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► **To cite this version:**

Caroline Pigeon, Claude Marin-Lamellet. Ageing effects on the attentional capacities and working memory of people who are blind. *Disability and Rehabilitation*, 2016, pp. 1-7. <10.1080/09638288.2016.1236407>. <hal-01393882v2>

HAL Id: hal-01393882

<https://hal.science/hal-01393882v2>

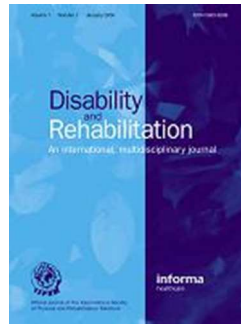
Submitted on 1 Dec 2016

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|------------------|--|
| Journal: | <i>Disability and Rehabilitation</i> |
| Manuscript ID | TIDS-02-2016-096.R1 |
| Manuscript Type: | Research Paper |
| Keywords: | Blindness, Ageing, Attention, Working memory, Cognition, Neuropsychological assessment |
| | |

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Ageing effects on the attentional capacities and working memory of people who are blind

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Keywords that are not in the title: Blindness, Cognition, Neuropsychological assessment

Abstract

Purpose. Adaptation to blindness can lead to the enhancement of the attentional capacities and working memory in young people. However, although the effects of ageing on the cognition of sighted people and people with age-related visual impairments are well-documented, no study seems to have investigated the age-related changes of these cognitive processes in people who are blind. The aim of this study was to assess the effects of age on the attentional processes and working memory in blind people.

Method. A cross-sectional study was conducted on 43 blind participants and 42 sighted participants. The participants performed auditory computerized tests assessing selective, sustained and divided attention, attentional switching and working memory.

Results. Two-way analyses of variance revealed significant visual status effect and age effect on most of the variables studied. No interaction was found between visual status and age effects.

Conclusions. These results suggest that the trajectories of cognitive age-related change are similar in blind people and in sighted people. This study has implications for rehabilitation, such as cognitive intervention.

1. Introduction

There is a consensus that normal ageing leads to the decline of certain cognitive processes, such as selective attention, sustained attention, divided attention, attentional flexibility and working memory [1, 2], involved in most everyday activities. Hence, age-related cognitive decline can lead to difficulties in everyday situations, for example in crossing the street [3] and in dual task situations [4] and can, therefore, result in a reduction in social participation [5].

According to a World Health Organization analysis, more than 80 % of blind people in the world are aged 50 and over [6]. Old people therefore make up an important part of the blind population. Consequently, the effects of ageing on the cognitive functioning, the mobility and the social participation of blind people constitute an important issue, since such people experience restrictions which go beyond the consequences of ageing.

However, little is known about cognitive ageing in blind people. Nevertheless, cognitive processes are important for the achievement of everyday activities without vision, such as navigation, which involves an important attentional effort [7-10]. Furthermore, attentional processes (selective, sustained and divided attention) and working memory have shown to be enhanced in young blind people [9, 11-14]. With ageing, a decrease of mobility is observed in blind people [15-17] but it is unknown whether this decrease could be related to a cognitive decline. The issue of age-related cognitive decline in blind people is all the more important as to maintain the cognitive capacities is more crucial for the everyday functioning in old people with a sensory impairment than in old people without sensory impairment [18].

On the contrary, the age-related visual impairment has been the focus of a large number of studies. The negative effects of the age-related visual impairment on the cognitive

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3 functioning [19-23] the mobility [24-26] and the social participation [27] are well
4 documented.
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7 The paucity of data about the cognitive ageing of blind people may be due to a lack of
8 available neuropsychological tests adapted for use without the visual modality [28-30]. In the
9 studies conducted on the cognition of people with age-related visual impairment, tests were
10 adapted either by modifying the visual items (magnified or with a reversed contrast [19]) or
11 by removing the visual items (for example in the MMSE-blind [20, 31] or in the MoCA-B
12 [23]) depending on whether the people tested were partially sighted or not. However, the
13 suppression of the visual items might decrease the sensibility and the accuracy of the tests
14 [19], highlighting the need to use tests which do not involve the visual modality.
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16
17 Furthermore, most of the tests adapted to be used on people with a visual impairment are
18 screening tools, which can efficiently detect a cognitive deficit (such as mild cognitive
19 impairment or dementia) [19], but they are not sensitive enough to provide the cognitive
20 status of people with no pathological cognitive impairment, such as a normal age-related
21 cognitive decline. The objective of this study was to assess the effects of age on performance
22 in tasks assessing selective, sustained and divided attention, attentional flexibility and
23 working memory in blind and sighted people. The hypotheses were that the performances of
24 blind participants would be better than those of sighted participants and that the performances
25 of younger participants would be better than those of older participants.
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27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 **2. Methods**

47 48 49 ***2.1. Sample selection and recruitment***

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51 A cross-sectional study with 43 blind participants and 42 sighted participants was conducted.
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53 Blind participants were recruited via an advertisement published by associations for people
54 with visual disabilities and by word of mouth. The inclusion criteria were: absence of any
55 neurological or sensory-motor impairment (except for visual impairment in the case of blind
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3 participants), habitual, independent mobility outside the home (with a white stick or a guide
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5 dog for blind participants), and living independently. The study was approved by the
6
7 IFSTTAR Research Ethics Committee and participants provided written informed consent
8
9 prior to participation.
10

