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# The effects of age on visual expertise for print

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ABSTRACT

Progressive visual processing decline is a known factor in aging. The present study investigates the evolution of visual expertise for printed stimuli with aging. Fifty-five participants of increasing age (20–30, 40–50, 60–70, 75–85 years old) were recruited. Behavioral and EEG data were collected during a lexical decision task, in which words and symbol strings were presented. Analyses of EEG data focused mainly on three major points: visual expertise for print, automatization of the expertise and differences in attentional demand between the processing of words and symbols. Results indicated a preservation of visual expertise with age, with larger N170 amplitude for words than for symbols. Moreover, a decrease in stimulus processing speed was observed as a function of age. No difference in attentional demand as a function of stimulus was observed.



## 1. Introduction

Aging involves a lot of changes; one of the negative ones is a progressive decline in visual processing. Deficits in visual processing have been observed across studies: a delay in visual processing speed (Bieniek, Frei, & Rousselet, 2013; Rousselet et al., 2009), deficits in low level processes such as contrast sensitivity (Owsley, Sekuler, & Boldt, 1981) and higher level processes such as face recognition (Daniel & Bentin, 2012; Gao et al., 2009). Age-related deficits in face processing have been reported in event related potential (ERP) studies through absence of right lateralization (Daniel & Bentin, 2012) and increased processing latency (Bieniek et al., 2013; Daniel & Bentin, 2012; Rousselet et al., 2009). However, visual expertise for face processing is intact as elderly people present greater ERP amplitudes after presentation of faces compared to non-face stimuli (Daniel & Bentin, 2012; Gao et al., 2009).

Visual expertise can be acquired for classes of visual stimuli other than faces, for example cars (Gauthier, Curran, Curby, & Collins, 2003), birds or dogs for experts in these categories (Tanaka & Curran, 2001) or more commonly, written language. Visual expertise for written language is thought to be acquired in the first years of learning to read. Visual expertise for print is assessed using the ERP technique and by observing the N170 component. This negativity peaks at around 170 ms after stimulus onset in the left occipito-temporal region and has been associated with the activity of the visual word form area (Cohen et al., 2000). The major result is a greater N170 amplitude elicited by orthographical stimuli (e.g. words or letter strings) than the amplitude elicited by non-orthographical stimuli (e.g. symbols; (Bentin, Mouchetant-Rostaing, Giard, Echallier, & Pernier, 1999). The modulation of N170 amplitude as a function of the presented stimulus has been interpreted as a marker of visual expertise for print. Two theories account for the emergence of expertise for print processing during reading acquisition. According to the dominant theory, the phonological mapping model (Brem et al., 2010; McCandliss & Noble, 2003; Yoncheva, Blau, Maurer, & McCandliss, 2010; Yoncheva, Wise, & McCandliss, 2015), letter-sound decoding skills are thought to play a central role in the occipito-temporal specialization for print processing. A second and more recent hypothesis suggests that the occipito-temporal specialization for print depends on appropriate attentional feedback from dorso-parietal regions to occipito-temporal regions (Lobier, Peyrin, Pichat, Le Bas, & Valdois, 2014).

From a developmental point of view from children to young adults, the degree of expertise, reflected by the difference in N170 amplitude between words and symbols, follows an inverted U-shape (Maurer et al., 2006). Expertise is absent in pre-readers then appears and increases in the first two years of learning to read, and diminishes in young adults but does not disappear completely (Bentin et al., 1999; Mahé, Bonnefond, Gavens, Dufour, & Doignon-Camus, 2012; Maurer, Brem, Bucher, & Brandeis, 2005). Two interpretations have been given to explain the greater difference in N170 amplitude between words and symbols for beginning readers compared to expert readers. Firstly, during

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reading acquisition an extensive neural network including word processing regions but also more general brain processes related to learning and plasticity would be recruited, resulting in large N170 tuning. With further reading practice however, this neural network might become more selective and less sensitive to some visual aspects of words, thus resulting in lower N170 modulation (Maurer et al., 2006). A second explanation is that the N170 modulation in beginning readers would reflect a process which is either more important (e.g. phonological processing) or requires more resources due to a lesser automatization in beginning readers compared to practiced ones (Brem et al., 2009). In addition to the reduction of N170 tuning with age, previous studies have observed an increased left lateralization as well as a decrease in N170 latency in adults compared to children. These results were again linked to an increase in specialization of brain regions responsible for print processing in adults (Brem et al., 2006; Maurer et al., 2006). With reading practice, word processing becomes more automatized and can be done faster and in more specialized brain regions.

In adults aged over 30, almost no information is available about visual expertise for print. Only two studies have investigated the effect of age on motor response generation using lexical material (Falkenstein, Yordanova, & Kolev, 2006; Kolev, Falkenstein, & Yordanova, 2006). They used a four choice reaction task in which one of four different letters were presented as stimuli and participants had to respond to each letter with a predefined finger. Potentials evoked by letters showed an increase in P1 and N1 latencies with age (Falkenstein et al., 2006; Kolev et al., 2006) and an increase in P1 amplitude with age (Kolev et al., 2006). These authors explained these differences with aging by delays in the early stages of stimulus processing and stimulus evaluation.

