International Journal of Physiology, Health and Physical Education
www.physiologyjournals.com
Online ISSN: 2664-7273; Print ISSN: 2664-7273
Received: 05-11-2018; Accepted: 06-12-2018; Published: 06-01-2019
Volume 1; Issue 1; 2019; Page No. 19-23

Information processing in a sensorimotor operation: Atkinson and Shiffrin's model revisited

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Abstract
Authors present the model of memory by Atkinson and Shiffrin as a starting point to a new interpretation and base for new model of information processing in humans. They point to the fact that already in their seminal paper, Atkinson and Shiffrin mentioned about some control processes. Therefore, though they termed specific units of memory "sensory register", "short term store" and "long term store", in their model information was not only preserved, but also somehow processed in particular "memory drawers".
The authors of this paper assume that the base of science are facts and observation, but it consists of interpretations and theories. Hence, the same facts may be interpret differently by different scientists. In the paper they present another concept of human memory, less mathematical, but more psychological than that by Atkinson and Shiffrin.

Keywords: sensorimotor operation, memory, static model of memory, dynamic model of memory, information stream in a sensorimotor operation

Introduction

According to a popular adage, the greatness of a scientist might be measured with the period of time, for which s/he was able to inhibit the progress in science. Because in science we have to do with a specific mental inertia. When an acknowledged scientist worked out and published a theory, which has been assessed as being right, then his/her followers apply old repair people's rule: Does it work? Then don't touch it!

Let us look from such a perspective at seminal paper (and idea) on memory structure by Richard C. Atkinson and Richard M. Shiffrin [Atkinson, Shiffrin, 1968] [1]. Let us remark that the science bases on empirical data, indeed, yet it consists of interpretations. Richard A. Schmidt remarked:

> *Since laws are the product of human creativity, different laws can be formulated by two different individuals who are examining the same observations. Laws do not automatically spring forth from the facts* [Schmidt, 1988, p. 29] [10].

In fact, the "*careful inference"* is not "*more reliable than actual observation*", but it makes the only way to build the Science (with great "S"). In this context, arises the question: is it possible to reinterpret the achievements by Atkinson and Shiffrin? Moreover, may such reinterpretation unveil new perspective on human memory, or, more generally, information processing in human mind?

1. Model of memory by Atkinson and Shiffrin

One cannot help the feeling that the seminal paper by Atkinson and Shiffrin of 1968 may be categorized as "Does it work? Don't touch it!" However, let us look at it as a malicious "devil's advocate" and try to find out the shortcomings of their model. The original figure from their paper of 1968 has been shown in Fig. 1 [Atkinson, Shiffrin, 1968, p. 93] [1].

The paper by Atkinson and Shiffrin evokes some remarks. Firstly, they have analyzed the mechanism, which they termed "memory" as a system. It was no doubts a very apt idea. Nevertheless, in their perspective it was a separate system, while – according to the conceptual cycle of information processing presented in Fig. 2 - it is in fact a sub-system of a higher-level information processing super-system. According to the concept presented in this paper, memory makes the "buckle" joining the mental links from "Perception" through "Efferent copies".

Secondly, they analyzed the mental and not motor processes, which are more primeval than the former ones. Thus, the movements may deliver "purer" information, because the process of their preparation needs less processing than that concerning exclusively intellectual activities, like, e.g., identification of letters.

It is worth noting that both Richard C. Atkinson and Richard M. Shiffrin have solid mathematical education. Their model bases on computational data. However, mathematics excellently works in the non-living world – in physics, or in technology – but is by far less efficient in biology, and, even more, in psychology. It is useful in ordering observables, indeed, but not in modeling of deeply hidden processes underlying them [Petryński, 2016; Petryński, 2019] [8, 9].

