Journal of EVOLUTION & Technology

A peer-reviewed electronic journal published by the **Institute for Ethics and Emerging Technologies**

ISSN 1541-0099

22(1) – December 2011

Memory Enhancement: The Issues We Should Not Forget About

Laura Y. Cabrera
Institute for Biomedical Ethics Basel
Basel, Switzerland
laura.cabrera@unibas.ch

Journal of Evolution and Technology - Vol. 22 Issue 1 – December 2011 - pgs 97-109

Abstract

The human brain is in great part what it is because of the functional and structural properties of the 100 billion interconnected neurons that form it. These make it the body's most complex organ, and the one we most associate with concepts of selfhood and identity. The assumption held by many supporters of human enhancement, transhumanism, and technological posthumanity seems to be that the human brain can be continuously improved, as if it were another one of our machines. In this paper, I focus on some of the ethical issues that we should keep in mind when thinking about memory enhancement interventions. I start with an overview of one of the most precious capacities of the brain, namely memory. Then I analyze the different kinds of memory interventions that exist or are under research. Finally, I point out the issues that we should not forget when we consider enhancing our memories. In this regard, my argument is not against memory enhancement interventions; rather, it concentrates on the need to "keep in mind" what kind of enhancements we want. We should consider whether we want the kind of "enhancements" that will end up making us lose synapse connections, or the kind that promote more use of them.

Human memory: an overview

The human brain is in great part what it is because of the functional and structural properties of the around 100 billion interconnected neurons that form it. Considering that, on average, each of the neocortical neurons has 7,000 connections to other neurons (SFN 2008), the brain is undeniably the body's most complex organ. One very important core faculty associated with our brains is memory.

When talking about the kind of technological interventions that are becoming available, we need to understand memory as more than just stored information in our minds. I am not trying here to fully explain what memory is, as memory has been studied in many different disciplines, from neurobiology to philosophy, and there is no obvious consensus on what it really is or how it really works. Thus, for my analysis here I will focus mostly on a brain-based account of memory (a neurobiological approach to the subject).

In the past, memory was viewed as a unitary system performing recall and learning of information, and associating related pieces of information with each other (Bear et al. 2001, Liao and Sandberg 2008). This unitary view was later replaced by an approach that divided memory into a number of functional systems, each with more specialized functions. As a result of this, memory is viewed now as the result of multiple systems that have different logics and neuroanatomical bases, which give us the capacity for retaining, recalling and "storing" experiences (Bear et al. 2001, Kandel and Squire 2000). This conception of memory allows for interventions to focus on particular functional systems, for instance memory consolidation or memory retrieval.

In the literature, one of the most influential classifications to date of memory's component systems is that developed by Atkinson and Shiffrin.[1] The Atkinson and Shiffrin model of memory, also known as the multi-store model, distinguishes between: sensory memory (SM), short-term memory (STM), and long-term memory (LTM). According to this model, our senses first receive stimuli from the environment. The sensory memory, which lasts just a few seconds (1-2s), translates this information into interpretable elements. The translated information is either relayed to STM or lost forever. Most biological theories of memory agree with the idea that STMs are first stored in the medial temporal system in the form of particular self-sustaining neural activity patterns with different synaptic weights). Some of these short-term memories (particularly, but not necessarily, those that persist) go through a process called memory consolidation, in which they are transferred out of the medial temporal system and distributed across networks in cortical regions, forming long-term memories (Kandel and Squire 2000). In LTM, the neurons involved in the patterns of neural activity become more strongly connected through a process called long-term potentiation (LTP), which alters the structure of the synapses involved (Bear et. al 2001, Kandel and Squire 2000). Thus, when we say we store memories, it is not that we have a particular area of storage in our brains; rather, this expression conveys that our memories are kept in the form of distributed networks of potentiated synapses across different regions and structures of our brains.

The outcome of all these processes is what we commonly perceive as "memory," that is to say, the capacity to retain information and to reconstruct past associations and active states, usually for present but also for future purposes. As Michael Gazzaniga has put it, our memories are "not so much a mechanism for remembering the past as a means to prepare us for the future" (2005, 142).

The multi-store model brings to light some important points for thinking about memory interventions. First, it is not the same to alter memories that can easily be forgotten compared with altering memories that can last a life time (LTM is less likely to be forgotten). This should exert some weight when we assess the ethical aspects of memory modification interventions. Second, memory is already affected by our different experiences even when we are not conscious of the way this is done. Third, memory plays a crucial role in cognition. Here, I am referring to cognition as the process or processes by which an individual gains knowledge, or becomes aware, of events in his/her environment, and uses that knowledge for comprehension and problem solving about him or herself and about the world. Fourth, there is evidence that the action of remembering itself quite often relies on information outside our brains (i.e. the external world). And finally, there is also evidence that the same mental state never occurs twice, at least for some classes of mental states. That is, we never remember the same event in the same way, as the recall is influenced by information available at the moment of recollection (Schacter 2001), the aims we have at that moment, our reinterpretations, our intervening experiences (Levy 2007, Popper and Eccles 1985), and our emotions (McDonald 2008, McGaugh 2000) and desires (Frankfurt 1984). Consequently, it seems plausible that in most cases we create a memory rather than actually recalling it (Engel 1999). Thus, connections between events and memory traces, and between memory traces and recollection, may be indirect, context-dependent, multiple, and sometimes not necessary at all.

