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Adaptive changes in human memory: a literature review

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Abstract

The paper contains a review of the literature concerning memory abilities and human senses performance under different environmental circumstances. A number of studies indicated that environment has a significant impact on human senses functioning. It can affect it in a mechanical way, by a chronic exposure to potentially harmful substances or processes in different work environments. Also, some cognitive abilities that have evolved to perform evolutionary essential functions lost their importance because of the change of environment impact. Moreover, training can be a source of improvement of both human senses and cognitive abilities, as well. That might suggest that, while using, under different environmental circumstances different cognitive abilities develop. We take into a particular consideration human memory and its role, show current studies in this field and suggest new research directions.

Key words: adaptation, environmental changes, long-term memory, short-term memory, working memory, sensory memory

Memory has been widely investigated in modern societies (Ericsson, & Kintsch, 1995; Goelet et al., 1986; Hulme, Maughan, & Brown, 1991; Pearson, & Brascamp, 2008; Peterson, 1966; Tulving, 1985). Among the other ones, the three broad types of memory: short-term memory, long-term memory and sensory memory have been described as the basic ones (e.g., Baddeley, Thomson, & Buchanan, 1975; Deutsch, & Deutsch, 1975; Hulme, Maughan, & Brown, 1991; Rumelhart, Lindsay, & Norman, 1972). As it was shown, the above types of memory are essential parts of human cognitive processes and human everyday activities, as well.

One of the most important components of any cognitive activity is long-term memory. It is described as a system or systems underpinning the capacity to store information over long periods of time (Baddeley, Eysenck, & Anderson, 2009). Long-term memory consists of two main components: explicit (declarative memory) and implicit (nondeclarative memory), which are accordingly divided into episodic and semantic memory and conditioning, skills, priming, etc. (Squire, 1992, see for review: Baddeley, Eysenck, & Anderson, 2009). Explicit memory refers to situations that generally involve memory, both for specific events (episodic memory) and general facts or information about the world (semantic memory) (Baddeley, Eysenck, & Anderson, 2009). As explicit memory requires conscious thought, it is an intentional recollection of previous experiences (Graf, & Schacter, 1985). Implicit memory, on the contrary, does not require conscious thought, as it refers to situations when previous experiences impact the performance of a task without conscious awareness of the previous ones (Schacter, 1987; see for review: Baddeley, Eysenck, & Anderson, 2009).

At the same time, short-term memory is assumed to retain small amounts of material (4-7 elements) over periods of a few seconds (Baddeley, Eysenck, & Anderson, 2009). Short-term memory is a crucial part of the general memory system, as it feeds information into and out of the long term store. It is responsible for selecting and operating strategies and can also be used while being involved in complex activities (Baddeley, Eysenck, & Anderson, 2009). What is more, short-term memory underpins complex cognitive activities and supports the capacity for mental work and coherent thoughts, serving as a working memory (Baddeley, & Hitch 1974). To exam the limits of working memory capacity, the Peterson task (Peterson, & Peterson, 1959) was mostly used (Baddeley, Eysenck, & Anderson, 2009). The task is based on recalling meaningless three-consonant syllables after a brief delay (3, 6, 9, 12 or 18 seconds) filled by a rehearsal-preventing task.

As it was shown, working memory can be subdivided into a central executive system and at least two slave systems, which are responsible for different modalities (Rouby, Schaal, Dubois, Gervais, & Holley, 2002). One of them is specialized for verbal information, while the other one for visual information (Baddeley, 1992). This division was also confirmed by neurological researches (Owen, 1997; Vallar, & Papagno, 1995). This way, we can distinguish iconic memory (e.g, Sperling, 1960), echoic memory (e.g., Neisser, 1967), olfactory memory (e.g., Brennan, Kaba, & Keverne, 1990), and haptic memory (e.g., Shih, Dubrowski, & Carnahan, 2009), at least. All together, they make sensory memory system.

Generally, sensory memory can be described as a tool to register sensory impressions and stimuli which are significant to survive (see: Baddeley, Eysenck, & Anderson, 2009). This function, called as sensory filtering, makes it possible to privilege the most essential data and to ignore the less essential ones. What is important, data are kept for a short time (1-2 seconds) only, and then they disappear or are replaced by new stimulus (Maruszewski, 2001, s.

128). After paying attention to the stimulus, data may be sent to short-term working memory, and the well-known stimuli are the privileged ones. The particular kinds of sensory memory impact significantly on human cognition abilities (Baltes, & Lindenberger, 1997).