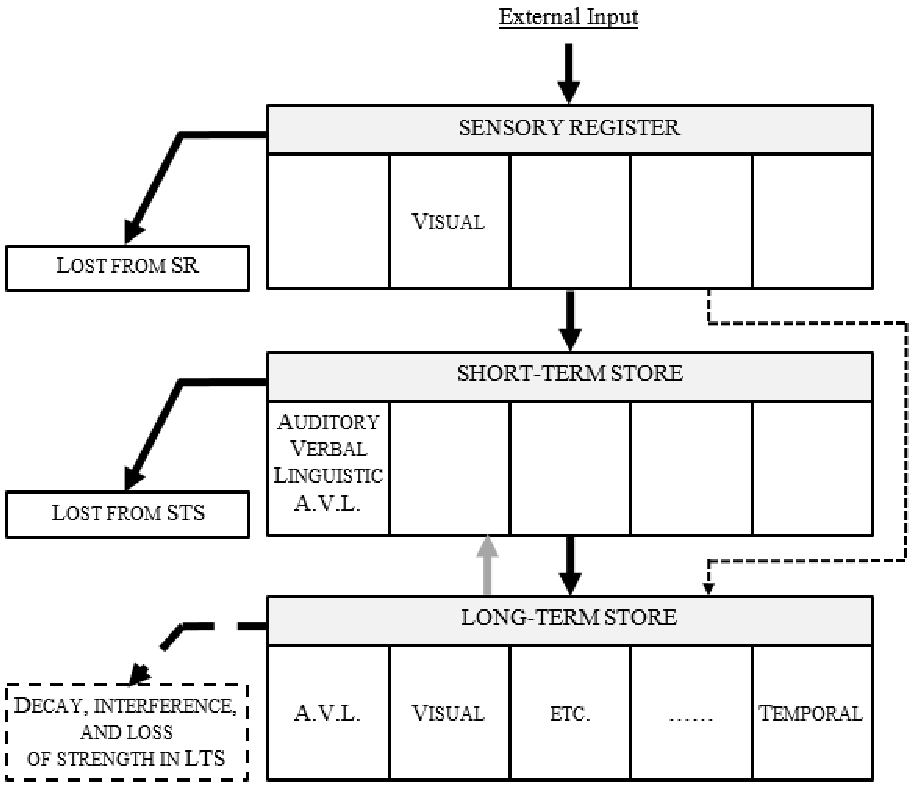

Fig 2: The original figure presenting the memory system according to Atkinson and Shiffrin [Atkinson, Shiffrin, 1968, p. 93] [1].

2. Static and dynamic image of memory

Atkinson and Shiffrin termed their memory units either "register", or "store". Symptomatically, in the original paper they did not use terms "short term sensory store", "short term memory" and "long term memory" (STSS. STM and LTM, respectively). These names suggest that they mainly preserve respective information. Accordingly, it is a static model of memory. Nevertheless, while describing the STS, they wrote:

A related attention process is the transfer to STS of a selected portion of a large information display within a sensory modality. [Atkinson, Shiffrin, p. 107].

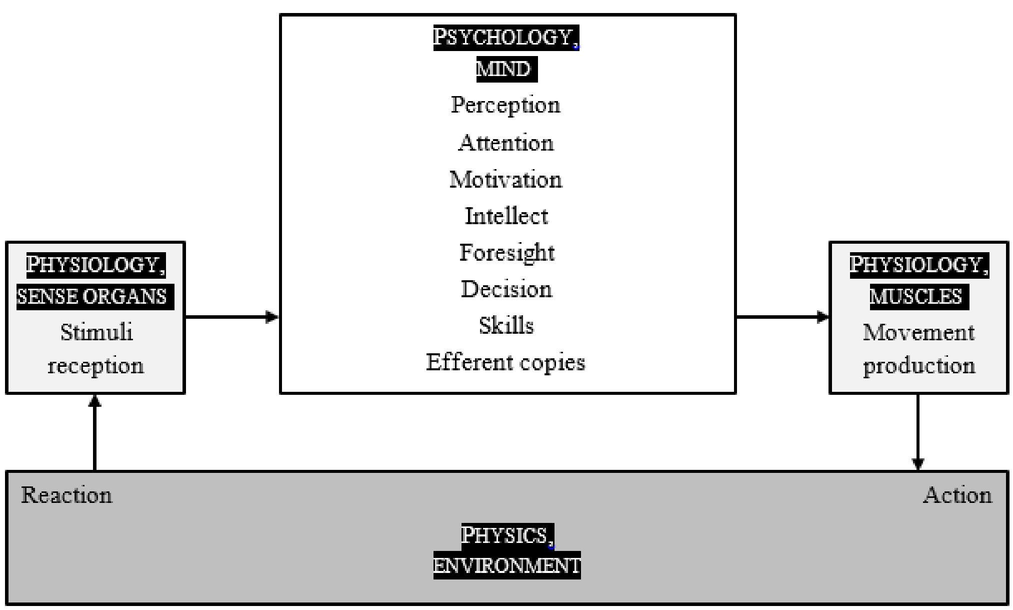

Fig 2: The conceptual cycle of information processing in human mind. Memory (not shown in the figure) makes a "buckle" joining the information processing units from "Perception" through "Efferent copies".