Summarizing, memory is one of the most central capacities we have in as much as it: (a) relates to the core of who we are in the most direct way (identity and continuity of the self); (b) helps us to build an interpretation of ourselves and our environment (it gives us a story, hopefully a coherent one, of ourselves and our world by interpreting, constructing, and condensing life experiences); and (c) gives

us a sense of continuity and connection to ourselves and others. All these are important insofar as our moral lives depend on the peculiar ways in which we are embedded in time (our past experiences enable us to find a narrative of how we come to be who we are now). It is because of all these characteristics that memory interventions should be taken seriously. In the next section, I will explore different memory enhancement interventions.

Memory enhancement: between the possible and the imaginable

As mentioned above, memory involves many mechanisms, and so there are many ways in which memory can be affected. In a broad sense, every technology, starting with painting and writing, has altered our ability to remember and our understanding of what it means to remember (Zoloth 2006).

Some methods for affecting memory have been used for thousands of years, and most people do not have any deep intuitive feelings for or against them. They include, for example, education and training (Bostrom and Sandberg 2009). Doing different exercises (e.g. playing video games or putting together jigsaw puzzles), practicing meditation, taking creativity courses, and drinking or eating certain herbs or food supplements are also among the common methods for affecting memory. There is also an expanding list of prospective biomedical enhancements, such as pharmaceuticals and neuromodulation techniques (Bostrom and Sandberg 2009, Farah et al. 2004). However, some researchers have argued that it is through non-biomedical means (e.g. advances in information technology and computing) that the most dramatic advances have been achieved, and will be achieved in future (Bostrom and Sandberg 2009).

The following are some examples of different kinds of memory interventions that are being researched and envisioned:

Chemical interventions

Considering that memory processes involve many different chemical messengers (neurotransmitters), one possible way to modify memory is by chemical interventions. These kinds of interventions are aimed at promoting or abolishing the formation of long term memories, or weakening patterns of potentiated synapses that would affect memory retrieval. A good example, and not precisely high-tech, of how to weaken memories is drinking alcoholic beverages. After a considerable amount of these substances, people seem to remember less details, and in some cases do not even remember anything at all.

It is already possible to observe a wide range of memory enhancing drugs (although not all of them are medically indicated for that particular purpose) that influence memory performance. The most common ones – including hormones, stimulants, nutrients, neuromodulators, and other drugs – improve memory encoding (Farah et al. 2004, Greely et al. 2008, Lynch 2002). These drugs improve recall of any episode experienced shortly after they are taken (e.g. modafinil improves working and episodic memory, while methylphenidate improves working memory).

Another group of drugs has an effect on memory consolidation, affecting long-term memory. Connected to these kinds of drugs, recent findings of specific neurons involved in the formation of memories are being used to develop new chemical strategies that can weaken responses connected to memories (Netherlands Organization for Scientific Research 2009). More recently, the finding of a molecule (PKMzeta) known to preserve memories (Serrano et al. 2008, Shema et al. 2011) and the role of calcium-permeable AMPA receptor dynamics in synapses (Clem and Huganir 2010) are intended to be used in the creation of therapies for treating depression, general anxiety, addictions, post-traumatic stress, and phobias. This kind of memory modification has received great interest from the military, particularly to treat soldiers with Post-Traumatic Stress Disorder (PTSD). Even though the long-term effects of these kinds of memory enhancement interventions in healthy individuals remain largely unknown, their potential clinical significance in the field of cognitive enhancement has been acknowledged by researchers (Greely et al. 2008, Shema et al. 2011).

Genetic intervention

Advances in genetics have made it possible to relate specific genes to memory and to synaptic plasticity (Carnegie Mellon University 2007). There are techniques now that allow us to turn genes on and off and to delete specific genes in specific brain regions. A recent example is the research of professor Li-Huei Tsai and colleagues, which shows that the gene HDAC2 regulates the expression of many genes implicated in brain plasticity and memory formation (Guan et al. 2009). This suggests that the HDAC2 gene could play a major role in eliciting memory enhancement.