Iconic sensual memory provides working memory system with a coherent representation of an entire visual perception (Dick, 1974). Iconic sensual memory is described as a large capacity, short-duration image, where iconic image is very brief (<1000 ms). Visual information obtained this way is limited and task dependent (Hayhoe, Bensinger, & Ballard, 1998).

The other kind of sensory memory is related to sound. Echoic memories can be defined as very brief sensory memory of some auditory stimuli (Javitt et al., 1997). Typically, echoic memories are stored for slightly longer periods of time than iconic memories, even up to 30 s. (Cowan, 1984, 1988; but see also: Sams et al., 1993).

There is also olfactory memory system (Croy, Zehner, Larsson, Zucco, & Hummel, 2015; for review, see: White, 1998). It refers to both memory for odors and memory that is connected to or evoked by odors (Herz, & Engen, 1996). Storage and decay processes in short-term odor memory still need to be accurately defined (Larsson, 2002).

Haptic memory can be described as an ability to retain impressions of haptically acquired information after removing the original stimulus. It is based on touch, described as an accurate and fast modality that allows to detect salient attributes of the spatial layout of tangible and unfamiliar objects (Heller, & Ballesteros, 2006). Haptic memory is the most effective for stimuli applied to the most sensitive areas of the skin (Murray, Ward, & Hockley, 1975). Shih et al. (2009) found that the haptic representation of object mass is shorter than 2 seconds of time and its duration and decay are similar to visual memory.

Evolutionary changes in human senses

A number of studies indicated that environment has a significant impact on human senses functioning (e.g., Burns, & Robinson, 1970; Guarneros, Hummel, Martínez-Gómez, & Hudson, 2009). It can affect the functioning in a mechanical way, by a chronic exposure to potentially harmful substances or processes in different work environments (e.g., Alberti, 1998; Ip, Rose, Morgan, Burlutsky, & Mitchell, 2008). According to Alberti (1998), in the United States 30 million people (about 11% of the total population) are at risk for hearing loss from excessive exposure to noise. Similarly, air pollution in large cities like Mexico City strongly impacts olfaction of the inhabitants, decreasing their olfaction abilities (Guarneros, Hummel, Martínez-Gómez, & Hudson, 2009) and leading to pathology at the level of the olfactory bulb (Calderon-Garciduenas et al., 2009). Also, some abilities that have evolved to perform evolutionary essential functions lost their importance because of the change of environment impact. For example, people in modern societies do not need to use olfactory cues to recognize items such as plants, whereas discriminating items by smell is practiced widely in traditional societies (Shephard, 1992, 2004).

On the other hand, training can be a source of improvement of both senses and working memory (e.g., Porter et al., 2007; Jiang, Olson, & Chun, 2000; Dwyer, & McKenzie, 1994; Dinse et al., 2005; Olesen, Westerberg, & Klinberg, 2004). For example, it was shown that vision training is a very effective method in sport (for review, see: Knudson, & Kluka, 1997). What is interesting, Gislén et al. (2006) proved that children in a tribe of sea-gypsies from South-East Asia, due to the environmental challenges, were found to have superior underwater vision compared to European children. This difference was reduced after one month of underwater training. Neurological works also suggest that practicing working memory task induces increasing in cortical activity (Olesen, Westerberg, & Klinberg, 2004). It might suggest that, while using, under different environmental circumstances different cognitive abilities develop.

Environment appears to impact significantly on human olfaction ability. In modern societies, olfaction is rarely used the way it is practiced in traditional societies. For example, the detection of food or medical plants (Brett, 1994, see for review: Shepard, 1992) by smell is still well explored in traditional populations (Stevenson, 2010). Sorokowska et al. (2013) found that Tsimane' (Bolivian Amazon), whose traditional subsistence patterns center on hunting, fishing, gathering, and horticulture have lower threshold (better smelling ability) of odor detection than industrialized German people. According to Byron's (2003) data, the majority of foods consumed within a typical Tsimane' household came from hunting, fishing, and crop products. 75% of meat consumed in such households was fish or wild meat. Likewise, some studies on the Matsigenka and Yora of the Peruvian Amazon (Shepard, 2004), the Kenyah Leppo` Ke of Borneo (Gollin, 2004), and the Aguaruna Jívaro of the northern Peruvian (Jernigan, 2008) proved the same eating habits (see for review: Sorokowska, Sorokowski, Hummel, & Huanca, 2013). Those studies suggest that, unlike modern societies, in traditional societies olfaction might be essential to find and identify food and medicinal plants (Sorokowska et al., 2013). Thus, as smell can be improved with training (e.g., Porter et al., 2007), olfaction in such societies might be more efficient than in industrialized groups.