According to this statement, the process of transferring from SR to STS involves the dynamical cooperation of attention, which performs another task than register or store; in attention, information undergoes a processing.

While characterizing the "*rehearsal capability in STS*", the authors wrote: "*A lower limit on this capacity can be found by identifying the series length at which a subject never errs; this series length is usually in the range of five to eight numbers*." [Atkinson, Shiffrin, 1968, p. 112] [1].

In general, in their model, the memory is being built of specific units, and the information has to adjust to one of them. For example, the limited information capacity of the STS makes a specific static attribute of this memory unit, and not dynamical ability, which may be assigned to this stage of information processing. Let us try to look at that problem from such a perspective.

Let us assume that the limited capacity of the STS is not an "inherited" attribute of this static "kind" of memory, but a symptom of deeper hidden, dynamical processes in human mind.

At first, however, let us remember that the idea of limiting the number of information chunks maybe traced in by far earlier works by Nikolai Aleksandrovich Bernstein. He described the process of "*reduction of freedom degrees*" [Bernstein, 1947, p. 20] [2]. George A. Miller-one of the first scientists, who dared to look into the ominous behavioristic "black box"-wrote about the "*magical number 7±2*" [Miller, 1956] [6]. Later, Andy Clark coined the "*007 Principle*": "*to know only as much as you need to know to get the job done*" [Clark, 1989, p. 64].

The "common denominator" of all these three concepts is the transformation of an uncontrollable system into a controllable one.

3. Sequence of events in a motor operation

At first, let us remark that the central nervous system of living creatures, including humans, has been "designed" by evolution for possibly most efficient control of motor behavior. As biologist James W. Kalat has stated, "*Ultimately, the purpose of a brain is to control behaviors, and behaviors are movements.*" [Kalat, 2007, p. 232]. Only then, it turned out that on such a "hardware" may be "installed" by far more complex "software", i.e., the mind. Nevertheless, just the motor operations make the only observable product of each mental process. Let us quote philosopher Andrzej Wohl: "*all that we dispose of, all that constitutes the resource of our culture, all the pieces of art, science and technology – all that results from motor activities*" [Wohl 1965, p. 5].

Consequently, there is no other behavior than the motor one, because just the movement is the only method of manifestation of what is going on in mind, and the only method of influencing the environment by a human as well. Even if only that of lips and tongue.

The structure of a sensorimotor response has been described in detail by Richard Schmidt [Schmidt, 1988, p. 65] [10]. He divided it into three periods: fore period (FP), reaction time (RT), and motor time (MT). RT and MT make together the response time.

The RT starts with the reception of releaser, but there is no yet any electrical activity in muscles; it ends with the appearance of electrical oscillations sent to muscles. At that moment starts the MT, when the electrical phenomena are already being observed, but there is no movement yet. The MT ends when the visible movement begins.

In such a model probably most interesting is the RT. It is the only period, when the abstract pattern of a motor response may be shaped. The conceptual cause-effect chain – which cannot be directly observed experimentally – may be presented as in Table 1.

The conceptual cycle of information processing in the mind of a living creature (especially human) in a physical environment, with two physiological "interfaces" (stimuli reception and movement production), may be illustrated with the Figure 2.

Symptomatically, in an active motor operation the first link of the presented chain of processes – stimuli reception – is not necessary. If this is a case, then we term the resulting observable motor phenomena "motor response". However, humans (and some other living creatures) are able to start the presented process without stimuli reception, only based on anticipation. However, the final link is always production of strength and movement.

Table 1: The links of a conceptual cause-effect chain in the motor reaction time.

Link	Process	Technical analogy	Product
Noticing (sensitivity)	Stimulus – stimulation of sense organs – production of sensory inputs	Sensor	Awareness
Perception	Sensory input – memory stimulation – retrieving of a respective information (identification of a sensory input)	Detector	Consciousness
Attention	Assessment of information importance	Initial filter	Hierarchy of information
Motivation	Further processing on, if the information is important enough, or off if not.	Initial discriminator and amplifier	Essential information which starts the intellect
Intellect	Main information processing unit (instinct, intuition, intelligence)	Processor	General motor response pattern
Foresight	Quality of the pattern control and anticipation of its effectiveness.	Final filter	Purposefulness of realization
Decision	Starting of realization (or not)	Final discriminator and amplifier	Start (or blocking) the executable motor operation production
Skills	Retrieving of sub-operation patterns from memory and joining them into one coherent motor operation pattern	Controllers	Executable motor operation pattern
Efferent copies	Recording of the motor operation pattern	Recorder	Archiving of the executable motor operation's pattern
Movement, strength	Bringing about desired changes in the environment	Actuators	Actual changes in environment

4. The information processing stream in a motor operation

The events described in previous chapter are not independent of each other, but they make a continuous stream. While analyzing the sequence of sub-processes, which together make the information processing stream from stimuli reception through movement production, one may create a model shown in Table 2.

