Perceptual-cognitive training improves biological motion perception: evidence for transferability of training in healthy aging

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In our everyday life, processing complex dynamic scenes such as crowds and traffic is of critical importance. Further, it is well documented that there is an age-related decline in complex perceptual-cognitive processing, which can be reversed with training. It has been suggested that a specific dynamic scene perceptual-cognitive training procedure [the three-dimensional multiple object tracking speed task (3D-MOT)] helps observers manage socially relevant stimuli such as human body movements as seen in crowds or during sports activities. Here, we test this assertion by assessing whether training older observers on 3D-MOT can improve biological motion (BM) perception. Research has shown that healthy older adults require more distance in virtual space between themselves and a point-light walker to integrate BM information than younger adults. Their performances decreased markedly at a distance as far away as 4 m (critical for collision avoidance), whereas performance in young adults remained constant up to 1 m. We trained observers between 64 and 73 years of age on the 3D-MOT speed task and looked at BM perception at 4 and 16 m distances in virtual space. We also had a control group trained on a visual task and a third group without training.
The perceptual-cognitive training eliminated the difference in BM perception between 4 and 16 m after only a few weeks, whereas the two control groups showed no transfer. This demonstrates that 3D-MOT training could be a good generic process for helping certain observers deal with socially relevant dynamic scenes. ***NeuroReport*** **00:000–000 © 2012 Wolters Kluwer Health | Lippincott Williams & Wilkins.**

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Introduction

Perceptual-cognitive changes with healthy aging are well documented [1,2]. Furthermore, the availability of training programs for improved-cognitive or perceptual-cognitive performance of the elderly population is increasing considerably. This arises from the fact that recent research in neurosciences has demonstrated that neuroplasticity is still very much present in the aging brain, lending support to the notion that training the brain is a useful process for building compensatory neural circuitry and recovering lost capacities [3]. However, a very important question remains: do brain-training programs transfer to socially relevant tasks? By transfer we imply that a brain-training procedure using a specific protocol does not only show improvements on the task itself but also on socially relevant functions. For instance, if a general memory-training task showed improvements for remembering socially relevant information such as chores, phone numbers etc., then we would consider that the training has shown 'transferability' and is therefore a useful exercise for the person undergoing the training program.

We wanted to test this assumption directly by using a perceptual-cognitive training procedure that we know shows improvements in aging and assess whether such training can transfer to a socially relevant task. It has been shown that training on the three-dimensional multiple object tracking (3D-MOT) speed task over several weeks generates a marked increase in performance in high-level athletes [4] and healthy aging observers [5]. Faubert and Sidebottom [4] have argued that a perceptual-cognitive training procedure has to contain certain characteristics for it to successfully show transferability for sports performance or for navigation tasks such as collision avoidance in crowds or traffic. The 3D-MOT task was designed following these principles and consists of a MOT component, a relatively large stimulated visual field area, stereoscopic 3D information, and measurement of speed thresholds. The readers are referred to Faubert and Sidebottom [4] for a detailed discussion and the underlying rational for the importance of each element that composes the 3D-MOT speed training task.

To test transferability, we chose to assess biological motion (BM) perception for 'life-size' point-light walkers in a virtual environment, as it has recently been shown that the distance in virtual space makes a huge difference in how well BM is perceived by older observers but not

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for young adults [6] and that it is arguably a socially relevant task [7].

Methods

Participants

Three groups participated in this study. Fourteen were included in the experimental group (mean age 67 years, range: 64–73 years old), fourteen in the untrained group (mean age 66 years, range: 64–72 years old), and 13 in the visual perceptual training group (mean age 66 years, range: 64–73 years old). All participants were unaware of the purpose of the experiment and had normal or corrected-to-normal vision (6/6 or better) with normal stereoacuity as measured by the Frisby test (40 s of arc or better). Viewing was binocular. Participants underwent a complete optometric exam at the University optometry clinic less than 6 months before testing. The complete eye examination included refraction, visual fields, tonometry, and retinal examination under pupil dilatation. No ocular pathology was found and all had normal visual fields. Furthermore, they completed the Mini-Mental State Examination [8], a screening measure for cognitive impairment and dementia. All the participants' scores were within the normal range (range: 27–30/30; the mean was 29.3/30) [9] and, therefore, all were considered cognitively healthy.