Similar to most pharmacological interventions, most genetic interventions affect LTP at synapses, having an effect on certain aspects of declarative memory tasks, such as memory for space and objects (Kandel and Squire 2000). While some researchers have argued that genetic interventions are not likely to be very efficient methods for memory enhancement (Craig and Plomin 2006), more research is needed to support their claims. Moreover, more research is needed in order to understand the possible negative and positive effects of memory enhancement obtained by using genetic intervention. This option does not seem to be viable in the short-term as it would require more research outside lab conditions and would need to be tested on humans.

Other

There are other ways to manipulate memory that do not necessarily use chemical or genetic interventions, such as exploiting some memory error features (e.g. inducing false memories or bias). Memory errors make our memories vulnerable to added or missing information. We can be led to confuse perceived and imagined events, and in some cases even to "remember" things that actually never happened (Garry and Gerrie 2006). In this regard, psychological manipulation, without being a high technology memory technique, has worked quite efficiently in inserting and manipulating memories (Levy 2007, Loftus 2003).

More sophisticated memory interventions include: (a) brain stimulation, such as transcranial magnetic stimulation and deep brain stimulation; (b) neural interfaces, such as brain computer interfaces (BCIs); and (c) enriched environments, such as augmented reality. In the case of brain stimulation, there is evidence, as showed by Hamani and colleagues (2008), that hypothalamic stimulation could be used to improve certain memory functions. Hamani and colleagues found, while using deep brain stimulation for morbid obesity, that stimulation also increased the recollection capacity of their patient. Less invasive methods of memory stimulation, such as transcranial magnetic stimulation, have been used by other research groups to demonstrate improvement in learning, better memory for names, and temporary boosts in memory for patients with Alzheimer's disease (Avril 2010, Chi and Snyder 2001, Kadosh et al. 2010).

One example of neural interfaces with the potential for memory enhancement is the use of carbon nanotubes attached to specific neurons for enhancing their natural signal-processing capabilities (Johnson 2008). Most of the current BCIs are predominantly non-invasive devices (Donoghue 2008), but the goal is to improve them so they can not only be implanted but also fully integrated within the brain and capable of interfacing with several other devices (National Academies Keck Futures Initiative 2007, National Research Council 2008).

In the case of enriched environments, there is evidence showing that they can enhance memory function in various learning tasks, as they promote an increase of the number and levels of certain neurotransmitters involved in memory (Ali et al. 2009, van Praag et al. 2000). Enriched environments can sometimes present us with more effective cues for retrieval of memories than those created by our own thought processes (Clark 2007, Wagenaar 2008); in particular, these can be beneficial when we are under conditions that are known to impair recollection capacity (such as too much stress or advancing age). The World Wide Web, virtual reality interfaces, and some basic augmented reality interfaces (such as those available for smart phones) are some common examples of enriched

environments that are already available. Considering the amount of research taking place and advancing quickly in this area, on both the hardware and the software side, web-based applications are among the most realistic and widely available means for enhancing memory.

Many people are already taking advantage of enriched or augmented environments that help to improve memory processes and extend the relevant mechanisms of memory beyond the implicated areas of the brain, such as when we use of smart phones and computers to remind us about things. These are more than merely useful tools; they can become integral elements in our memory processes (Clark and Chalmers 1998). The environment and context-based aspect of memory has been acknowledged by many scholars (Clark 1997, Clark and Chalmers 1998, Popper and Eccles 1985). This presupposes the idea that memories are not disembodied logical reasoning outcomes of the isolated brain, but are, rather, embodied (they are partially dependent upon extra-cranial bodily processes) and embedded (they are partially dependent upon extra-bodily processes), and as such are affected by the social system and by the environment.

Finally, the most radical forms of memory enhancement interventions are those suggested by people who see the human brain (and the different mental capacities it enables) as something that can continuously be improved as if it were another one of our machines. Within such a view, memory is reduced to the transfer of informational patterns from the environment to the brain. A common example of a memory enhancement intervention envisioned by these people is mind-uploading, in other words uploading and downloading of memories to our computers at will (Bostrom 2005, Kurzweil 2005). Such a process, according to its supporters, would enable us to edit, erase and add new memories.

The idea of uploading a human mind to a computer, by replicating in silico the detailed computational processes that would normally take place in a particular human brain, also fits with the transhumanist desire for immortality. Insofar as we regard our neural pattern as the essential aspect of who we are, we could upload our memory's pattern to a computer and "live" in cyberspace even after our biological bodies have died. If this kind of memory intervention were to become possible, the ethical and philosophical issues related to memory interventions would become more urgent. For instance, what happens to the subject – to the idea of a self – if we reduce the human subject to just a particular pattern of information?