Table 2: The conceptual continuous information chain (simplified) in a sensorimotor response. In afferent stream, the discrete information chunks are being processed; at "Intellect", the operation pattern is being produced with previously processed information chunks; in efferent stream, the operation patterns – i.e., intentionally created systems of information – are being processed. Grey circles denote discrete information, dark stars – worked out patterns or sub-patterns of a motor operation.

Reception	**Perception**	**Attention**	**Intellect**	**Skills**	**Efferent copies**	**Movement**
Physics → physiology	**Physiology → psychology**	**Psychology**	**Psychology**	**Psychology**	**Psychology → physiology**	**Physiology → physics**
Continuous stream of stimuli → sensory inputs	Sensory inputs → discrete information	Discrete information → essential discrete information	Essential discrete information → general operation pattern	General information pattern → realizable operation pattern	Realizable operation pattern → discrete motor commands	Discrete motor commands → continuous movement
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Stimuli → sensory inputs	Information chunking	Selection of the most important information	Most important information processing; general response pattern creation	Retrieving from memory useful sub-patterns	Information patterns → motor commands	Motor commands → strength → movement
Memory stimulation	Quick information identification	Slower information assessment	Slow information and pattern processing	Quicker pattern processing	Quick muscle stimulation	Movement execution

The whole stream may be divided into two parts

- Afferent stream, from "Perception" through "Intellect",
- Efferent stream, from "Intellect" through "Efferent copies".

In afferent stream, the more and more "voluminous" information chunks are being processed. "Intellect" makes a component of both afferent and efferent path. It is a "destination station" for information chunks processing, and "departure station" for information patterns processing.

Roughly, to keep a continuity of the conceptual stream of information processing, the number of slowly processed chunks in intellect has to be by far lower than the number of quickly processed chunks of information at the stage of, say, perception.

By the way: the SR, STS and LTS as by Atkinson and Shiffrin may be associated with the afferent stream, whereas the WM (working memory) as by Miller, Galanter and Pribram [Miller, Galanter, Pribram, 1960, p. 65] [7]- with the efferent stream of the chain.

Conclusion

To sum up, while analyzing the system-theoretical model of memory, one might state:

1. The dynamic model of information processing in humans is by far more detailed than static model by Atkinson and Shiffrin, consisting of three "stiff drawers".
2. The "volume" of information chunk depends on stage of processing in information processing stream.
3. The speed of processing depends on depth of this process at a given stage of information processing stream.
4. Both the volume (and number) of information chunks or patterns and the speed of their processing is being determined by continuity of information processing stream.

The presented analysis leads to a more general reflection. Contemporary science is being characterized by more and more powerful torrent of "new, original experimental data". Their production, while having a good laboratory, is light, joyful and easy. Moreover, they are undisputable. Therefore, their production is not risky. However, science is being built not of experimental data, but of interpretations. This was clearly and wittily described by Bernard K. Forscher [Forscher, 1963]. Since then, computer technology made a great advance and the production of "new, original experimental data" became still easier. While paraphrasing mathematician Hugo Dyonizy Steinhaus, "*due to dissemination of computer technology, it becomes possible to conduct researches, publish papers, and achieve scientific degrees and titles while keeping to be an idiot.*"

In this context highly illustratively sounds the following anecdote:

> *During his Zurich stay, the woman doctor, Paulette Brubacher, asked the whereabouts of his* (Einstein's) *laboratory. With a smile, he took a fountain pen out of his breast pocket and said: "Here".*

It becomes increasingly obvious that contemporary science disposes of more and more computers. However, it needs, like an oxygen, the fountain pens, like that of Einstein. Unfortunately, they are very, very rare. This is why, in conclusion, we would like to bow down to fountain pens of Professors Richard C. Atkinson and Richard M. Shiffrin.

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