Hardware and stimuli

Apparatus

All tasks were assessed using a fully immersive virtual environment: the Cave Automatic Virtual Environment (CAVE) system [10,11]. The CAVE is an $8 \times 8 \times 8$ ft room that includes three canvas walls (one frontal and two laterals) and an epoxy floor that all serve as surfaces for image projection [12]. Four high-resolution projectors are synchronized and the image is updated in real time to maintain the true viewing perspective of the observer. The CAVE was equipped with a magnetic motion tracker system (Flock-of-Birds) capable of measuring head position and therefore correcting for the viewing perspective of the observers in real time. The CAVE was under the computer control of an SGI ONYX 3200 (two Infinite Reality 2 graphic cards; SGI, Fremont, California, USA) generating a stereoscopic environment. Stereoscopic vision was made possible using stereographics' LCD stereo shutter glasses (Crystal Eyes; StereoGraphics RealD, Beverly Hills, California, USA) operating at 96 Hz.

Stimuli and procedure

We formed three groups of observers including one experimental group that came to the lab once a week for 5 consecutive weeks. Every week, they were trained on the 3D-MOT speed task and the BM task was presented at week 5. One control group came once and ran three blocs of 3D-MOT and the BM task. Another control group trained on a visual perceptual task; they came to the lab once a week for 5 consecutive weeks. Every week, they were trained on the contrast task and the BM task was presented at week 5.

Three-dimensional multiple object tracking speed task

Stimuli consisted of nine spheres projected into a virtual cube with transparent virtual light blue walls. The anterior side of the cube measured 42° of visual angle and was seen at 57 cm. The virtual size of the spheres was between 20 and 55 cm (larger when they were in front of the virtual cube). The spheres followed a linear trajectory in the 3D virtual space but were bouncing on one another and on the walls when collisions occurred. Each trial had three targets.

Each bloc (i.e. staircase) lasted about 10 min. In one session, participants ran three staircases, for a total of 30 min. Each trial had five phases (Fig. 1). Speed thresholds were then evaluated using a 1-up 1-down staircase procedure [13], that is, after a correct response, the dependent variable (speed ball displacement) was increased by 0.05 log and decreased by the same proportion after each incorrect response, resulting in a threshold criterion of 50%. The staircase was interrupted

Fig. 1

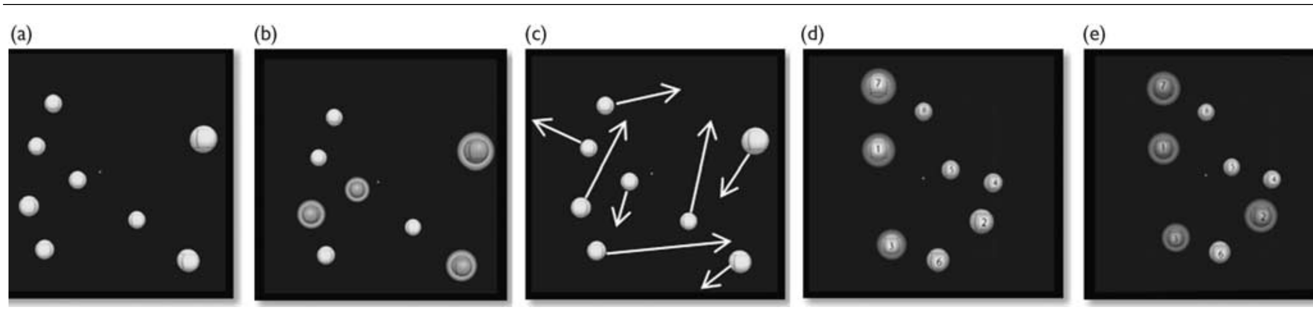


Illustration of the five critical phases: (a) presentation of randomly positioned spheres in a virtual volumetric space, (b) identification of the spheres to track during the trial, (c) removal of identification and movement of all spheres with dynamic interactions, (d) stoppage and observer's response by identifying the spheres, (e) feedback is given to the observers.

after eight inversions and the threshold was estimated by the mean of the speed at the last four inversions.