Some important issues we should not forget

There are important issues to be considered regarding memory enhancement interventions, particularly those that are radical and directly affect the brain. This is particularly so, considering that at present the detailed cellular and molecular mechanisms underlying memory formation, encoding, consolidation, and retrieval remain largely obscure. Supposing that in the future we manage to overcome the technical limitations around memory enhancement interventions, there is another set of issues to be considered, ones we should not forget about – the ethical issues. Memories are not discrete objects; this imposes limits on the exactness of memory "editing" and creates uncertainty about the consequences for subsequent retention and encoding of new memories.

For instance, an increased ability to remember every event could overflow our capacity to categorize memories, which could then impair our selectivity process, our ability to form abstractions of our lived experiences, and our ability to distinguish larger patterns (Liao and Sandberg 2008, Luria 1987). An "enhanced" memory could also end up in our remembering things that we do not want to remember, such as painful events or just trivial things that we do not consider important. Consider the case described by Alexander Luria, a Russian psychologist, in his book *The Mind of a Mnemonist: A Little Book About A Vast Memory* (1987). In this case, an individual had the ability to recall individual experiences with great clarity and after long periods of time, but also experienced difficulty in drawing any meaning from them (1987).

Furthermore, some memory enhancement interventions could impair our creativity and imaginative capabilities. In relation to this point, Hassabis and colleagues (2007) have published a study in which patients with hippocampus amnesia suffered an impaired capacity to imagine future scenarios. Memory interventions can also bring undesired side effects (e.g. greater sensitivity to pain or addiction), as it has been demonstrated by experiments with genetically modified mice (Wei et al. 2001).[2] Based on these cases, it can be concluded that altering memories, either by enabling more memory capacity or deleting certain memories, is likely to have direct implications for our ability to understand the meaning of the past and imagine the future. Given the role memory has in our lives, there are four specific ethical issues that deserve serious consideration and attention, and thus should not be forgotten when assessing memory enhancement interventions. I am not arguing that these are the only ethical issues around memory enhancement interventions, but they are the ones that seem to be closely related to brain interventions. Moreover, even though the issues are grouped in four different clusters this is essentially for presentational purposes, as I acknowledge they are interlinked in many ways.

(a) Identity: the core of who we are

It is because our existence takes place in time, and because our awareness of it requires self-reflection, that our memories are considered to be significantly constitutive of our identities (Locke 2004, Parfit 1971, Schechtman 1996). Most enhancement interventions affect our identities, even if only in very subtle ways (Brey 2009, DeGrazia 2005, Glannon 2007). For some researchers, the prospect of transforming an existing individual into a new one (altering his or her identity) is the most worrisome aspect of "enhancement technologies," perhaps exceeded only by the fact that we can end up pathologizing our identities as syndromes and disorders to be treated (Elliot 1998). Nonetheless, some researchers, such as DeGrazia (2005), find flaws in arguments that locate something highly problematic in enhancement technologies, based on their relationship to ideas of identity. For DeGrazia, these arguments fail to establish what they claim by appealing to different aspects or forms of identity, e.g. by confusing what he calls numerical identity and narrative identity.

We might think (as DeGrazia does) that it is highly implausible that enhancing a person's mental features would create a numerically distinct individual. It is more likely that a post-enhancement individual will still remember life before the intervention without any major alteration to her memories, goals, unique skills, and many important aspects of her personality. If so, we may be able to claim that she is the very same person that she was prior to the intervention: they are not numerically distinct individuals. However, with novel forms of increasingly sophisticated and precise memory enhancement interventions, this reasoning is not as stable as it might have seen. Clear examples, although still fictional ones, would be cases of fusion and brain duplication, which are implicit in the idea of mind-uploading.

Coming back to DeGrazia's point, even if he is right in that there is currently no real threat to numerical identity, we still have the issue that enhancement interventions affect one's self-conception and thereby one's narrative identity. This is not only a more common concern, but also, given its plausibility, to some degree a more important one (Zoloth 2006, Schechtman 1996). In this regard, the idea of an "identity crisis" can be understood as an instance in which there is no coherence between an individual's values and projects and the kind of things she authentically identifies with. For instance in cases where an individual values and projects are more the result of societal pressures and trends rather than the individual own convictions. Moreover, we cannot discard the possibility that certain memory changes could alter someone's self-narrative so profoundly, that they could result in a different individual altogether.

Whether or not a better distinction between the different aspects of identity could play a crucial role in moving forward the debate about identity in the moral discussions of memory enhancement interventions, what is important here is that these interventions do impact in one way or another on identity. Considering that identity has become essential to contemporary political discourse (including

models of the self, possibilities for solidarity and resistance, and political inclusiveness), it seems we have sufficient grounds to consider memory enhancement interventions carefully.