11 **2.2. Participants**

12
13 Eighty-five people participated in the study. Twenty seven of them were blind adults aged
14
15 under 50 years (50- blind group); 16 participants were blind adults aged over 60 years (60+
16
17 blind group); 24 were sighted adults aged under 50 years (50- sighted group) and 18 were
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19 sighted adults aged over 60 (60+ sighted group). The etiology of visual impairment in blind
20
21 participants varied, and blind participants had no useful vision (light perception or less). The
22
23 verbal portion of the Wechsler Adult Intelligence Scale - Revised (WAIS-R [32]) was used to
24
25 determine that there was no significant difference in verbal intellectual functioning (verbal
26
27 IQ) between the groups ($F(3, 81) = 0.569, p = 0.637$). Table 1 provides a description of the
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29 groups.
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35 Insert table 1 about here
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37 **2.3. Procedure and materials**

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39 The experiment was conducted in a quiet room and lasted 90 to 120 min. Sighted participants
40
41 were blindfolded during testing.
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44 Participants were assessed with the set of computerized auditory tests detailed in our previous
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46 publication [14]. This set of tests consists of a selective attention test, a sustained attention
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48 test, a divided attention test, a simple reaction time test, and an auditory version of the Plus-
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50 minus task [33] to assess attentional switching. Working memory was assessed using an
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52 auditory version of the N-back test and the Digit span subtest of the WAIS-R [32]. The Digit
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54 span subtest was presented orally by the experimenter. Delivery of the stimuli in the other
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56 tests, programmed using SuperLab Pro software (version 2.04), was auditory and carried out
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3 by computer. The tests and the dependent variables (mainly scores, which correspond to the
4
5 number of correct responses and reaction times) are described briefly in table 2.
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8 Insert table 2 about here
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10 3. Results 11

12 All statistical analyses were conducted using SPSS (IBM SPSS Statistics 22). Performances
13 (scores and reaction times) were statistically analyzed with two-way analyses of variance
14 (ANOVA) using a design with two between-subject factors: visual status (blind/sighted) and
15 age group (50- /60+). Differences at a level of 0.05 were considered significant. Means and
16 standard deviations for each of the performance measures for the four groups and results of
17 the ANOVAs (mean effects and interaction effects) are shown in table 3.
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25 Insert table 3 about here
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28 **Selective attention test.** A two-way ANOVA on the scores obtained in the selective attention
29 test revealed a significant main effect of visual status ($F(1, 83) = 4.110, p = 0.046$), and a
30 significant main effect of age group ($F(1, 83) = 15.295, p = 0.000$). However, the analysis did
31 not reveal a significant interaction effect between visual status and age group ($F(1,$
32 $83) = 1.265, p = 0.264$). A two-way ANOVA on the false alarm number did not reveal a
33 significant main effect of visual status ($F(1, 83) = 2.464, p = 0.120$) but a main age effect
34 emerged ($F(1, 83) = 4.544, p = 0.036$). The analysis did not show a significant interaction
35 between visual status and age group ($F(1, 83) = 0.393, p = 0.532$). A two-way ANOVA on
36 the reaction times revealed a significant visual status main effect ($F(1, 83) = 11.729,$
37 $p = 0.001$) and an age group main effect ($F(1, 83) = 40.420, p = 0.000$), but no significant
38 interaction effect between visual status and age group ($F(1, 83) = 1.694, p = 0.197$).
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53 **Sustained attention test.** A two-way ANOVA on the scores demonstrated a significant main
54 effect of visual status ($F(1, 83) = 6.912, p = 0.010$), but it did not reveal a main effect of age
55 group ($F(1, 83) = 3.521, p = 0.064$) or an interaction effect between visual status and age
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3 group ($F(1, 83) = 0.833, p = 0.364$). A two-way ANOVA on the reaction times revealed a
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5 significant visual status main effect ($F(1, 83) = 9.117, p = 0.030$) and a significant age group
6
7 main effect ($F(1, 83) = 25.633, p = 0.000$). However no significant interaction effect between
8
9 visual status and age group ($F(1, 83) = 0.556, p = 0.458$) was found.

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11 **Divided attention test.** A two-way ANOVA on the scores obtained in the first task revealed
12
13 significant main effects of visual status ($F(1, 83) = 13.320, p = 0.000$) and age group
14
15 ($F(1, 83) = 9.840, p = 0.002$), but no interaction effect appeared between visual status and age
16
17 group ($F(1, 83) = 0.920, p = 0.340$). A two-way ANOVA on the reaction times obtained in
18
19 the first task revealed significant main effects of visual status ($F(1, 83) = 18.092, p = 0.000$)
20
21 and age group ($F(1, 83) = 17.750, p = 0.000$) but no interaction effect between visual status
22
23 and age group ($F(1, 83) = 2.559, p = 0.114$). A two-way ANOVA on the scores obtained in
24
25 the second task did not reveal a significant main effect of visual status ($F(1, 83) = 0.000,$
26
27 $p = 0.997$), or of age group ($F(1, 83) = 0.273, p = 0.603$), or any an interaction effect between
28
29 visual status and age group ($F(1, 83) = 1.135, p = 0.290$).

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31 **N-back test.** A two-way ANOVA on the scores obtained in the 0-back condition did not
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33 reveal a significant main effect ($F(1, 83) = 0.520, p = 0.473$) of either visual status or age
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35 group ($F(1, 83) = 0.077, p = 0.782$). Nor was there any interaction effect between visual
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37 status and age group ($F(1, 83) = 0.373, p = 0.543$). However, a two-way ANOVA on the
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39 reaction times obtained in this 0-back condition revealed a significant visual status main
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41 effect ($F(1, 83) = 4.147, p = 0.045$) and a significant main effect of age group ($F(1,$
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43 $83) = 11.213, p = 0.001$). No interaction effect between visual status and age group was
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45 found ($F(1, 83) = 0.372, p = 0.544$).