Similarly, both vision and touch appear to be shaped by environmental influence. They both play an important role in traditional populations' medicine (Shepard, 1992, 2004), while not necessarily in modern societies. Visual and tactile properties of plants provide them with some information on therapeutic attributes of plants (Shepard, 1992). It is important to mention that medical system of some traditional populations, like Matsigenka (see: Shepard, 1998) or Kraho (Rodrigues, & Carlini, 2005) consists mostly of medical and psychoactive plants. Thus, both Matsigenka and Yora of the Peruvian Amazon value a number of plants with red, blood-like latex or juice in the treatment of illnesses associated with blood (Shepard, 1992), and red color is considered as the sole efficacious property. Some plants are used to cure infections only due to their suggestive shape and color (Shepard, 2004). For example, some twenty spiny plants from different botanical families are in common use to treat e.g., fever, pain, inflammation, headache and toothache (Shepard, 2004). As it was shown, both vision and touch performance can be impaired with training (see: Dinse et al., 2005; Gislén et al., 2006), thus, also these kinds of abilities might be more efficient in traditional populations.

Alike, hearing in modern societies is no more used the way it serves in traditional ones. For indigenous hunters (e.g., Hadza, see: Marlowe, 2005, 2009) where traditional way of hunting with bow and arrows (Levi et al., 2009; Shepard, 1992) is still the most important opportunity to gain food, sense of hearing is useful in their attempts to find a prey (see: Nadasdy, 2007). Some groups in Southern Africa developed even hunting signs (see: Mohr, & Fehn, 2014) to avoid being heard by animals and to hear them better by themselves. Matsigenka hunters use auditory cues to locate monkey troops, imitating woolly and spider monkey calls successfully enough to attract naïve troops (da Silva, Shepard, & Yu, 2005). Also, in some cultures hearing seems to be particularly important in intercommunication. For example, among a Lowland Amazonian people hearing is connected with cultural phenomenon of "Tchimap", "to hear-listen-understand" and value of good hearing is perceived in the generation of good relations between humans (Passes, 1998). As also hearing can be improved with training (e.g., Wright et al., 1997; see also: Song et al., 2012), it might be more developed in traditional societies than in modern ones.

Evolutionary changes in human memory

Furthermore, working memory appears to be an effective tool to save several information for a short time (Baddeley, Eysenck, & Anderson, 2009). Thus, this kind of memory seems to be widely used among modern Western societies, as is a predictor of multitasking performance (Konig, Buhner, & Murling, 2005). According to Gleick (1999), humans today function in a way similar to computer's working on several processes at the same time (see: Persson, & Erlandsson, 2002). Those variable activities, such as driving to work, talking on the phone, checking emails and listening to the music at the same time appear to support working memory improvement. What is more, short term memory is involved in learning new words, grammar processing and sentence comprehension (Baddeley et al. 1998). There is a rapidly growing number of studies demonstrating that training causes increase in working memory capacity (e.g., Lee, Lu, & Ko, 2007; Melby-Lervag, & Hulme, 2013; Morrison, & Chein, 2011). Thus, we can assume that working memory of humans in modern societies today might be more developed than in traditional ones.

Whereas short term working memory appears to be more efficient in multitasking performance, long term memory might be more useful while being involved in less simultaneous activities, typical for traditional populations.

As mentioned before, long term memory consists of two main components: explicit (declarative memory) and implicit (nondeclarative memory). Within the declarative memory, procedural component [memory for the performance of repeated types of actions, like routine (Cohen, & Bacdayan, 1994), which is typical for traditional populations (see: Hobsbawm, 2012)] seems to be strongly linked to "onetasking" performance.

Additionally, long term memory might be supported by oral transmission, typical for traditional societies (Rubin, 1977). Oral narratives play an important role in a transmission of common knowledge (e.g., food acquisition, interpersonal matters, responses to rare and challenging events), stories (see: Huanca, 2006), and healing abilities (Shepard, 2004) in traditional populations. Since elderly people are a source of local knowledge, this may be the reason of more positive aging attitudes in pre-industrial settings, as it was investigated by Sorokowski et al. (2015). Also, in traditional societies elderly people's memory was perceived as better than it was in modern societies. The importance of oral transmission is also connected with an illiteracy phenomenon among these societies (Cowgill, & Holmes, 1972). It has been proved that increasing access to formal education is connected with loss of local knowledge, including self--treatment with herbal remedies and use of traditional healers (see: Vandebroek et al., 2011). At the same time, Bottiroli et al. (2008) demonstrated that tasks related to everyday life affected in improvement of memory (but see also: Bruel-Jungerman, Laroche, & Rampon, 2005). In result, long term memory might be more efficient among traditional societies.