Although there has been a substantial amount of research on the developmental trajectory of visual expertise for print from childhood to young adulthood, research for later stages of development is lacking. The present study is the first to explore the evolution of visual expertise for print in subjects during aging. Fifty-five participants of ages ranging between 20 and 85 were recruited. Using behavioral and electrophysiological data, this study tested the evolution of visual expertise for print with age, its latency in the time course of word processing, and the attentional cost required to process lexical material.

## 2. Method

### 2.1. Participants

Fifty-five participants were recruited and divided into four different age groups: the ages from the first group ranged from 20 to 30 years (median age = 25 ± 3; n = 13); the second from 40 to 50 (median age = 44 ± 3; n = 15); the third from 60 to 70 (median age = 62 ± 3; n = 15); the fourth from 75 to 85 (median age = 78 ± 3; n = 12). All the participants were native French speakers. The exclusion criteria were neurological impairment, cranial trauma, general anesthesia, use of benzodiazepines or substance abuse during the three month prior to testing. The study was conducted in accordance with the Helsinki Declaration, all participants gave their written informed consent and the study procedure was approved by the local ethics committee. One participant in the 20–30 and one in 40–50 age group did not participate in the reading test. Three participants from 20–30 did not take the verbal intelligence test and one of the same three did not take the non-verbal intelligence test.

First, participants took a reading test (Lefavrais, 2006), which provides scores for reading rate and accuracy. No significant difference between the four groups was observed in reading rate ($F < 1$) and accuracy ($F(3,49) = 1.20$, $p = 0.32$). Non-verbal intelligence was assessed by Raven's Progressive Matrices (PMR; (Raven & Court, 2003)) and verbal intelligence was assessed by the digit span task of the Wechsler Adult Intelligence Scale (WAIS; (Wechsler, 2008)). Non-verbal intelligence did not differ between the four groups ($F(3,50) = 2.01$, $p = 0.12$) but a significant effect of group was measured on verbal intelligence ($F(3,47) = 4.56$, $p = 0.007$). The score obtained on the latter test increased with age. Results are summarized in Table 1.

### 2.2. Material and procedure

Participants performed a lexical decision task. Half the 210 stimuli presented were high frequency words chosen from the French database Lexique 3 (New, Pallier, Ferrand & Matos, 2001) with a mean lexical frequency of 190.7 [46.1–732.4] words per million. The other half were symbol strings. Stimuli were five characters long and written in "Courrier New" font with 28-point lowercase letters. The list of stimuli used can be found in Appendix A. They were presented on a CRT screen (white print, black background) and covered 2.63° of the visual angle. Viewing distance was at 75 cm and no chinrest was used.

Participants had to determine as rapidly and accurately as possible whether or not the presented stimulus was a word. Responses were given with a computer keyboard. The "yes" response was given with the dominant hand and the "no" response with the other one. Each trial began with the presentation of a fixation cross for 400 ms which was replaced by a black screen for 120 ms, then the stimulus was displayed in the center of the screen for 500 ms. Data were inspected to observe a potential effect of offset response due to the fixation cross disappearance however no such effect was observed. Participants performed ten practice trials then the task, which was divided into two blocks.

**Table 1**
Characteristics of participants.

| | 20–30 (n = 13) Mean (SD) | 40–50 (n = 15) Mean (SD) | 60–70 (n = 15) Mean (SD) | 75–85 (n = 12) Mean (SD) | Effect of group |
|---|---|---|---|---|---|
| Gender (female:male) | 7:6 | 8:7 | 8:7 | 6:6 | |
| Age (years) | 25.23 (3.19) | 44.66 (3.79) | 63.40 (2.89) | 78.75 (3.07) | $F(3,51) = 6879$, $p < 0.001$ |
| Education (years) | 13.61 (2.81) | 13.00 (2.92) | 14.26 (2.89) | 16.08 (3.55) | $F(3,51) = 1.86$, $p = 0.14$ |
| Reading rate | 418.25 (69.79) | 441.52 (79.02) | 432.30 (60.92) | 427.52 (93.50) | $F < 1$ |
| Reading accuracy | 98.80 (0.80) | 98.24 (1.63) | 98.88 (0.70) | 98.45 (0.52) | $F(3,49) = 1.20$, $p = 0.30$ |
| PMR | 77.9 (17.5) | 82.0 (14.6) | 91.3 (4.8) | 85.83 (19.86) | $F(3,50) = 2.01$, $p = 0.12$ |
| WAIS | 9.11 (2.5) | 10.3 (1.6) | 11.6 (2.3) | 12.5 (2.71) | $F(3,47) = 4.56$, $p < 0.01$ |

WAIS: Wechsler adult intelligence scale, PMR: progressive matrices of Raven.