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47 A two-way ANOVA on the scores obtained in the 1-back condition did not reveal a
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49 significant main effect of visual status ($F(1, 83) = 0.164, p = 0.687$). A significant main effect
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51 of the age group did, however, emerge ($F(1, 83) = 3.949, p = 0.050$). The analysis did not
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3 reveal a significant interaction between visual status and age group ($F(1, 83) = 2.234$,
4 $p = 0.139$). A two-way ANOVA on the 1-back reaction times revealed significant main
5 effects of visual status ($F(1, 83) = 9.939$, $p = 0.002$) and age group ($F(1, 83) = 23.342$,
6 $p = 0.000$) but no interaction effect between visual status and age group ($F(1, 83) = 0.002$,
7 $p = 0.968$).

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14 A two-way ANOVA on the 2-back scores did not reveal a significant visual status main
15 effect ($F(1, 83) = 0.108$, $p = 0.744$). However it did reveal a significant main effect of age
16 group ($F(1, 83) = 17.302$, $p = 0.000$). The analysis did not reveal a significant interaction
17 effect between visual status and age group ($F(1, 83) = 2.387$, $p = 0.126$). A two-way ANOVA
18 on the reaction times obtained in the 2-back condition revealed significant main effects of
19 visual status ($F(1, 83) = 8.298$, $p = 0.005$) and of age group ($F(1, 83) = 22.197$, $p = 0.000$) but
20 no interaction effect between visual status and age group ($F(1, 83) = 0.140$, $p = 0.709$).

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30 A two-way ANOVA on the scores obtained in the 3-back condition did not reveal a
31 significant main effect of visual status ($F(1, 83) = 2.760$, $p = 0.101$). However, a significant
32 main effect of age group was observed ($F(1, 83) = 13.584$, $p = 0.000$). No interaction effect
33 appeared between visual status and age group ($F(1, 83) = 0.268$, $p = 0.606$). A two-way
34 ANOVA on the reaction times obtained in the 3-back condition did not reveal a significant
35 visual status main effect ($F(1, 83) = 3.084$, $p = 0.083$), an age group main effect ($F(1,$
36 $83) = 2.700$, $p = 0.104$), or an interaction effect between visual status and age group ($F(1,$
37 $83) = 0.843$, $p = 0.361$).

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48 **Digit span.** A two-way ANOVA on the forward span did not reveal a significant main effect
49 of visual status ($F(1, 83) = 0.067$, $p = 0.796$), but a significant main effect of age group was
50 found ($F(1, 83) = 3.976$, $p = 0.050$). No interaction effect between visual status and age group
51 was observed ($F(1, 83) = 1.532$, $p = 0.219$).

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3 A two-way ANOVA on the backward span revealed significant main effects of visual status
4 ($F(1, 83) = 7.425, p = 0.008$) and of age group ($F(1, 83) = 8.254, p = 0.005$), but no
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6 interaction effect between visual status and age group ($F(1, 83) = 0.304, p = 0.583$).
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10 Standard age scores were calculated by adding the scores obtained in the two conditions and
11
12 converting this obtained score based on the age of the participants. A two-way ANOVA on
13
14 the standard age scores did not reveal a significant main effect of visual status ($F(1,$
15
16 $83) = 1.818, p = 0.181$), or of age group ($F(1, 83) = 0.329, p = 0.568$), or an interaction effect
17
18 between visual status and age group ($F(1, 83) = 2.939, p = 0.090$).
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21 **Plus-minus task.** A two-way ANOVA on the cost of switching obtained in the plus-minus
22
23 task did not reveal a significant main effect of visual status ($F(1, 83) = 0.171, p = 0.680$), of
24
25 age group ($F(1, 83) = 0.294, p = 0.589$) or an interaction effect between visual status and age
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27 group ($F(1, 83) = 0.038, p = 0.845$..
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31 **Simple reaction time test.** A two-way ANOVA on the reaction times obtained revealed a
32
33 significant visual status main effect ($F(1, 83) = 4.266, p = 0.042$) and a significant age group
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35 main effect ($F(1, 83) = 47.737, p = 0.000$), but no interaction effect between visual status and
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37 age group was found ($F(1, 83) = 3.175, p = 0.079$).
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39 Discussion