Biological motion task

Stimuli consisted of two components: a walker and a mask. The point-light walkers were dynamic representations of human form walking and were made up of 15 black dots, which represented the head, shoulders, hips, elbows, wrists, knees, and ankles on a white background. Each dot had a diameter of 0.1 m. The height of the walker was 1.80 m disposed at a virtual distance from the observer of 4 and 16 m subtending 25 and 6.4 degrees of visual angle, respectively. Walkers were randomly placed within the noise display area from trial to trial by 30 cm left or right from the central presentation and were presented facing left or right in an upright position. The walker stimulus was constructed using the average motion capture data; for a full explanation of the generation and representation of the stimuli [14]. The stimulus duration was 1 s with a gait cycle at a rate of 30 frames/s followed by a 500 ms interstimuli delay. The walker was masked by a number of noise, dots varying in each trial. The mask was a scrambled walker mask generated by taking walker stimuli and scrambling the initial spatial position of each dot. We designed a virtual box surrounding the stimulus within which the noise was constrained. Each box volume was 1.76 m^3. These dimensions are in virtual space and therefore all appropriate cues changed with experimental distance conditions (i.e. size, binocular disparity, and perspective cues). Each participant sat at 1.2 m from the CAVE's central wall with eye height at 1.60 m from the ground. They were asked to fixate straight ahead. A practice block trial was then presented using a constant stimuli method with 20 trials where the participant had to identify the direction of the unmasked walker and report their answers verbally. Testing was blocked for distance. Noise thresholds were evaluated using a 2-up 1-down staircase procedure [13], that is, after two consecutive correct responses, the dependent variable (noise dots' density) was increased by 10% and decreased by the same proportion after each incorrect response, resulting in a threshold criterion of 70.7%. The staircase was interrupted after 10 inversions and the thresholds were estimated by the mean of the noise quantity of the last six inversions. As in the practice trial, each observer's task consisted of identifying the walker's direction (right or left).

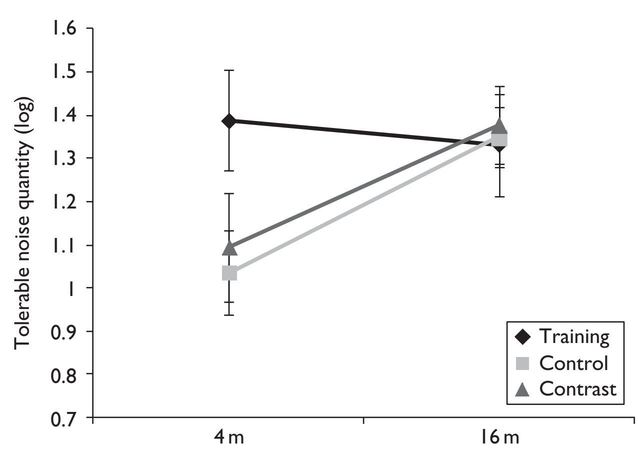
Contrast task

Stimuli were presented in a square hard-edged patch subtending 42° in diameter (same size as the virtual cube used for the 3D-MOT task). The stimulus extended over the entire 42° patch, and consisted of static, luminance-defined, sine modulated gray-scale noise, where the envelope (sine) and carrier (noise) are added. The sine wave had a frequency of 0.5 cpd. The mean luminance was 24 cd/m^2. Each participant was asked to look straight ahead at the fixation point. The task consisted of identifying the orientation (vertical or horizontal) of the grating, and answers were reported verbally. Stimulus duration was 1 s and was followed by a noise mask for 1 s. Contrast thresholds were then evaluated using a 2-up 1-down staircase procedure [13], that is, after two consecutive correct responses, the dependent variable (contrast) was decreased by 10% and increased by the same proportion after each incorrect response, resulting in a threshold criterion of 70.7%. The staircase was interrupted after 10 reversals and thresholds were estimated by taking the mean contrast intensity of the last six reversals.

