Global Workspace Model

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Abstract

This article reinterprets the Global Workspace theory in the form of a coherent model. The model is initial and simple. It interconnects the Working Memory and the Long Therm Memory using the graph theory.

The model can be used for software or mental experiments which can explain properties and behaviour of human mind. It is used for explaining the magical problem of 4 and for identifying the nature of context.

Keywords: global workspace, GW, working memory, short term memory, STM, long term memory, LTM, memory consolidation, brain model, mind model, sensory buffer, vision, context, HM, graph, hippocampus.

1 List of Shortcuts

EVO - id of the model described in this article

GW - global workspace

WM - working memory

STACK - stack memory

LTM - long term memory

2 Introduction

This article is a study above the Global Workspace (GW) theory, formulated in [BAARS 88]. It contains thoughts of a computer vision guy in robotic industry as he reads Baars books and intuitively translates it in a design of a piece of software. The primary target of this study is to create a model which can really operate. Similarity with the original pattern is target too, but it is the secondary one.

The model is not done in the manner of neurons and synapses, but using expected functional blocks of barin. Each mental process expected by GW theory is attempted to have reflection in this model. If they do not feet the functional whole, some minor aspects of GW theory are customized.

The GW theory is reinterpreted using the following principles:

1.) Theoretical assumption: the long term memory (LTM) content is a graph in the mathematical expression. The working memory (WM) [BAARS 88] content is a subgraph of this graph.

2.) Lingua Franca [BAARS 88] of the GW is defined and consistently applied in whole the model of GW.

Basic model taken for reinterpretation is captured from [BAARS 13 DYNAMICS] and it is shown in the Figure 1.

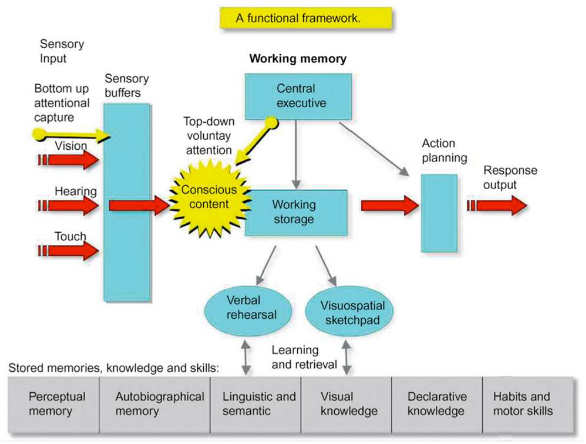

Figure 1: Global workspace model. Source: [BAARS 13 DYNAMICS]

3 Model Simplification

The model of the human brain is called EVO in this article. The animal which uses EVO brain can move, turn, eat and see. EVO can be eaten by the Beast.

The model from the Figure 1 is rearranged. It is partially simplified. The sensory input is reduced in vision. All the memory types (declarative, visual, autobiographical, semantic, ...) are unified in one. The purpose of this unifying is the possibility to do the associations across all the memory items.

The memory is decomposed in two functional parts.

One part of the memory is the Long Term Memory (LTM) which is a generally accepted concept in the current psychology.

In addition to LTM a temporary memory store named STACK is defined. STACK reflects the active system consolidation hypothesis mentioned in [RASH 13 SLEEP]. The duration of memory in STACK is several days.

The dual model of memory is derived on the fact, that LTM is really permanent and it is difficult to change it. Try to forget anything what is already stored in LTM. It is impossible without a physical destruction of a part of brain [1]. On the other side, it is easy to forget the events of today.

This duality is not possible to explain only by using the LTM consolidation process. This is the reason for accepting the active system consolidation hypothesis in this model.

The functionality of these two memory types is described later in the text.

The memory in this first iteration contains the following simplifications for now:

a.) the duration of the STACK memory is exactly one day.

b.) only LTM is accessible, STACK is not acessible.

c.) one of the purposes of STACK is the partial consolidation done exclusively inside STACK. This process is excluded from the model, too.

The action planning is completely removed from the model. The target of this model is to trace the processes only to the decision point.

The components of the model after the rearangement are shown in the Figure 2

[1] it includes ageing too

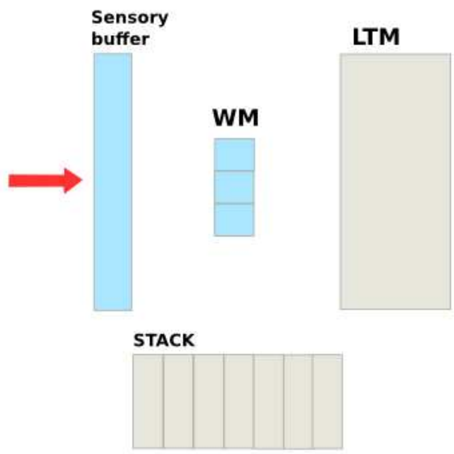

Figure 2: Rearanged GW model.

The map between the rearranged and original model is shown in the Figure 3

EVO functionality is tested in virtual world shown in the Figure 4. The ellipses in the figure represents the space which is seen by EVO. Each elliptical space is named and the name is the exact position of EVO when it observes the ellipse content. The trace through the world is polyline: A, B, C, D, E, F.

The legend for this world is shown in the Figure 5.

4 EVO Activity

Now imagine what happens when EVO goes through the world. It starts at the position A. This is shown in the Figure 6.