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41 The aim of this study was to examine the effects of age on performance in tasks assessing
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43 selective, sustained, divided attention, attentional flexibility and working memory in blind
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45 and sighted people.
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49 Visual status effects were found: blind participants achieved better performances than sighted
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51 participants in many of the measured variables. Blind participants obtained higher scores and
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53 had faster reaction times than sighted participants in the selective attention test, in the
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55 sustained attention test and in the first task of the divided attention test. These results are
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57 consistent with those obtained in previous studies in which blind people achieved better
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3 performances than sighted ones in tasks assessing selective, sustained and/or divided
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5 attention [9, 11-14]. When working memory was measured, blind participants were faster in
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7 the 0-, 1- and 2- back conditions of the n-back task, and their backward spans were greater.
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9 These results confirm those obtained in our previous study [14] in which blind people
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11 achieved better performances than sighted ones in the same tests assessing working memory.
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13 Contrary to our previous study [14], in which blind participants and sighted participants aged
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15 less than 50 years did not exhibit significantly different reaction times in the simple reaction
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17 time test, the blind participants in the present study displayed faster reaction times than the
18
19 sighted ones. However, in the present study, the reaction times obtained by the 50- blind
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21 group (270.9 SD 69.1) and the 50- sighted group (275.7 SD 70.7) were comparable with a
22
23 difference of just 5 ms., although reaction times obtained by the 60+ blind group (358.1 SD
24
25 50.9) and those of the 60+ sighted group (423.5 SD 114.0) differed by more than 60 ms.
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27 Therefore even if there was no significant interaction, the visual status main effect seems to
28
29 relate more to the two 60+ groups' reaction times than to the reaction times of the two 50-
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31 groups. Globally, the results confirmed our hypothesis that the performance of blind
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33 participants would be better than that of sighted participants.
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39 Concerning the age effect, the 50- participants obtained better performances than the 60+
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41 participants in most of the measured variables. The 50- participants obtained higher scores
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43 and had faster reaction times than the 60+ participants in the selective attention test and in the
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45 first task of the divided attention test, and they were faster and tended to have a higher scores
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47 in the sustained attention test. In tasks assessing working memory, the 50- participants
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49 responded faster and had higher scores than 60+ participants in the 1- and 2-back conditions
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51 of the n-back task, responded faster in the 0-back condition and had higher scores in the 3-
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53 back condition. They also had greater forward and backward spans. In the simple reaction
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55 time test, the 50- participants exhibited faster reaction times than the 60+ participants. These
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3 results are consistent with the literature on cognitive ageing stating that normal ageing leads
4 to the decline of cognitive processes [1, 2], and confirmed our hypothesis that younger
5 participants would have better performances than older participants. Although the old
6 participants in this study were relatively young (the mean ages of the two 60+ groups were
7 under 66 years), age effects were demonstrated, suggesting that the tests used are sensitive
8 enough to detect a moderate cognitive decline.
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16 The age-related decline of attention seems not more or less marked in blind people, as it is
17 suggested by the absence of interaction between the visual status and age effects. Other
18 studies have shown that people with age-related visual impairment obtained lower
19 performances in cognitive tests than sighted people of the same age, suggesting that cognitive
20 decline is more marked in old people with an age-related visual deficit [34-36]. In the present
21 study, the old blind participants obtained higher performances than sighted ones. This
22 suggests that ageing with blindness does not, therefore, have the same effects on cognition as
23 dealing with a visual impairment in the course of ageing. A possible explication could be that
24 the cognitive decline and the visual decline of people with an age-related visual deficit may
25 share common biological causes [37]. In the contrary, the visual impairment of blind people
26 (who are blind before be old) is not caused by an ageing processes but by ocular illness or
27 injuries. Hence, people with an age-related visual impairment would be a part of the
28 population particularly affected by the age-related cognitive decline.
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46 Otherwise the results obtained from visually impaired people in tests involving visual items
47 may due to visual rather than cognitive aspects [34]. Indeed, studies conducted on people
48 with a visual impairment [38] and on people with a simulated visual impairment [39, 40]
49 have stressed the importance of using cognitive tests which are not vision dependent to assess
50 people with visual impairments. This issue would be handled with a cognitive assessment in
51 people with an age-related visual impairment with the tests used in the present study.
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3 The results of the present study show that blindness leads to an attentional improvement,
4 even in people aged more than 60. The blind participants included in this study were
5 accustomed to being independently mobile outside of the home. As only a third of blind
6 people enjoy autonomous mobility [41], these participants could be considered as a high-
7 level sample of the blind population, with over capacities. We can hypothesize that their
8 higher performances compared to the sighted participants may be due to this independence,
9 which can be considered as a cognitive training. Indeed, navigating without vision is an activity
10 cognitive costly. As standard cognitive trainings, navigating without vision is an activity
11 which i) involves cognitive stimulations, ii) includes positive reinforcements (let to have a
12 social participation, the satisfaction to be autonomous), iii) can be performed with gradual
13 difficulty steps, completed when an expertise level is reached (from in a short, simple and
14 known itinerary, accompanied, to in a complex, long and unknown itinerary, independently).

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Adaptation to a visual impairment is a dynamic mechanism. People who have been blind for
a longer time are, for example, more likely to have adapted from a psychological point of
view (i.e. have a greater acceptance of vision loss, be less depressed, enjoy better social
support) than people whose visual impairment is more recent [42, 43], even if adaptation to
visual impairment can involve several cycles of grieving and acceptance [44] and depends on
the coping strategies used by people [45]. Further investigations using longitudinal studies
are required to determine how cognitive adaptation (i.e. the improvement of selective,
sustained, divided attention and working memory) occurs over time in people who are blind
and how ageing-related changes take place. In addition, longitudinal studies would avoid the
generational bias potentially present in the present study [46].

With ageing, blind people suffer of a decrease of mobility [15-17], which can result in less
cognitive stimulations. As cognitive abilities have been found to be related to everyday
functioning in ageing [47], particularly in people with age-related visual impairment [48], a

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3 cognitive training intervention could be a promising possibility for the rehabilitation of aged
4 blind people and let them to be autonomous as long as possible. In the field of the mobility,
5 cognitive interventions have been conducted on sighted old people with a view to improving
6 their gait [49, 50]. However, only physical interventions seem to have been attempted to
7 improve the gait of people with visual impairments [51].
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14 Other types of intervention can also be considered when dealing with the effects of ageing in
15 blind people. For example, since optimized social participation is related to the preservation
16 of cognitive functioning [52] and functional autonomy [53], improvement of the social
17 participation of people who are blind could be another encouraging approach. Being engaged
18 in social activities is a means of cognitive stimulation and can attenuate age-related cognitive
19 decline [54] and therefore preserve functional autonomy.
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27 **Conclusion**

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30 Our study appears to be the first piece of research which assesses cognitive functioning in old
31 blind people. The results suggest that people who are blind follow a similar age-related
32 cognitive trajectory to that of sighted people. The study underlines the need to study
33 cognition and its links with everyday functioning throughout the entire lifespan. It also
34 provides possibilities, such as cognitive intervention, for the rehabilitation for people who are
35 blind.
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44 **Acknowledgments**

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46 We gratefully thank all the volunteers and the *Fédération des Aveugles et Handicapés Visuels*
47 *de France, Association Valentin Haüy de Lyon, Association Valentin Haüy de Marseille,*
48 *Association Valentin Haüy de Grenoble* and *Point de Vue sur la Ville* for their collaboration.
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53 **Declaration of interest**

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55 The authors report no declarations of interest. This study has been funded by IFSTTAR.
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References