Results

The results are presented in Fig. 2 and are immediately obvious from observing the graph. There is a clear effect of 3D-MOT speed training on the experimental group for BM perception performance scores at 4 m whereas the other two control groups show no effect. No effect is seen for the 16 m condition for any group. Statistically, there is a significant difference in 3D-MOT speed performance for trained versus untrained older adults ($F_{[1,25]} = 8.631$, $P = 0.005$). We found that older adults did not show a significant increase in their performance on the contrast task after 5 weeks of training ($F_{[1,13]} = 1.936$, $P = 0.187$). A repeated measures analysis of variance showed a significant Group (trained/control/contrast) by Conditions (distances) interaction ($F_{[1,38]} = 4.621$, $P = 0.016$). The results show that at 4 m, trained participants' noise tolerance was significantly higher than the control group performance ($t_{[1,13]} = 2.538$, $P = 0.025$). Moreover, untrained observers obtained a significant difference between both BM distance conditions ($t_{[1,13]} = -3.017$, $P = 0.011$), and trained older adults' noise tolerance at 4 m was equivalent to 16 m ($t_{[1,13]} = 0.579$, $P = 0.573$)

Fig. 2



Older adults' noise tolerance level at 4 and 16 m distance.

(Fig. 2). No significant difference was found with the control groups, P's more than 0.7 in both conditions. Furthermore, there was a significant difference between control-contrast and trained older adult group for the 4 m condition ($t_{[1,12]} = 2.299$, $P = 0.040$), but no significant difference for the 16 m condition ($t_{[1,12]} = -0.188$, $P = 0.854$).

Discussion

The main goal of this study was to assess whether training older observers on the 3D-MOT speed task can transfer to a socially relevant task such as BM perception. The results are clear in this respect where the only effective training transfer was seen for the 3D-MOT training experimental group, whereas the control (no training) and training control (spatial contrast) showed identical results.

Relevance of the three-dimensional multiple object tracking speed task speed task

As mentioned in the introduction, the 3D-MOT virtual reality speed task was originally developed on the basis of the rationale that a task with such high dynamic perceptual-cognitive processing demands would be quite analogous to the processing requirements required for scene dynamics such as sports and when navigating in crowds. Faubert and Sidebottom [4] argued that certain characteristics were essential for a positive transfer. The stimulus needs to cover a significant visual field dimension, speed thresholds are necessary, tracking dynamic and multiple elements is essential, and stereoscopy generated the best results. The relevance of these characteristics have been made elsewhere and would require too much space to be covered in the present paper. However, visual field size and speed thresholds, two inherent components of the method proposed by Faubert and Sidebottom, have been shown to be critical factors when training older observers in other perceptual tasks. In fact, recent results obtained by Edwards and colleagues [15,16] have shown that training the useful field of view (which had both a visual field and a speed training component) in older observers had a positive impact on retrospective driving abilities. This is very encouraging but still represents a correlational study. Here, we were able to directly test the transferability of a complex perceptual-cognitive dynamic scene on what is generally accepted as a socially relevant task, namely BM perception.

Relevance of biological motion task

The BM task is viewed by most researchers in the field as a critical and fundamental ability of social relevance. Many characteristics of an individual can be derived just by the dynamics of the motion signals between the point lights. For instance, one can perceive demographic characteristics such as sex, body weight, emotions, and other social activities [7,17–22]. It is therefore a very strong dynamic cue that can be used for collision avoidance and to even anticipate moves in sports [23]. The fact that it was recently shown that older observers could not use this information in a context representing critical life-size conditions (such as a life-size walker at 4 m) emphasizes the relevance of this age-related loss [6]. It is therefore quite telling that that training on our 3D-MOT speed task actually improved this particular ability.

Conclusion

In conclusion, we have successfully shown a transfer of training from a perceptual-cognitive dynamic scene task to a socially relevant ability in the elderly, namely the capacity to process BM for life-size walkers at a critical distance of 4 m.

Acknowledgements

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Conflicts of interest

There are no conflicts of interest.

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