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Evaluation of the attentional capacities and working memory of early and late blind persons

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ABSTRACT

Although attentional processes and working memory seem to be significantly involved in the daily activities (particularly during navigating) of persons who are blind and who use these abilities to compensate for their lack of vision, few studies have investigated these mechanisms in this population. The aim of this study is to evaluate the selective, sustained and divided attention, attentional inhibition and switching and working memory of blind persons. Early blind, late blind and sighted participants completed neuropsychological tests that were designed or adapted to be achievable in the absence of vision. The results revealed that the early blind participants outperformed the sighted ones in selective, sustained and divided attention and working memory tests, and the late blind participants outperformed the sighted participants in selective, sustained and divided attention. However, no differences were found between the blind groups and the sighted group in the attentional inhibition and switching tests. Furthermore, no differences were found between the early and late blind participants in this set of tests. These results suggest that early and late blind persons can compensate for the lack of vision by an enhancement of the attentional and working memory capacities.

1. Introduction

Because vision is the most useful sense for processing spatial information (Thinus-Blanc & Gaunet, 1997), the navigation of persons who are visually impaired requires that they manage a large amount of information through available sensorial modalities, mobility aids and mnesic information. Moreover, because navigation is a dynamic activity, temporal constraints require the regular updating of processed information.

There is a long-standing debate regarding the possibility that blind persons compensate for their lack of vision through improvements in tactile and auditory sensitivities. Although some results are in agreement with this perspective (Gougoux et al., 2004; Wan, Wood, Reutens, & Wilson, 2010), there is strong evidence that blindness does not lead to improvements in basic sensorial acuity (Lewald, 2002; Pascual-Leone & Torres, 1993) but rather leads to more efficient processing of available information (Grant, Thiagarajah, & Sathian, 2000; Hatwell, 2003). In agreement with this latter assumption, Hugdahl et al. (2004) reported that the perceptual improvements observed in blind persons occur only for perceptual functions that involve higher-level processes (such as speech discrimination and the detection of echoes as signals for the guidance of locomotion) and that basic sensorial functions are not improved.

Thus, several authors have proposed that blindness might result in the enhancement of higher-level cognitive processes, such as attentional processes, and have suggested that navigation without vision appears to involve the mobilization of selective attention and attentional inhibition (of irrelevant information), sustained attention, divided attention, attentional switching and working memory (Espinosa, Ungar, Ochaita, Blades, & Spencer, 1998; Geruschat & Turano, 2007; Kujala, Lehtokoski, Alho, Kekoni, & Näätänen, 1997; Occelli, Spence, & Zampini, 2013). Some of these attentional processes have previously been studied in blind individuals.

For example, Collignon, Renier, Bruyer, Tranduy, and Veraart (2006) and Collignon and De Volder (2009) found that early blind persons answer more rapidly (but not more accurately) than sighted persons in Go–NoGo tasks composed of auditory and tactile stimuli. In a more recent study, Lerens and Renier (2014) found that early blind participants are faster than sighted ones in the detection of auditory targets coming from frontal and/or peripheral locations and that the improved performance of blind persons is greater when there are multiple sound sources. Thus, the results obtained in these studies suggest an enhancement of spatial selective attention in early blind persons. Additionally, to measure the inhibition process, Collignon et al. (2006) and Collignon and De Volder (2009) compared the rates of false alarms (i.e., when participants respond to a distractor) of blind and sighted participants and found no differences between the two groups. Furthermore, Collignon

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et al. (2006), Collignon and De Volder (2009) and Kujala et al. (1997) found that early blind individuals have divided attention abilities that are improved compared to those of sighted persons; these individuals are faster at detecting targets among auditory and tactile stimuli. Thus, blind persons are familiar with the simultaneous use of auditory and tactile systems and are less impaired by the cost of sharing attention.

Additional studies have been conducted regarding the working memory of blind persons, and these studies have primarily focused on the tactile modality. For example, Bliss, Kujala, and Hämäläinen (2004) compared the performance of early and late blind and sighted participants in N-back tasks. The blind participants outperformed the sighted ones in a tactile task involving raised letters. The performance of the sighted participants in a visual task was better than that of the blind participants in the task with the raised letters but did not differ from the performance of the blind participants in a task with Braille characters. Thus, the performance of blind persons and sighted persons in an N-back task seems to be related to the participants' familiarity with the material used. Using a haptic adaptation of the Corsi Block-Tapping task, Ruggiero and Iachini (2010) found that the tactile forward span of late blind participants was higher than that of sighted participants, and the performance of early blind participants was intermediate. The tactile backward spans of the three groups were similar. However, the differences in the performance of the groups can be explained by different familiarity with the tactile modality for spatial perception. Thus, these two studies emphasize the need to use identical materials and to control the familiarity level between the groups being tested. To account for tactile processing in blind persons, Cohen, Voss, Lepore, and Scherzer (2010) and Cohen, Scherzer, Viau, Voss, and Lepore (2011) proposed the addition of a tactile subsystem to the working memory model of Baddeley and Hitch (1974). Using different concurrent tasks during the realization of a tactile working memory task, Cohen et al. (2011) concluded that the tactile subsystem of the working memory of blind persons has a spatial nature. The working memory capacities of blind children have also been assessed. Although some authors have shown that blind children's performance is superior to that of sighted children in working memory and short-term memory tasks (Withagen, Kappers, Vervloed, Knoors, & Verhoeven, 2013), other authors have found that blind children outperform sighted children in short-term memory tasks, but not in working memory tasks (Swanson & Luxenberg, 2009). Moreover, Hull and Mason (1995) demonstrated that blind children achieve greater forward and backward spans than do sighted children. Although it is difficult to draw conclusions from some studies of the working memory of blind persons because of the use of different tasks for sighted and blind participants, the overall trend of the relevant studies tends to demonstrate an enhancement of working memory in blind persons.