1. Braver TS, West R. Working Memory, Executive Control, and Aging. In: Craik FIM, Salthouse TA, editors. *The Handbook of Aging and Cognition*. 3rd ed. New York (NY): Psychology Press; 2011. p. 311–372.
2. Kramer AF, Madden D J. Attention. In: Craik FIM, Salthouse TA, editors. *The Handbook of Aging and Cognition*. 3rd ed. New York (NY): Psychology Press; 2011. p. 189–250.
3. Dommes A, Lay TL, Vienne F, Dang N-T, Beaudoin AP, Do MC. Towards an explanation of age-related difficulties in crossing a two-way street. *Accident Analysis & Prevention*. 2015;85:229–238.
4. Li KZ, Lindenberger U, Freund AM, Baltes PB. Walking while memorizing: age-related differences in compensatory behavior. *Psychological Science*. 2001;12:230–237.
5. Wilkie R, Peat G, Thomas E, Croft P. The prevalence of person-perceived participation restriction in community-dwelling older adults. *Quality of Life Research*. 2006;15(9):1471–1479.
6. Pascolini D, Mariotti SP. Global estimates of visual impairment: 2010. *British Journal of Ophthalmology*. 2012;96(5):614–618.
7. Espinosa MA, Ungar S, Ochaita E, Blades M, Spencer C. Comparing methods for introducing blind and visually impaired people to unfamiliar urban environments. *Journal of Environmental Psychology*. 1998;18:277–287.
8. Geruschat DR, Turano KA. Estimating the amount of mental effort required for independent mobility: persons with glaucoma. *Investigative Ophthalmology & Visual Science*. 2007;48:3988–3994.
9. Kujala T, Lehtokoski A, Alho K, Kekoni J, Näätänen R. Faster reaction times in the blind than sighted during bimodal divided attention. *Acta Psychologica*. 1997;96:75–82.
10. Occelli V, Spence C, Zampini M. Auditory, tactile, and audiotactile information processing following visual deprivation. *Psychological Bulletin*. 2013;139:189–212.
11. Collignon O, De Volder AG. Further evidence that congenitally blind participants react faster to auditory and tactile spatial targets. *Canadian Journal of Experimental Psychology*. 2009;63:287–293.
12. Collignon O, Renier L, Bruyer R, Tranduy D, Veraart C. Improved selective and divided spatial attention in early blind subjects. *Brain Research*. 2006;1075:175–182.
13. Lerens E, Renier L. Does visual experience influence the spatial distribution of auditory attention? *Acta Psychologica*. 2014;146:58–62.
14. Pigeon C, Marin-Lamellet C. Evaluation of the attentional capacities and working memory of early and late blind persons. *Acta Psychologica*. 2015;155:1–7.

15. Douglas G, Pavey S, Corcoran C, Clements B. Evaluating the use of the ICF as a framework for interviewing people with a visual impairment about their mobility and travel. *The British Journal of Visual Impairment*. 2011;30:6–21.
16. Mac Cobb S. Mobility restriction and comorbidity in vision-impaired individuals living in the community. *British Journal of Community Nursing*. 2013;18(12):608–613.
17. Manduchi R, Kurniawan S. Mobility-related accidents experienced by people with visual impairment. *Research and Practice in Visual Impairment and Blindness*. 2011;4:44–54.
18. Heyl V, Wahl HW. Managing daily life with age-related sensory loss: cognitive resources gain in importance. *Psychology and aging*. 2012;27(2):510–521.
19. Bertone A, Wittich W, Watanabe D, Overbury O, Faubert J. The effect of age-related macular degeneration on non-verbal neuropsychological test performance. *International Congress Series*. 2005;1282:26–30.
20. Busse A, Sonntag A, Bischkopf J, Matschinger H, Angermeyer MC. Adaptation of dementia screening for vision-impaired older persons administration of the Mini-Mental State Examination (MMSE). *Journal of Clinical Epidemiology*. 2002;55:909–915.
21. Elyashiv SM, Shabtai EL, Belkin M. Correlation between visual acuity and cognitive functions. *British Journal of Ophthalmology*. 2014;98(1):129–132.
22. Rozzini L, Riva M, Ghilardi N, Facchinetti P, Forbice E, Semeraro F, Padovani A. Cognitive dysfunction and age-related macular degeneration. *American Journal of Alzheimer's Disease and Other Dementias*. 2014;29(3):256–262.
23. Wittich W, Phillips N, Nasreddine ZS, Chertkow H. Sensitivity and specificity of the Montreal Cognitive Assessment modified for individuals who are visually impaired. *Journal of Visual Impairment & Blindness*. 2010;104(6):360–368.
24. Sengupta S, Nguyen AM, Landingham SW van, Solomon SD, Do DV, Ferrucci L, Friedman DS, Ramulu PY. Evaluation of real-world mobility in age-related macular degeneration. *BMC Ophthalmology*. 2015;15(9):1-11.
25. Black A, Wood J. Vision and falls. *Clinical and Experimental Optometry*. 2005;88:212–222.
26. Gallagher B, Jackson J. Ageing and the impact of vision loss on independent living and mobility. *Optometry in Practice*. 2012;13:45–54.
27. Alma MA, Van der Mei SF, Melis-Dankers BJ, Van Tilburg TG, Groothoff JW, Suurmeijer TP. Participation of the elderly after vision loss. *Disability and rehabilitation*. 2011;33(1):63–72.
28. Bylsma FW, Doninger N. Neuropsychological assessment in individuals with severe visual impairment. *Topics in Geriatric Rehabilitation*. 2004;20(3):196–203.