On the other hand, a line of studies shows that schooling and the acquirement of school-related skills significantly affects some cognitive and non-cognitive skills (e.g., Carlsson, Dahl, Ockert, & Rooth, 2015; Muhlenweg, Blomeyer, Stichnoth, & Laucht, 2014; Zahodne et al., 2011; but see also: Reyes-Garcia et al., 2016). Literacy correlates with almost all neuropsychological measures impacting different spheres of cognitive functioning (Ardila et al., 2010). Learning to read and write effects both remembering strategies (Laboratory of Comparative Human Cognition, 1983) and several kinds of memory: verbal, visual and working memory, as well (for review, see: Ardila et al., 2010). According to that, schooled literates generally obtain better results than illiterates on some neuropsychological memory measures, such as wordlist learning and recall, complex figure drawing, digit backwards, verbal paired associates and letter-number sequencing tasks, and story learning and recall (for review, see: Ardila et al., 1989). The phenomenon might be explained by poor organization of the material to be memorized or inefficient encoding and retrieval strategy (Ardila, Ostrosky-Solis, & Mendoza, 2000). However, there is no significance difference between the two groups in object memory (e.g., Folia, & Kosmidis, 2003) and wordlist recognition memory (Ardila et al., 1989). Thus, the results of the future studies on memory in traditional societies are not obvious. It is not clear if people in those societies have better or worse memory and if so, what are the functions of the memory.

Environmental and evolutionary differences in cognitive abilities - further directions

Much of the research in cognitive abilities has been conducted in modern societies (e.g., Carlsson, Dahl, Ockert, & Rooth, 2015; Morrison, & Chein, 2011; Muhlenweg, Blomeyer, Stichnoth, & Laucht, 2014; Zahodne et al., 2011), whereas investigating the subject in traditional populations might bring important results. Lifestyle patterns of participants of indigenous societies might be considered as similar to prehistorcal habits. For example, a majority of the Yali tribe (Papua, Indonesian province, previously known as West Papua or Irian Jaya) lived the same way as average prehistorical people even in the 60s of 20th century, using stone tools only (Sorokowski, Sorokowska, & Danel, 2013; see also: Marlowe, 2010).

To our best knowledge, there have already been some studies on cognitive abilities in traditional populations (e.g., Cashdan et al., 2012; Sjoberg, Cannon, & Cole, 2014; Trumble et al., 2015; Vashro, & Cashdan, 2015) and the subject seems to pique the new researchers' interest, as well (e.g., Reyes-Garcia et al., 2016). As regards different cognitive abilities, Vashro and Cashdan (2015) investigated sex differences in spatial ability among Twe and Tjimba in Namibia. Likewise, Silverman, Choi and Peters (2007) examined object member location in a cross-cultural way, finding specific spatial advantages in both sexes.

In memory field, there was a study by Shepherd et al. (1974) on recognition memory for ethnically different faces, comparing African and European populations. European subjects performed at significantly higher level on recognizing European faces compared with African faces and African subjects performed at significantly higher level on recognizing African faces compared with European faces. Then, visual spatial memory was investigated in Australian Aboriginal children by Kearins (1981). The results of the study showed that Aboriginal children were superior at the tasks. There was also no difference for them between familiar and unfamiliar objects, while for white Australian children familiar items were easier than less familiar ones. Also, Wagner (1974) examined short term and incidental memory in two contrasting populations in urban and rural Yucatan, finding the developmental changes in memory performance of rural participants different than in urban educated ones. In a recent study, Reyes-Garcia et al. (2016) analyzed if the acquirement of two different forms of knowledge, schooling and local ecological knowledge, relates differently to cognition. Participants among three contemporary hunter-gatherer societies were tested for working memory, schooling and school related skills, local knowledge and skills related to hunting and medicinal plants. In the result, the differences between recall strategies of people who had attended school or not were found. Those without schooling performed better on semantic clustering, what suggests reliance on semantically meaningful categories rather than on rote learning (Reyes-Garcia et al., 2016, see also: Cole, & Scribner, 1974).

Considering the obtained results, the next studies on environmental influence on above kinds of memory appear to be an effective way to explain the existing adaptive changes in memory and the direction of the changes. Especially conducting studies in traditional populations and comparing the results to the ones obtained in the modern populations seem to give that opportunity. We suggest that the environmental influence on above kinds of memory will become an important research trend in cognitive sciences in the next years.

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