Some final remarks connected to identity. We live in times in which our identities are shaped by the way the boundaries between the human and the technological are blurred, and those concepts are seen as coextensive, mutually defining and co-dependent (Bukatman 1993). At the same time, the collective is harder to distinguish from the individual self, as our identities are dissolved, simulated, and reconstructed (Hayles 1999). Given that these identities are "an unmistakably doubled articulation in which we find both the end of the subject and a new subjectivity" (Bukatman 1993, 17), they are also regarded by some as cyborg or posthuman identities (Gray 1995, Hayles 1999). This new type of identity brings along changes related to our representation for others and ourselves in terms of social influence, and relationships of power, pleasure, virtuality and reality. All of these also deserve serious consideration.

(b) (Self-)knowledge and learning

It is through our memories that we can appreciate the uniqueness of each situation (once they're located in the past we cannot live events again, only remember them) but also the similarities of different situations that we have been confronted with. The memories we have about ourselves and the world shape our views and beliefs about the world and ourselves. Thus, the crucial role that memory plays for (self-)knowledge and learning is generally accepted (Hoerl 1999). While it is plausible to think that some memory enhancement interventions will enable people to acquire more self-knowledge, for instance by adding emotional valence to a past learning memory or experience, there are cases in which the results might not be so encouraging.

An important aspect for knowledge and learning has to do with the truthfulness of our memories. Our memories help us to build a frame of things we believe to be true about ourselves and the world (Bublitz and Merkel 2009, Elliot 1998, Taylor 1991). Therefore, the authenticity of our memories becomes an important concern, in particular, for those holding that the authenticity of our memories is based upon the individual actually having experienced the remembered things. According to this view, it is reasonable to think that by editing our memories, or allowing others to insert false memories into our minds, we are not only threatening the authenticity of what we know about the world and ourselves. If we go down this path, it might even amount to living in falsehood.

Imagine remembering a life and finding out that our "memories" are not really memories of our life experiences. We can have conflicting memories, such as remembering being in two different places at the same time on the same day, remembering that my car is blue when in fact I am looking at my red car, or having a memory of me and my sister at the beach when I was little while also knowing that I do not have a sister. Such conflicts would certainly put into question the truthfulness of our memories and what we know about ourselves and the world. In response to this, some authors have argued that, given the social nature of remembering, there must be a limit "to how inconsistent our false memories can be" (Liao and Sandberg 2008, 91). This seems like a reasonable point, unless, of course, we all live in a type of simulation or in a society in which the memories of a large proportion of the population have already been altered. Given the way our memories are kept in the form of distributed networks of potentiated synapses across different regions and structures of our brains, it might be argued that, even if a particular memory were crucial to our self-knowledge, it would be highly unlikely that we could achieve a radical alteration of it. Nevertheless, because of our memories' distributed nature even small changes to certain memories might end up distorting others.

A related concern is connected to the idea of what would happen if many different people were to share their memories through being permanently connected to databases. What happens to the "uniqueness" of the individual as it merges with the communal? In the words of Bert Gordjin, this "could blur the borderline between the self and the cyberthink community" and "between the real world and the virtual world" (2006, 730).

If memory interventions meant that people did not need to go through experiences themselves in order to learn from them, this might plausibly challenge common understandings of learning. Consider, for instance, that you might have a brain implant that enables you to speak Spanish without having had any Spanish lessons. For some people, the fact that no learning process was involved is not a source of special concern: what matters is that the individual has useful information available to her. Against this view, however, it can be argued that the learning process itself is important because it is what distinguishes us from being mere cogs in a machine. Learning something involves more than the acquisition of new knowledge, and thinking otherwise would imply a mechanistic and reductionist account of what it means to be human. Likewise, memory is more than keeping the newly acquired information in our heads so we can make use of it at some point in the future. More importantly, learning is a process that seems to be designed so that only things that are meaningful, important, or enjoyable are remembered. Thus, merely having more capacity to remember more things – without being able to grasp their meaning, or being able to know how to use all this information in the relevant context – could be considered an instance in which memory enhancement actually impairs our ability to learn.

(c) The moral agent and agency

Closely connected to (self-)knowledge and learning is the importance of memory for enabling the moral agent, particularly if we agree that agency is shaped by our knowledge about ourselves and the world, as well as by our learned experiences (Levy 2007, Liao and Sandberg 2008). Some memory enhancement interventions precisely exploit the links between memory and agency in someone's best interests. For example, there could be cases where the harm done to us is so traumatic and damaging to our well-being that we might need to forget the event by weakening, or in the future even deleting, the associated memories. Think of soldiers who "may not just want to forget that they killed; they may also want to forget how to kill" (Liao and Sandberg 2008, 93), or cases of destructive habits (such as drug abuse), in which, even when the person desires to break free of them, it is difficult so long as she retains the memories (a type of reward-based conditioning) associated with her habits.