- 1
2
3 29. Hill-Briggs F, Dial JG, Morere DA, Joyce A. Neuropsychological assessment of persons
4 with physical disability, visual impairment or blindness, and hearing impairment or deafness.
5 Archives of Clinical Neuropsychology. 2007;22:389–404.
6
- 7 30. Bauman MK, Kropf CA. Psychological tests used with blind and visually handicapped
8 persons. School Psychology Digest. 1979;8(3):257–70.
9
- 10 31. Reischies FM, Geiselman B. Age-related cognitive decline and vision impairment
11 affecting the detection of dementia syndrome in old age. The British Journal of Psychiatry.
12 1997;171(5):449–451.
13
- 14 32. Wechsler D. Manual for the Wechsler Adult Intelligence Scale-Revised. New York (NY):
15 Psychological Corporation; 1981.
16
- 17 33. Spector A, Biederman I. Mental set and mental shift revised. American Journal of
18 Psychology. 1976;89:669–679.
19
- 20 34. Wahl H-W, Heyl V. Connections between vision, hearing, and cognitive function in old
21 age. Generations. 2003;27:39–45.
22
- 23 35. Lindenberger U, Baltes PB. Sensory functioning and intelligence in old age: a strong
24 connection. Psychology and aging. 1994;9(3):339.
25
- 26 36. Lindenberger U, Scherer H, Baltes PB. The strong connection between sensory and
27 cognitive performance in old age: not due to sensory acuity reductions operating during
28 cognitive assessment. Psychology and Aging. 2001;16:196–205.
29
- 30 37. Salthouse TA, Hancock HE, Meinz EJ, Hambrick DZ. Interrelations of age, visual acuity,
31 and cognitive functioning. Journal of Gerontology. 1996;51:317-330.
32
- 33 38. Killen A, Firbank MJ, Collerton D, Clarke M, Jefferis JM, Taylor J-P, McKeith IG,
34 Mosimann UP. The assessment of cognition in visually impaired older adults. Age and
35 Ageing. 2013;42(1):98–102.
36
- 37 39. Wood J, Chaparro A, Anstey K, Lacherez P, Chidgey A, Eisemann J, Gaynor A, La P.
38 Simulated visual impairment leads to cognitive slowing in older adults. Optometry and
39 Vision Science. 2010;87(12):1037–1043.
40
- 41 40. Bertone A, Bettinelli L, Faubert J. The impact of blurred vision on cognitive assessment.
42 Journal of Clinical and Experimental Neuropsychology. 2007;29(5):467–476.
43
- 44 41. Sander M-S, Bournot M-C, Lelièvre F, Tallec A. La population en situation de handicap
45 visuel en France. Importance, caractéristiques, incapacités fonctionnelles et difficultés
46 sociales. Exploitation d'enquêtes HID 1998/99. [People with visual disabilities in France.
47 Importance, functional disability and social difficulties. Analysis of HID 1998-1999 surveys].
48 Nantes (France): Observatoire régional de la santé des Pays de la Loire; 2005.
49
- 50 42. Senra H, Barbosa F, Ferreira P, Vieira C, Perrin PB, Rogers H, Rivera D, Leal IP.
51 Psychologic adjustment to irreversible vision loss in adults. Ophthalmology.
52 2015;122(4):851–861.
53
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55
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57
58
59
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2
3 43. Bergeron CM, Wanet-Defalque M-C. Psychological adaptation to visual impairment: The
4 traditional grief process revised. *British Journal of Visual Impairment*. 2013;31(1):20–31.
5
6 44. Kaminsky TA, Mitchell PH, Thompson EA, Dudgeon BJ, Powell JM. Supports and
7 barriers as experienced by individuals with vision loss from diabetes. *Disability and*
8 *Rehabilitation*. 2014;36(6):487–496.
9
10 45. Garnefski N, Kraaij V, De Graaf M, Karels L. Psychological intervention targets for
11 people with visual impairments: The importance of cognitive coping and goal adjustment.
12 *Disability and Rehabilitation*. 2010;32(2):142–147.
13
14 46. Schaie KW, Willis S. *Handbook of the Psychology of Aging*. 8th ed. San Diego (CA):
15 Academic Press; 2015.
16
17 47. Baltes MM, Maas I, Wilms H-U, Borchelt M, Little TD. Everyday competence in old and
18 very old age: Theoretical considerations and empirical findings. *The Berlin aging study:*
19 *Aging from*. 1999;70:384–402.
20
21 48. Heyl V, Wahl H-W. Managing daily life with age-related sensory loss: cognitive
22 resources gain in importance. *Psychology and aging*. 2012;27(2):510.
23
24 49. Smith-Ray RL, Hughes SL, Prohaska TR, Little DM, Jurivich DA, Hedeker D. Impact of
25 cognitive training on balance and gait in older adults. *The Journals of Gerontology Series B:*
26 *Psychological Sciences and Social Sciences*. 2013;70(3):357–366.
27
28 50. Schoene D, Valenzuela T, Lord SR, de Bruin ED. The effect of interactive cognitive-
29 motor training in reducing fall risk in older people: a systematic. *BMC Geriatrics*.
30 2014;14(107):1-22
31
32 51. Ray CT, Wolf SL. Review of intrinsic factors related to fall risk in individuals with visual
33 impairments. *J Rehabil Res Dev*. 2008;45(8):1117–24.
34
35 52. Kuiper JS, Zuidersma M, Oude Voshaar RC, Zuidema SU, van den Heuvel ER, Stolk RP,
36 Smidt N. Social relationships and risk of dementia: A systematic review and meta-analysis of
37 longitudinal cohort studies. *Ageing Research Reviews*. 2015;22:39–57.
38
39 53. Levasseur M, Gauvin L, Richard L, Kestens Y, Daniel M, Payette H, Group NS, others.
40 Associations between perceived proximity to neighborhood resources, disability, and social
41 participation among community-dwelling older adults: Results from the Voisinuage study.
42 *Archives of physical medicine and rehabilitation*. 2011;92(12):1979–1986.
43
44 54. James BD, Wilson RS, Barnes LL, Bennett DA. Late-life social activity and cognitive
45 decline in old age. *Journal of the International Neuropsychological Society*.
46 2011;17(06):998–1005.
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Table 1. General characteristics of the four groups

