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Low diversity and low frequency of participation in leisure activities compromise working memory efficiency in young adults

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ABSTRACT

People perform leisure activities (LA) every day; pursuits that entail applying cognitive, physical and social abilities. As in old age, doing LA during early and middle adulthood is related to a reduced risk of dementias, probably by generating a cognitive reserve. As it is possible that a relation between doing LA and working memory (WM) efficiency exists in young adults, we assessed whether the diversity and frequency of LA are related to WM efficiency in this population. Ninety-three healthy young subjects solved the *n*-back task at two levels of difficulty (2, 3), and answered an LA questionnaire on the activities in which they had participated in the month prior to the experiment. Subjects were classified separately on their scores for (1) diversity (high/low) and (2) frequency (high/low) in order to test the relation between each variable and WM efficiency. Though no differences were found, a subsequent analysis of the average of diversity and frequency ratios of LA performance taken together—the diversity/frequency index—showed that low diversity plus low frequency was significantly associated with reduced WM efficiency at this age; results that suggest that frequent participation in diverse LA during youth is related to WM efficiency.

1. Introduction

Leisure activities (LA) are defined as non-remunerated pursuits carried out at times when one is free from work or other obligations. They are intended to amuse, gladden or entertain, and can be categorized as cognitive (or intellectual), social and physical (Aartsen, Smits, Tilburg, Knipscheer, & Deeg, 2002; Scarmeas, Levy, Tang, Manly, & Stern, 2001; Verghese et al., 2003). Their performance involves exercising different cognitive abilities—*e. g.*, memory, attention, and reasoning (Fabrigoule, 2002; Scarmeas et al., 2001). These cognitive, social and physical activities appear to generate a cognitive reserve that delays the onset of neurological pathologies (Aartsen et al., 2002; Scarmeas et al., 2001; Verghese et al., 2003; Wilson et al., 2002).

LA are part of one's everyday life. We know that both diversity (Scarmeas et al., 2001)—*i.e.*, participating in different types of LA—and a high practice frequency have been shown to be related to a reduced risk of suffering dementias and other diseases later in life (Verghese et al., 2003; Stern & Munn, 2010). In particular, frequency has been associated with a lower risk of diminished global cognition and lower rates of decline in working memory efficiency in old age (Wilson et al., 2002), and with a reduced risk of developing Alzheimer's disease (AD; Lautenschlager et al., 2008). In addition, when older adults participate in training programs that involve performing physical (e. g., walking, for 24 weeks) or intellectual activities (e. g., playing video games for 23.5 h during 4–5 weeks), their memory, attention, language and praxis all improved compared to control subjects (Basak, Boot, Voss, & Kramer, 2008; Lautenschlager et al., 2008; Miller, 2005). In children, a 10-day training program in yoga, but not one in fine arts, was shown to increase spatial short-term memory recall (Manjunath & Telles, 2004). These and other results suggest that not all types of LA are related to cognitive abilities equally (Fritsch et al., 2007; Schellenberg, 2004), nor do they all lower the risk of suffering AD and other dementias to the same degree (Fritsch et al., 2007; Stern & Munn, 2010). However, the fact is that involvement in physical and intellectual activities are related to better cognitive performance (Basak et al., 2008; Green & Bavelier, 2006a; Lautenschlager et al., 2008; Manjunath & Telles, 2004; Miller, 2005).

The means through which LA reduce the risk of dementias and potentially improve cognitive function remains unclear; nevertheless, we believe it is possible that doing LA presents the individual with a new environment or new problem to solve that challenges his/her abilities. Therefore, it may be that with practice, synaptic mechanisms in

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the brain operate to enhance cognitive functions; for example, musical, athletic and game experiences have effects on perception, motor skills and cognition (for a review, see Green & Bavelier, 2008). In this way, the habitual performance of LA may promote brain plasticity; hence, the performance of LA by humans might be comparable to the conditions of enriched environments (EE) used in animal models. Under EE conditions, sensory, motor and cognitive stimulation take place and foster behavioral, cellular and molecular changes, such as neurogenesis and synaptogenesis (see Nithianantharajah & Hannan, 2009). Complementary studies in humans have shown that impoverished environments that impose no cognitive or sensory demands—e. g., solitary confinement—are related to psychiatric symptoms and alterations in signal processing (Bartesaghi, Raffi, & Ciani, 2006; Grassian, 2006; Haney, 2003; Sireteanu, Oertel, Mohr, Linden, & Singer, 2008).

In recent generations, activities such as watching television, playing video games and using computers and the Internet have become common practices that enhance certain abilities (Bavelier, Green, & Dye, 2010; Patriarca, Di Giuseppe, Albano, Marinelli, & Angelillo, 2009). These pursuits have been described as modifying attention control and short-term memory in young adults (Boot, Kramer, Simons, Fabiani, & Gratton, 2008; Green & Bavelier, 2003, 2006a, 2006b) and practices that enhance specific brain responses (Gaddipati, Moody, Shirinyan, Small, & Bookheimer, 2010; Mishra, Zinni, Bavelier, & Hillyard, 2011; Small, Moody, Siddarth, & Bookheimer, 2009).