However, there are cases in which the interventions might not be in someone's best interests. When we are not able to recall the things we have experienced, we are missing the opportunity to form ideas of how we should act when confronted with similar situations in the future. George Santayana captured this idea when he said that "those who cannot remember the past are condemned to repeat it" (1905). Hence, if we cannot remember, or are not able to grasp and reflect about, the moral of our previous experiences, it is likely that we will keep committing over and over again the same mistakes. Moreover, as Hoerl pointed out, "sensitivity to the fact that certain deeds cannot be undone is inseparable from the insight that we have to live with the consequences of our past deeds (and of past events in general" (1999, 245).

Some memory enhancement interventions, such as neural prostheses, also suggest a different configuration of agency, as they are not just a medium but materially reconfigure "the intersubjective unit body and technology as an intrasubjective entity" (Cartwright and Goldfarb 2006, 138). In the past, most of our mental world was just for ourselves; however, certain memory interventions are likely to put at risk the privacy of our mental world. Consider, for instance, the use of mind-reading technologies for screening whether or not someone is telling the truth. It is significantly different to search a house compared with going into someone's brain in search of memories and thoughts.

Modifying our memories could also affect our normative status as agents (Liao and Sandberg 2008, Glannon 2007). Retaining certain memories gives us an opportunity to think through them for ourselves and to address them. This seems to be part of exercising appropriate agency and respecting ourselves as agents. Therefore, modifying memories before we have come to realize the underlying moral of the experience could impair our development as moral agents. This, in turn, would impair our ability to react in an "appropriate" moral way (forgiving someone after s/he has harmed you, for example, or feeling regret after having harmed others). For this reason, having the capacity to reflect

upon our memories for ourselves and address them accordingly, is crucial for exercising appropriate agency (Glannon 2007, Liao and Sandberg 2008) and respecting ourselves as agents (Taylor 1991).

(d) Memory enhancement as moral obligation

There might be cases where our memories are about certain events, or certain people, and it is important for others that we retain those memories (e.g. the case of someone who is the only witness of a crime or the only person who could have some important information about the criminals). These cases seem to imply a duty not to lose those memories (Levy 2007, Liao and Sandberg 2008). In such cases, we might have an obligation to use memory enhancement interventions to assure the preservation of the relevant memories. However, if the memory is adversely affecting its holder, it is hard to see, once the memory has been materialized in a different format (such as a book), why the person still has a duty to keep it in his or her mind.

At present, one is generally not held responsible for forgetting. However, this might change once memory enhancement (in the form of retaining memories longer) becomes widely available. This problem is exacerbated if we consider that half of the ten leading causes of disability around the world involve some form of memory impairment. Thus, while it would be unethical to force people to use memory enhancement technologies in order to remember things we regard as important, we might, as a society, have a moral duty to make these technologies accessible for those who desire to keep their memories and need assistance.

Conclusion

My main theme here is cautionary. I have argued that technologies which would bring memory enhancement to the fore may be much more imminent than is often thought. Secondly, the issues involved are complicated ones, but we already have examples of the crucial role that memory plays in our lives. In this sense, there is a contrast with other technological interventions where we do not yet understand the ethical issues at stake. For instance, people suffering from amnesia or Alzheimer's disease, both disorders in which memory is greatly impaired, provide clear examples of how the quality of human life and the range of opportunities are affected by memory. Moreover, people who are closely connected to them (i.e. family and friends) also suffer as a result of a person's memory impairment.

My limited aim has been to draw attention to issues that should not be forgotten when dealing with memory enhancement. Thus, we need to "keep in mind" the kind of memory enhancement interventions we promote in society. In particular, we should question the use of high technological interventions when we already know there are less problematic ways to enhance our memories (such as a diary, notes or even smart environments) that involve neither direct nor radical changes to our brains. Finally we should ask ourselves whether we want the kind of memory "enhancements" that will end up making us lose synapse connections, or the kind of enhancements that promote more usage of them.

Notes

1. Although it has been criticized for being too simplistic, mechanistic, and reductionist, this model explains well how information is processed. However, it does not explain how behavior is affected, and that is the main source of the different critiques.

2. However, some researchers think the results presented by Wei and colleagues just show that mice learn about pain and thus seem to react to it differently (Tang et al. 2001).

Bibliography

Ali, A., Y. Wilson, and M. Murphy. 2009. A single exposure to an enriched environment stimulates the activation of discrete neuronal populations in the brain of the fos-tau-lacZ mouse. *Neurobiology of Learning and Memory* 92: 381-90.

Avril, T. 2010. A tiny zap to improve memory? *Philadelphia Inquirer* October 23. [Reprinted in The Dana Foundation's Brain in the News, November 2010 (pp.1-2)].

Bear, M., B. Connors, and M. Paradiso. 2001. *Neuroscience: Exploring the brain*. Baltimore: Lippincott Williams & Wilkins.

Bostrom, N. 2005. A history of transhumanist thought. *Journal of Evolution and Technology* 14 (1).