| | Means (SD; range) | | | |
|-------------------------------|-----------------------------|-----------------------------|-------------------------------|-------------------------------|
| | 50- blind group (n = 27) | 60+ blind group (n = 16) | 50- sighted group (n = 24) | 60+ sighted group (n = 18) |
| Age (years) | 35.0 (7.8; 18-47) | 65.9 (5.1; 60-80) | 31.4 (8.2; 22-50) | 65.4 (7.1; 61-83) |
| Gender (female number) | 16 | 7 | 15 | 9 |
| Years of education | 14.2 (2.9; 7-18) | 11.7 (3.4; 7-17) | 14.9 (2.1; 11-20) | 10.8 (3.1; 7-16) |
| Verbal IQ | 109.6 (16.8; 87-140) | 106.8 (10.7; 86-126) | 105.7 (10.3; 88-127) | 105.6 (7.5; 95-120) |
| Duration of blindness | 26.4 (11.2; 7-47) | 31.8 (17.4; 5-72) | - | - |

Table 2. Description of the tests used and the dependent variables

| Cognitive function assessed | Test | Instructions | Responses of participants (dependent variables) |
|-----------------------------|--|--|--|
| Selective attention | Selective attention test | Detect consonants among numbers | Press the space bar (number of correct responses and reaction times) |
| Sustained attention | Sustained attention test | | |
| Divided attention | Divided attention test | First task: detect consonants; second task: detect the number 6 among consonants and numbers | First task: press the space bar (number of correct responses and reaction times); secondary task: verbally (number of correct responses) |
| Attentional switching | Auditory plus-minus task [33] (3 conditions) | Condition 1: add 3 to each number presented Condition 2: subtract 3 to each number presented Condition 3: alternate between addition and subtraction | Verbally, written by the experimenter (cost of switching: difference between the time required to complete the condition 3 and the average of the times required to complete the first two conditions) |
| Working memory | N-back test (4 conditions) | Detect when a consonant is the same as the n last consonant | Press the space bar (number of correct responses and reaction times) |
| | Digit span subtest of the WAIS-R [32] | Condition 1: repeat a digit sequence in the same order of presentation Condition 2: repeat a digit sequence in the reverse order of presentation | Verbally, written by the experimenter (forward and backward spans and standard age scores) |
| Simple reaction time | Simple reaction time test | Detect the occurrence of a sound | Press the space bar (reaction times) |

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Table 3. Means (standard deviations) for each performance measures of group and results of the ANOVAs (mean effects and their interactions)

| Test | variable | Mean (SD) | | | | Visual status effect | | Age group effect | | Interaction | |
|--------------------------|-------------------------------|-----------------------|-----------------------|-------------------------|-------------------------|----------------------|-------------|------------------|-------------|-------------|---------|
| | | 50- blind (n = 27) | 60+ blind (n = 16) | 50- sighted (n = 24) | 60+ sighted (n = 18) | F value | p value | F value | p value | F value | p value |
| Selective attention test | Score (/40) | 38.8 (1.1) | 35.3 (4.2) | 36.6 (3.2) | 34.6 (4.1) | 4.110 | .046 | 15.295 | .000 | 1.265 | .264 |
| | False Alarm number | 0.9 (0.9) | 1.6 (1.7) | 0.7 (0.9) | 1.1 (0.6) | 2.464 | .120 | 4.544 | .036 | 0.393 | .532 |
| | Reaction time (ms) | 670.5 (54.9) | 768.9 (57.4) | 731.2 (65.3) | 796.2 (51.9) | 11.729 | .001 | 40.420 | .000 | 1.694 | .197 |
| Sustained attention test | Score (/120) | 112.5 (22.9) | 111.1 (11.4) | 109.5 (10.6) | 107.5 (10.8) | 6.912 | .010 | 3.521 | .064 | 0.833 | .364 |
| | Reaction time (ms) | 681.4 (69.9) | 765.6 (63.5) | 755.3 (72.4) | 798.5 (57.1) | 9.117 | .030 | 25.633 | .000 | 0.556 | .458 |
| Divided attention test | First task score (/40) | 34.3 (7.7) | 31.1 (5.6) | 30.6 (5.7) | 28.1 (5.2) | 13.320 | .000 | 9.840 | .002 | 0.920 | .340 |
| | First task reaction time (ms) | 743.2 (67.7) | 845.0 (62.3) | 846.5 (110.4) | 891.5 (56.0) | 18.092 | .000 | 17.750 | .000 | 2.559 | .114 |
| | Second task score (/8) | 6.7 (1.1) | 7.2 (2.0) | 7.4 (1.0) | 6.9 (1.0) | 0.000 | .997 | 0.273 | .603 | 1.135 | .290 |
| Auditory N-back test | 0-back score (/10) | 9.9 (0.2) | 10.0 (0.0) | 9.9 (0.2) | 9.9 (0.2) | 0.520 | .473 | 0.077 | .782 | 0.373 | .543 |
| | 1-back score (/10) | 9.8 (0.5) | 9.8 (0.4) | 9.9 (0.2) | 9.5 (1.0) | 0.164 | .687 | 3.949 | .050 | 2.234 | .139 |
| | 2-back score (/10) | 9.1 (1.6) | 6.4 (3.0) | 8.2 (1.8) | 7.0 (2.1) | 0.108 | .744 | 17.302 | .000 | 2.387 | .126 |
| | 3-back score (/10) | 5.7 (1.7) | 4.6 (1.4) | 5.3 (1.4) | 3.8 (1.9) | 2.760 | .101 | 13.584 | .000 | 0.268 | .606 |
| | 0-back reaction time (ms) | 530.0 (72.7) | 621.4 (71.2) | 591.0 (137.7) | 654.4 (116.2) | 4.147 | .045 | 11.213 | .001 | 0.372 | .544 |
| | 1-back reaction time (ms) | 584.0 (81.1) | 673.9 (76.7) | 642.3 (101.0) | 733.8 (73.7) | 9.939 | .002 | 23.342 | .000 | 0.002 | .968 |
| Digit span | 2-back reaction time (ms) | 713.9 (124.2) | 912.9 (281.3) | 838.0 (132.7) | 1012.8 (193.2) | 8.298 | .005 | 22.197 | .000 | 0.140 | .709 |
| | 3-back reaction time (ms) | 893.8 (220.8) | 1014.5 (267.5) | 1010.1 (135.6) | 1051.9 (233.2) | 3.084 | .083 | 2.700 | .104 | 0.843 | .361 |
| | Forward span | 7.3 (1.8) | 6.3 (1.4) | 6.9 (1.2) | 6.6 (1.1) | 0.067 | .796 | 3.976 | .050 | 1.532 | .219 |
| | Backward span | 6.0 (1.3) | 5.0 (1.6) | 5.0 (1.2) | 4.4 (0.9) | 7.425 | .008 | 8.254 | .005 | 0.304 | .583 |
| Auditory plus-minus task | Standard age score | 14.9 (3.4) | 13.4 (3.6) | 12.9 (2.1) | 13.6 (2.1) | 1.818 | .181 | 0.329 | .568 | 2.939 | .090 |
| | Cost of switching | 7.43 (12.1) | 8.4 (10.6) | 8.1 (11.7) | 10.3 (19.5) | 0.171 | .680 | 0.294 | .589 | 0.038 | .845 |