These results suggest that the deeds we perform every day have an impact on our cognitive function. Though it would clearly be unethical to deprive a person of doing his/her habitual LA, it is possible to test in a more naturalistic and habitual way whether the diversity and frequency of such activities are related to working memory efficiency in young adults. We decided to study working memory because this particular type of memory is needed to perform actions in the short term and requires the integration of perception and actions (Fuster, 2008). Working memory is a limited store that maintains and manipulates information and associated strategies of online processing in the short term in order to achieve intermediate goals (Raz, 2000). Also, it facilitates other cognitive processes, such as reasoning, learning and comprehension (Baddeley, 1996, 2003). The main question here is whether doing LA is related to an enhancement of working memory efficiency in young adults, as other studies have shown for older adults (e. g., Wilson et al., 2002). It is well known that working memory reaches its highest peak during young adulthood and then shows a decline during the rest of one's lifespan (Hardy & Scanlon, 2010; Park & Payer, 2006). However, working memory, even in young adults, might improve under certain conditions, such as training or exercise (Mcnab et al., 2009; Stroth et al., 2010). These earlier results suggest, first, that performance levels do not reach 100% in all people but, rather, achieve their maximum levels during young adulthood; and, second, that performance is susceptible to improvement. Thus, the aim of this study was to further clarify the relation between the diversity and frequency of doing LA and working memory efficiency in healthy young adult subjects. We hypothesized that if LA have the aforementioned relation in older adults, then comparable levels of diversity and frequency of LA, performed habitually by young subjects, will be related to an improved performance on working memory tasks. On the other hand, one would expect that a lower diversity and frequency of doing LA would be related to lower performances on such tasks by subjects.

2. Methods

2.1. Participants

Ninety-three young, neurologically and psychiatrically healthy, right-handed (Edinburgh Inventory, +41 to +100; Oldfield, 1971) subjects (46 males, 47 females; Mean ± SD: 23.68 ± 2.67 years of age, range: 21–30 years; 16.45 ± 1.85 years of schooling, range: 12–20.5 years) were recruited for this study. A structured interview was used to detect if any of them, or their first-degree relatives, had suffered a neurological or psychiatric disease. Only subjects who reported a complete absence of neurological or psychiatric disease and negative inherited/family antecedents were accepted for the study. The Beck Depression and Anxiety Inventories were then used to rule out prospective participants with depression or anxiety symptoms before beginning the experimental session. None of the participants were taking any medications that might have affected their central nervous system during the session. Also, subjects had no history of drug addiction and none reported consuming an illicit drug in their lifetime. All had normal-to-corrected vision. The experiments were performed on one of three different schedules—at 10:00, 13:00 or 16:00 h—in order to keep constant diurnal effects (Monk et al., 1997). The study was approved by the Research and Ethics Committee of the Faculty of Medicine at the *Universidad Nacional Autónoma de México*. After participants received a detailed description of the study, their written informed consent was obtained.

2.2. Working memory assessment: the n-back task

Participants were asked to solve an *n*-back task at two levels of difficulty (2, 3) in two separate, counterbalanced blocks. In the *n*-back task, subjects are shown a sequence of stimuli, and for each one they must detect whether or not it matches the stimulus presented at *n* places earlier in the series. The task requires storing, manipulating and updating information in the working memory (Jonides et al., 1997). As the *n*-value rises, the task becomes more difficult and brain metabolism responses increase (Jonides et al., 1997). In this study, we challenged our subjects to one medium (*2*-back) and one high-level (*3*-back) working memory task.

2.3. Procedure

An 8 × 8 matrix was displayed in the center of a screen (horizontal visual angle, HVA: 5.6104°; vertical visual angle, VVA: 5.6104°). The lines of the matrix were depicted in dark gray on a light gray background to prevent the appearance of post-images. A cross in the center of the matrix (HVA: 0.6875°, VVA: 0.5730°) was used as a fixation point throughout the experiment. A dark gray-filled circle (HVA and VVA: 0.4011°) appeared for 500 ms in one of the 60 possible positions in the matrix; the four cells bordering the fixation point were not used during the task. Using their index fingers (counterbalanced among subjects), participants were required to press one button if the position of the circle was the same as that presented during *n*-back trials (2 or 3), and another button if it was different. Subjects had 1500 ms to respond, timed from the moment at which the circle appeared. The inter-stimulus interval was 1000 ms, and each block consisted of 120 trials, 24 of which (20%) were target—*i.e.*, the position of the circle was the same as that presented *n* items before—and 96 (80%) non-target trials, where the position of the circle was different from the one presented *n* items before.

An Adjusted Hit Rate (AHR) was calculated to detect subjects' efficiency in discriminating between target and non-target stimuli (Abi-Dargham et al., 2002). The operation is Hit Rate-minus-Error Rate (HR–ER). HR was calculated by dividing the number of correct responses for targets by the total number of targets (maximum = 1, minimum = 0); while ER resulted from dividing the number of errors for non-targets by the total number of non-targets (maximum = 1, minimum = 0) (Abi-Dargham et al., 2002). Thus, obtaining all correct responses with no errors gave an AHR equal to 1; while obtaining all incorrect responses and no correct ones resulted in an AHR equal to −1. An AHR equal to 0 represents a response level that is equal to chance (Abi-Dargham et al., 2002).