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Helping older pedestrians navigate unknown environments through vibrotactile guidance instructions

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A B S T R A C T

Many studies have consistently found evidence of aging-related navigation difficulties that lead to disorientation behaviors and/or reduced travel. Despite technological advances, older pedestrians mainly use paper maps to find their way in unknown environments while they have a lot of difficulties in using and interacting with them efficiently. In this context, the present study was aimed at assessing the effectiveness and acceptability and study older pedestrian's behavior when wearing a vibrotactile instructions to help them finding their way in an unknown city as compared with visual instructions provided by a paper map. Fifty-eight participants (20 young adults ages 21–45, 20 younger-old adults ages 61–70, and 18 older-old adults ages 71–80) took part in a simulated navigation task where participants had to go from point A to point B in a virtual city. The task was performed either with a vibrotactile wristband delivering directional messages or with a standard paper map showing the visual instructions to follow. The data showed that vibrotactile guidance instructions improved the correct numbers of turns taken (left/right) at simple intersections. They also reduced travel time as compared with visual guidance instructions provided by a paper map. These benefits were greater among the older-old participants, who had trouble using the paper map and thus benefited greatly from the assistance provided by the vibrotactile guidance instructions. These findings suggest that such an assistance device using simple haptic guidance messages is able to improve older pedestrians' mobility.

1. Introduction

The present experimental study was aimed at assessing the effectiveness and acceptability of using vibrotactile instructions to help older pedestrians finding their way in an unknown city as compared with visual instructions provided by a paper map. Despite technological advances, older people mainly use paper maps to find their way in unknown environments while they have a lot of difficulties in using and interacting with them efficiently (Eriksson & Fabricius, 2015; Kobayashi &

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Yamamoto, 2009). For example, only 15% of French people over 70 have a smartphone while 90% of the 18–24 years old own one (ARCEP, 2015), and among older smartphone owners, only less than 10% seem to use geo-tracking services. In the USA, 42% of people over 65 and 92% of the 18–29 own a smartphone (Pew Research Center, 2017). Some older pedestrians even admit "to never travel anywhere without a paper map" (Emmerson, Guo, Blythe, Namdeo, & Edwards, 2013).

1.1. Navigation difficulties with aging

In recent years, many studies have looked into the effects of both normal and pathological aging on navigation skills and guidance (for a review see e.g., Moffat, 2009). With normal aging, these skills decrease due to the structural and functional damage of the prefrontal cortex (Raz et al., 2004) and of the striato-frontal and striato-hippocampal systems (Moffat, Kennedy, Rodrigue, & Raz, 2007). Surveys indicate that older people self-report deficits in navigation and often avoid unfamiliar routes and places in order to limit uncomfortable situations (Burns, 1999; Devlin, 2001). Wayfinding, i.e., the process by which people navigate from place to place and orient themselves in a physical space (Kruijff, Donath, & Regenbrecht, 2001), is highly affected by the aging process (Allen, 1999; Wolbers & Hegarty, 2010). Older people have more difficulty locating their destination points and remembering the route than do younger adults (Jansen, Schmelter, & Heil, 2010; Moffat, 2001; Rodgers, Sindone, & Moffat, 2012). Even when their performance is correct, they are less confident in their choices, judgments, or responses (Kukolja, Thiel, & Fink, 2009).

Whereas older people have no difficulty using and memorizing landmarks when they are navigating in simple virtual environments containing few details, they have proven unable to use landmark information efficiently and to select the most relevant cues when they are moving in complex environments (Moffat & Resnick, 2002). Route planning difficulties also increase with aging (Allain et al., 2005; Salthouse & Siedlecki, 2007). In a map-learning task, older people were shown to make more route errors when returning to their starting point and more long-distance estimation errors than younger people (Mahmood, Adamo, Briceno, & Moffat, 2009). But when a route has been learned perfectly via a reinforced learning method, no age-dependent differences in the ability to find a correct route in a virtual maze without landmarks has been observed (Jansen et al., 2010). This last result suggests that with specific aids, spatial skills can be improved in older people.

1.2. Navigation in virtual reality

These navigation difficulties have been highlighted in several studies using virtual reality. Navigation performance in natural environments and virtual environments has actually been shown to be similar in both young and older participants (Cushman, Stein, Duffy, 2008; Kalová, Vlcek, Jarolímová, & Bures, 2005), which makes the use of virtual reality to study navigation skills an interesting option.

Insofar as it ensures a safe, controlled, and standardized environment (Rizzo, Schultheis, Kerns, & Mateer, 2004), virtual reality allows one to study situated spatial cognition (Klinger, 2006), i.e., spatial cognition in relation to the physical body interacting with the world (Wilson, 2002), unlike paper-pencil tasks, which are much less representative of the cognitive processes involved in complex spatial activities. Ruddle, Payne, and Jones (1997), for example, found that participants construct cognitive maps in virtual environments that are very similar to those constructed in the real world. Moreover, virtual reality enables (i) to conceive a large variety of navigation scenarios simulating real large-scale environments (Taillade et al., 2013), and (ii) to control several parameters of the situation, which allows to place individuals in realistic situations without the safety risks associated with natural situations (Fuchs, Nashahibi, & Lourdeaux, 1999). Virtual reality also allows the fine measurement of many parameters of interaction with a navigation device, which is difficult to implement in a real environment.

1.3. Maps

Maps are the most common navigation aids. However, maps require high visual-attention abilities so it can be dangerous to use them while walking because they may distract road users from environmental information. Orienting and interpreting maps can also generate a high cognitive load. This is especially true for older people, who have difficulty with mental rotation, i.e., the ability to mentally rotate an object in two or three dimensions and to make perceptual judgments about its new spatial configuration (Berg, Hertzog, & Hunt, 1982; Dror, Schmitz-Williams, & Smith, 2005).

Compared to young people, older people are known to have trouble learning a map (Klencklen, Desprès, & Dufour, 2012; Meneghetti, Borella, Grasso, & De Beni, 2012) and orienting it correctly in their walking direction (Meneghetti, Fiore, Borella, & De Beni, 2011; Wilkniss, 1997). However, these studies used recall tasks after a map learning stage and few took an interest in the performance of older people navigating in a complex environment with an unlearned map. Among these, Aubrey, Li, and Dobbs (1994) studied the use of "You are here" maps by young and older people. In the first condition, the sign indicating the individual's position was oriented in the correct walking direction (alignment condition); in the second one, the "You are here" sign was not aligned with the walking direction (counter-alignment condition). The results indicated poor performance in the second condition by older participants, who were slower and made more errors in following the map than did younger participants. However, the older participants were almost as good as the young ones in the first condition, suggesting that they were able to interpret a simple map (few intersections and a small area) that was correctly oriented.