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|---------------------------|--------------------|--------------|--------------|--------------|---------------|-------|-------------|--------|-------------|-------|------|
| Simple reaction time test | Reaction time (ms) | 270.9 (69.1) | 358.1 (50.9) | 275.7 (70.7) | 423.5 (114.0) | 4.266 | .042 | 47.737 | .000 | 3.175 | .079 |
|---------------------------|--------------------|--------------|--------------|--------------|---------------|-------|-------------|--------|-------------|-------|------|

For Peer Review

Implications for rehabilitation

- Blind people show improved attentional capacities compared to sighted people, even in old blind people.
- Old blind people have lower performances than younger blind people in tests assessing selective, sustained and divided attention and working memory.
- Cognitive approaches to rehabilitation may help people who are blind to deal with age-related cognitive decline and its effects on everyday functioning.
- A high level of cognitive stimulation, provided by a cognitive training or a developed social participation, might reduce the age-related effects in people who are blind.

Manuscript ID: TIDS-02-2016-096

Title: **Ageing effects on the attentional capacities and working memory of people who are blind**

Disability and Rehabilitation

Dear Professor Dave Müller,

We would like to thank the editor and the reviewers for their constructive feedback. We carefully revised the manuscript based on the comments, and feel that this considerably improved the manuscript.

In the following, we provide specific response to each comment.

| Reviewer #1 | Authors' reply |
|---|---|
| 1. The discussion section requires some further work. Many papers cited in the discussion do not engaged with authors' idea, but rather used to show the similarity with previous papers. Moreover, authors have not provided any cognitive adaptation model/hypothesis for discussing the results. They only mentioned that further investigations are required. | The discussion section has been better developed and a cognitive adaptation hypothesis for discussing the results has been more exposed. |
| 2. Table 3 is only showing mean (SD) without the result of statistical analysis, so that it was very hard to understand the results. Moreover, the part of Digit span is not written properly. | The results of statistical analysis have been added in the Table 3 and the part of Digit span in the table 3 has been corrected |
| 3. There is a part incorrectly cited in the discussion. In the results, reaction times obtained in the 3-back condition did not show a significant age group main effect (page8, line 25). However, in the discussion it was mentioned that the 50- participants were faster in the 0- and 3-back conditions (page 10, line 28). | This is effectively an error in the discussion that we corrected: "In tasks assessing working memory, the 50- participants responded faster and had higher scores than 60+ participants in the 1- and 2-back conditions of the n-back task, responded faster in the 0-back condition and had higher scores in the 3-back condition " |
| 4. There are a few careless mistakes in the references. | Errors in the references section have been corrected. |
| Reviewer #2 | |
| 1. It is pretty exploratory, which makes it atheoretical. I guess that's not a problem on its own, so long as the authors are up front about it, but I have to say that the introduction did not really tell me where this paper was going at all. When I started reading the methods I needed to go back up to the abstract to have any idea what the point was. question that the authors put forward, which is how blind people develop the ability to walk independently out of home. | We restructured the introduction part and we hope that the introduction is now clearer. |
| 2. What are the dependent variables? It is kind of hard to judge the quality of research without this info. For instance, n-back score of "5.7". Okay? Is that simply hits? Are all of these hits? | The dependent variables have been add in the table 2 which describe the tests used. The scores correspond to the number of correct responses, this has been specified in the Procedure and materials section. In the table 3, for each score, the maximal number of hits have been had. |

| Editor | |
|--|--|
| I would also like you to add a fourth bullet point in your section on “implications for rehabilitation” which perhaps elaborates on the third point which focused on the potential benefits of cognitive rehabilitation. | A fourth bullet has been add: “A high level of cognitive stimulation, provided by a cognitive training or a developed social participation, might reduce the age-related effects in people who are blind.” |

We would like to thank again the reviewers for their careful reading and relevant suggestions and we hope that this revised version will be clearer.

The authors

For Peer Review