Bostrom, N. and A. Sandberg. 2009. Cognitive enhancement: Methods, ethics, regulatory challenges. *Science and Engineering Ethics* 15: 311-41.

Brey, P. 2009. Human enhancement and personal identity. In *New waves in philosophy of technology*, ed. J. Kyrre, B. Olsen, E. Selinger, and S. Riis, 169-85. New York: Palgrave Macmillan.

Bublitz, J. C. and R. Merkel. 2009. Autonomy and authenticity of enhanced personality traits. *Bioethics* 23(6): 360-74.

Bukatman, S. 1993. *Terminal identity: The virtual subject in postmodern science fiction*. Durham, NC: Duke University Press.

Carnegie Mellon University. 2007. Scientists identify genes activated during learning and memory. *ScienceDaily* 19 April.
http://www.sciencedaily.com/releases/2007/04/070418104300.htm, accessed November 22, 2009.

Cartwright, L. and B. Goldfarb. 2006. On the subject of neural and sensory prostheses. In *The prosthetic impulse: From a posthuman present to a biocultural future*, ed. M. Smith and J. Morra, 125-154. Cambridge, MA: MIT Press.

Chi, R. and A. Snyder. 2011. Facilitate insight by non-invasive brain stimulation. *PlosONE* 6 (2): e166655: 1-7.

Clark, A. 1997. Being there: Putting brain, body, and world together again. Cambridge, MA: MIT Press.

Clark, A. and D. Chalmers. 1998. The extended mind. *Analysis* 58(1): 14-16.

Clem, R. and R. Huganir. 2010. Calcium-permeable AMPA receptor dynamics mediate fear memory erasure. *Science* 330 (6007): 1109-1112.

Craig, I. and R. Plomin. 2006. Quantitative trait loci for IQ and other complex traits: single-nucleotide polymorphism genotyping using pooled DNA and microarrays. *Genes, Brain and Behavior* 5: 32-37.

DeGrazia, D. 2005. Enhancement technologies and human identity. *Journal of Medicine and Philosophy* 30: 261-83.

Elliot, C. February 26, 1998. What's wrong with enhancement technologies? CHIPS Public Lecture. University of Minnesota.
http://www.ucl.ac.uk/~ucbtdag/bioethics/writings/Elliott.html, accessed January 23, 2009.

Engel, S. 1999. *Context is everything: The nature of memory*. New York: W.H. Freeman.

Farah, M., J. Illes, R. Cook-Deegan, H. Gardner, E. Kandel, P. King, E. Parens, B. Sahakian, and P. Wolpe. 2004. Neurocognitive enhancement: What can we do and what should we do? *Nature Reviews Neuroscience* 5: 421-25.

Frankfurt, H. 1984. Necessity and desire. *Philosophy and Phenomenological Research* 45(1): 1-13.

Garry, M. and M.P. Gerrie. 2006. When photographs create false memories. *Current Directions in Psychological Science* 146: 321-25.

Gazzaniga, M. 2005. *The ethical brain*. New York: Dana Press.

Glannon, W. 2007. *Bioethics and the brain*. New York: Oxford University Press.

Gordijn, B. 2006. Converging NBIC technologies for improving human performance: A critical assessment of the novelty and the prospects of the project. *Journal of Law and Medical Ethics* 34(4): 726-32.

Gray, C. H. ed. 1995. *The cyborg handbook*. New York and London: Routledge.

Greely, H., B. Sahakian, J. Harris, R. Kessler, M. Gazzaniga, P. Campbell and M. Farah. 2008. Towards responsible use of cognitive enhancing drugs by the healthy. *Nature* 456 (7223): 702-705.

Guan, J., S. Haggarty, E. Giacometti, J. Dannenberg, N. Joseph, J. Gao, T. Nieland, and H. Tsai. 2009. HDAC2 negatively regulates memory formation and synaptic plasticity. *Nature* 459(7): 55-59.

Hamani, C., M. P. McAndrews, M. Cohn, M. Oh, D. Zumsteg, C. Shapiro, R. Wennberg and A. Lozano. 2008. Memory enhancement induced by hypothalamic fornix deep brain stimulation. *Annals of Neurology* 63(1): 119-23.

Hassabis, D., D. Kumaran, S. Vann, and A. Maguire. 2007. Patients with hippocampal amnesia cannot imagine new experiences. *PNAS* 104(5): 1726-1731.

Hayles, N. K. 1999. *How we became posthuman: Virtual bodies in cybernetics, literature and informatics*. Chicago: University of Chicago Press.

Hoerl, C. 1999. Memory, amnesia, and the past. *Mind and Language* 14(2): 227-51.

Johnson, C. December 29, 2008. Nanotubes shown to boost neural signals. *EETimes*. http://www.eetimes.com/news/latest/showArticle.jhtml?articleID=212700093, accessed December 11, 2009.

