcoli, et al., 2014; Gaab, Gabrieli, Deutsch, Tallal, & Temple, 2007; Gillam et al., 2008; Given, Wasserman, Chari, Beattie, & Eden, 2008; Hook, Macaruso, & Jones, 2001; Stevens, Fanning, Coch, Sanders, & Neville, 2008; Temple et al., 2003; Valentine, Hedrick, & Swanson, 2006), but also for normal readers (Fostick, Eshcoli, et al., 2014).

Although dyslexia is typically associated with literacy skills, recent studies have also evaluated the perception of spoken speech sounds among readers with dyslexia (e.g., Dole, Meunier, & Hoen, 2014; Fraga González et al., 2015; Lohvansuu et al., 2014; Messaoud-Galusi, Hazan, & Rosen, 2011; Noordenbos, Segers, Serniclaes, Mitterer, & Verhoeven, 2012; Noordenbos, Segers, Serniclaes, & Verhoeven, 2013; Ortiz, Estévez, Muñetón, & Domínguez, 2014). These studies report that children and adults with dyslexia show difficulties in speech perception when speech is accompanied by background noise, especially speech noise. This provides some support for the idea that ATP is related to both speech perception, as well as to reading and phonological awareness, at least among readers with dyslexia.

Studies on aging adults have examined all kinds of language processing abilities, such as vocabulary (Park et al., 2002; Verhaeghen, 2003), naming (Allen, Bucur, Grabbe, Work, & Madden, 2011; Zec, Burkett, Markwell, & Larsen, 2007), word identification (Gordon-Salant, Yeni-Komshian, & Fitzgibbons, 2008; Lindfield, Wingfield, & Goodglass, 1999), and tip-of-the-tongue phenomena (Facal, Juncos-Rabadán, Rodríguez, & Pereiro, 2012; Farrell & Abrams, 2011; Salthouse & Mandell, 2013). Except for vocabulary (shown to increase with age), all other tested abilities evidenced more errors and longer reaction time among aging adults than young ones. However, no study to date has explored reading and phonological awareness among aging adults. In the present study, we wished to explore the possible presence of difficulties in these abilities among aging adults. The rationale for doing so is supported by three lines of evidence: (1) age-related decline in speech perception is well-documented in the literature (Ben-David et al., 2011; Fostick et al., 2013; Heinrich et al., 2015, 2016; Taitelbaum-Swead & Fostick, 2016a), and since phonological awareness represents the ability to perceive and manipulate speech sounds, it may be related to aging adults' difficulty in speech perception; (2) studies showing a relationship between reading ability and phonological awareness, which prompted us to test both abilities among aging adults; and (3) studies showing both an age-related deficit in ATP (Babkoff & Fostick, 2017; Ben-Artzi et al., 2011; Fostick & Babkoff, 2013a; Ozmeral et al., 2016), and a relationship between ATP, reading, and phonological awareness among dyslexic and normal readers (Ahissar et al., 2000; Babkoff & Fostick, 2017; Ben-Artzi et al., 2005; Breier et al., 2001; Fostick et al., 2012a; Fostick, Babkoff, & Zukerman, 2014; Fostick, Eshcoli, et al., 2014; Jafari et al., 2013; Jin et al., 2014; Ramus et al., 2003; Reed, 1989; Tallal, 1980), which made it interesting to explore whether this relationship would be evident in a different population, namely, aging adults. Therefore, in the present study we aimed to test: (1) whether aging adults would show a deficit in reading and phonological awareness; and (2) whether aging adults' ATP would be related to their reading ability and phonological awareness.

Finding that aging adults have difficulties in reading and phonological awareness could have some important implications. First, such difficulties would need to be well-considered and managed in order to improve aging adults' quality of life. Second, it would strengthen the relationship between ATP, reading, and phonological awareness; as mentioned earlier, this relationship was previously reported among dyslexic and normal readers, but finding such a relationship among this additional population may suggest that this association is robust and independent of population.

In order to test whether aging adults have difficulties in reading and phonological awareness, we proposed to evaluate the magnitude of a possible decrease in aging adults' reading and phonological awareness, by comparing their measurements of ATP, speech perception, reading, and phonological awareness to both a group of participants with known deficits in these abilities, namely, young readers with dyslexia, and to young normal readers as well. A similar design was used in a previous study in which we tested sleep deprived young adults on measures of ATP, speech perception, reading, and phonological awareness (Fostick, Babkoff, & Zukerman, 2014). In that study, aging adults were found to have longer ATP thresholds than young normal readers, and shorter than readers with dyslexia (Fostick, Babkoff, & Zukerman, 2014). That finding was consistent with the existing literature, which supports a relationship between ATP and speech perception, as well as between ATP, reading, and phonological awareness. Therefore, we hypothesized that aging adults would show, in addition to longer ATP thresholds, a decrease in reading and phonological awareness, as compared with young normal readers. However, since there is no common complaint among aging adults about difficulties in reading, and since their ATP thresholds are shorter than readers with dyslexia, we hypothesized that aging adults' performance would be better than that of young readers with dyslexia.

The choice of reading and phonological awareness tests in studies