Regarding the sustained attention and attentional switching capacities of blind persons, no studies have been conducted. However, Kujala et al. (1997) suggested that blind persons would have an attentional switching mechanism that is more efficient than that of sighted persons due to the more extensive practice with the available perceptual modalities, particularly during pedestrian traveling.

Despite the important involvement of attention in navigation by blind persons and studies of some of the attentional capacities of blind persons, a global consideration of all of the attentional processes of this population has not been performed, possibly due to the difficulty of assessing attentional processes without the visual modality because attention has traditionally been considered through the lens of vision. Clinical professionals note that the number of neuropsychological tests accessible to persons with visual impairments is limited and that there are no appropriate norms for this population (Hill-Briggs, Dial, Morere, & Joyce, 2007).

In addition, most of the studies discussed did not distinguish between the two main sub-groups of the population of persons who are blind, early and late blind people. Indeed, blindness has different effects on cognitive processes depending on the age at which it occurs (Hatwell, 2003). Late blind persons have better abilities to understand spatial arrangements as a whole than do early blind persons because late blind persons have experienced the simultaneous character of vision (Thinus-Blanc & Gaunet, 1997). Thus, the spatial processing required for navigation involves a greater cognitive effort (particularly in terms of attentional and working memory levels) for early blind than for late blind persons. This difference can result in greater attention and working memory capacities in early than in late blind persons. Nonetheless, although some authors have studied these two sub-populations separately (Bliss et al., 2004; Ruggiero & Iachini, 2010), the majority of the studies on attention have focused only on early blind persons (Collignon & De Volder, 2009; Collignon et al., 2006; Kujala et al., 1997; Lerens & Renier, 2014).

The first aim of the present study was to design a set of cognitive tests that assesses selective attention, sustained attention, divided attention, inhibition, attentional switching and working memory and that is accessible to persons with visual impairments. The second aim was to compare the performance of early and late blind persons with the performance of sighted people in this set of tests. According to the theory that blind persons overcome their lack of vision via improvements in higher-level cognitive processes, we propose that the performance of the blind participants should be superior to the performance of the sighted participants and that the performance of the early blind participants should be superior to the performance of the late blind participants.

2. Methods

2.1. Participants

Fourteen early blind participants (10 females and 4 males) aged 27–52 (mean age = 35 years, SD = 8.6), ten late blind participants (5 females and 5 males) aged 28–51 (mean age = 39 years, SD = 7.4) and 24 sighted participants (15 females and 9 males) aged 22–50 (mean age = 31 years, SD = 8.2) took part in the study. The blind participants had no residual eyesight or were able to see bright light and had no other neurological or sensory-motor impairments. Only three early blind participants were not blind from birth; these participants became blind at three, five and six years old. The late blind participants became blind between the ages of 14 and 46 years (mean age of onset = 15.9 years, SD = 9.5). The blindness of the participants was due to various etiologies. The early and late blind participants were able to move independently outside of their homes with a white cane (18) or a guide dog (6). Six subtests from the verbal portion of the Wechsler Adult Intelligence Scale — Revised (WAIS-R, Wechsler, 1955; 1981) were used to determine that the intellectual functioning of the three groups was similar ($F(2, 45) = 0.595$, $p = 0.556$). Although this verbal portion of the test assesses only verbal IQ, this was the only portion of the test that is available to evaluate the intellectual functioning of visually impaired persons. According to Price, Mount, and Coles (1987), this verbal part is appropriate for assessing persons who are blind and provides a verbal IQ that correlates with the IQ acquired with the complete scale at a level of 0.95. The simple reaction times of the participants were also compared. Using a simple reaction time test, we demonstrated that the three groups of participants exhibited equivalent sensory-motor rapidity ($F(2, 45) = 3.628$, $p = 0.644$). The sighted participants were blindfolded during the testing. The subjects provided written informed consent prior to participation. This experiment was approved by the ethics committee of the IFSTTAR.

2.2. Procedures and materials

The participants were seated in a quiet room during the experiment. The duration of the session varied from 90 to 120 min. The different attentional components of the participants were assessed with tests