Kadosh, R., S. Soskic, T. Luculano, R. Kanai and V. Walsh. 2010. Modulating neuronal activity produces specific and long-lasting changes in numerical competence. *Current Biology* 20(22): 2016-2020.

Kandel, E. and L. Squire. 2000. Neuroscience: Breaking down scientific barriers to the study of brain and mind. *Science* 290(5494): 1113-1120.

Kurzweil, R. 2005. *The singularity is near: When humans transcend biology*. New York: Viking Penguin.

Levy N. 2007. *Neuroethics*. Cambridge: Cambridge University Press.

Liao, M. and A. Sandberg. 2008. The normativity of memory modification. *Neuroethics* 1(2): 85-99.

Locke, J.2004. Essay concerning human understanding. eBooks@Adelaide. http://ebooks.adelaide.edu.au/l/locke/john/l81u/. Accessed January 13, 2009. (Orig. pub. 1690.)

Loftus, E. 2003. Make believe memories. *American Psychologist* 58(11): 857-73.

Luria, A. R.1987. *The mind of a mnemonist: A little book about a vast memory*. Harvard: University Press.

Lynch, G. 2002. Memory enhancement: The search for mechanism-based drugs. *Nature Neuroscience* 5 Suppl: 1035-1038.

McGaugh, J. L. 2000. Neuroscience-memory – A century of consolidation. *Science* 287(5451): 248-51.

McDonald, K. October 24, 2008. Emotion, memory and small conductance channels QBI scientists describe cellular mechanism for enhanced memory formation. Australian Life Scientist. http://www.biotechnews.com.au, accessed February 24, 2009.

National Academies Keck Futures Initiative. 2007. Smart prosthetics: Exploring assistive devices for the body and mind. http://books.nap.edu/openbook.php?record_id=11864, accessed November 22, 2009.

Netherlands Organization for Scientific Research. March 12, 2009. Spotless mind? Fear memories in humans weakened with beta-blocker propranolol. *ScienceDaily*. http://www.sciencedaily.com /releases/2009/03/090311103611.htm. Accessed October 21, 2009.

National Research Council. 2008. Emerging cognitive neuroscience and related technologies. http://www.nap.edu/openbook.php?record_id=12177. Accessed January 4, 2009.

Parfit, D. 1971. Personal identity. *The Philosophical Review* 80(1): 3-27.

Popper, K. and J. Eccles. 1985. *The self and its brain*. Berlin: Springer-Verlag.

Santayana, G. 1905. *The life of reason*. Project Gutenberg. http://www.gutenburg.org/ebooks/15000. Accessed December 12, 2011.

Schacter, D. 2001. *The seven sins of memory: How the mind forgets and remembers*. New York: Houghton Mifflin.

Schechtman, M. 1996. *The constitution of selves*. Ithaca: Cornell University.

Serrano P., E. L. Friedman, J. Kenney, S. M. Taubenfeld, J. M. Zimmerman, J. Hanna, C. Alberini, A.E. Kelley, S. Maren, J.W. Rudy, J.C. Yin, T.C. Sacktor and A.A. Fenton. 2008. PKMzeta maintains spatial, instrumental, and classically conditioned long-term memories. *PLoS Biology* 6(12): e318.

Shema, R., S. Haramati, S. Ron, S. Hazvi, A. Chen, T. Sacktor, and Y. Dudai. 2011. Enhancement of consolidated long-term memory by overexpression of protein kinase Mz in the neocortex. *Science* 331(6021): 1207-1210.

Society for Neuroscience (SFN). 2008. Brain facts: A primer on the brain and nervous system. http://www.sfn.org, accessed January 27, 2009.

Tang, Y.-P., E. Shimizu, and J. Z.Tsien. 2001. Do “smart” mice feel more pain, or are they just better learners? *Nature Neuroscience* 4: 453-54.

Taylor, C. 1991. *The ethics of authenticity*. Cambridge, MA: Harvard University Press.

van Praag, H., G. Kempermann, and F. Gage. 2000. Neural consequences of environmental enrichment. *Nature Reviews Neuroscience* 1: 191-98.

Wagenaar, W. 2008. Enhancing memory in the criminal trial process. In *Reshaping the human condition: Exploring human enhancement*, eds. Zonneveld, L., H. Dijstelbloem and D. Ringoir. The Hague: Rathenau Institute.

Wei, F., G. Wang, G.A. Kerchner, S.J. Kim, H.M. Xu, Z.F. Chen and M. Zhuo. 2001. Genetic enhancement of inflammatory pain by forebrain NR2B overexpression. *Nature Neuroscience* 4: 164-69.

Zoloth, L. 2006. Ethical agent. In *Neuroethics: Defining the issues in theory, practice and policy*, ed. J. Illes, 61-75. Oxford: Oxford University Press.