Now it is necessary to include in the model the term Lingua Franca of GW [BAARS 88]. Lingua

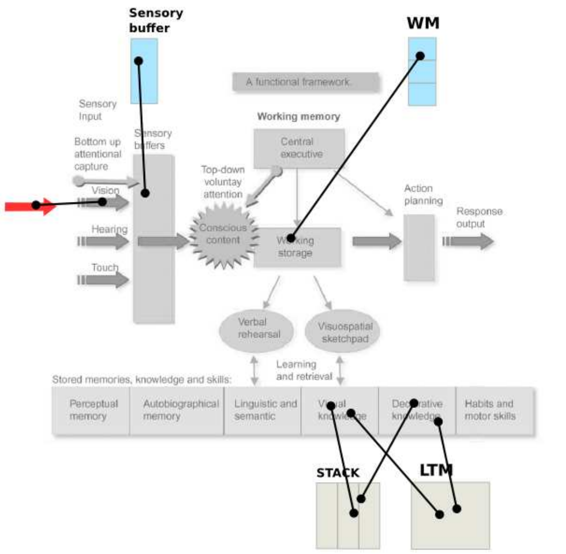

Figure 3: Rearanged and original GW model correlation.

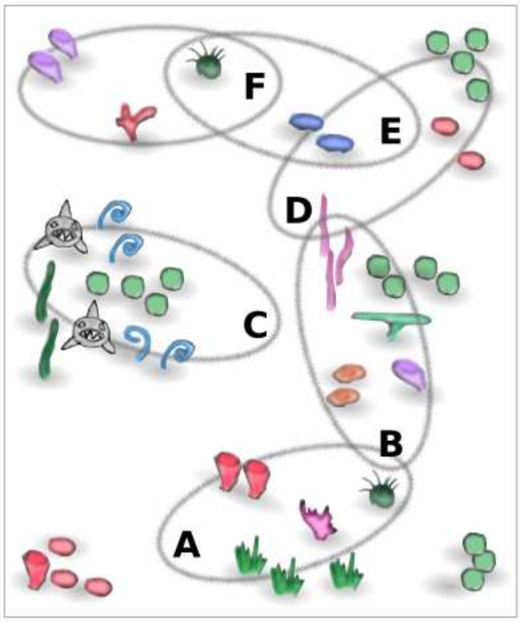

Figure 4: Virtual world for EVO simulation.

Figure 5: The legend of the EVO virtual world.

Franca is not in [BAARS 88] specified, but it is possible to do it here. Lingua Franca of GW is the Mental Image (MI) of the object in this article.

MI is mentioned many times in [BAARS 97 THEATER], but without an exact definition. MI is defined in this article only by its two properties, which enable the model to work.

1.) the MI of an object is produced by the processing of visual senses. This processing isolates the partial objects and translates them in MIs. This processing is implicit and uses its own memory.

2.) the mental images created by 1.) and the MIs stored in LTM can be matched each to other.

Besides this definition I will bring an example of a better picture of MI: imagine that you see an object and you close your eyes. Only the idea of this object remains and this is MI. This feeling of MI is similar to the MI recalled from memory. It is possible to imagine MI in this simple way, because EVO can see only. There are no complications with voices or smells.

MI is symbolized by an image of the object itself. **The images of MIs in this article are not the MIs themselves, they are only sym-**

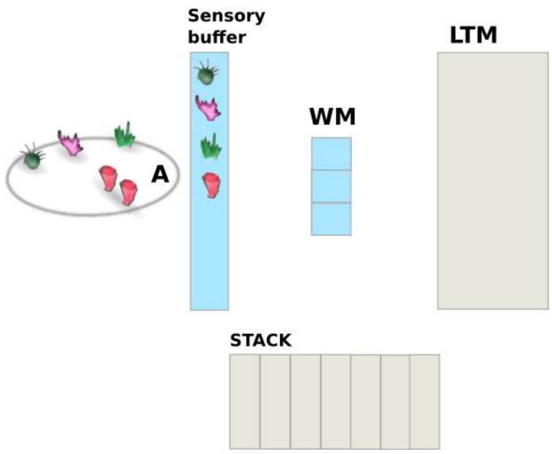

Figure 6: EVO at the position A.

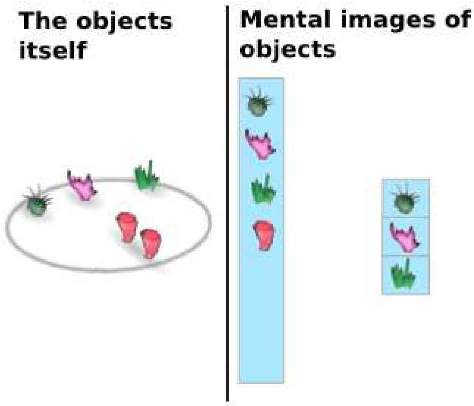

Figure 7: Image of object and corresponding MI looks the same. It depends on the context how they are interpreted.

bols of MIs. The nature or structure of MI is not the subject of this article. It can not be even the subject of a single article.

The same images as MI symbols are used in the model of the world, too. These images are not MIs of course. The difference between the object and MI is illustrated in the Figure 7

The subject of this article is in short substituting MI (Lingua Franca) in the schema in the Figure 2. Mental images are included in all parts of the model. They are substitued in sensory buffer, in GW, in STACK and in LTM. Shifting MIs between these components is the main functionality of this model.

Back to EVO. At the beginning it stays at the position A and it has the sensory buffer filled by MIs from the position A. The next step is filling the MIs in the working memory (WM) [BAARS 88]. But there are only three slots in the WM and there are more than three items in sensory buffer. The number of slots is estimated to 3-5 by current research [COWAN 00 NUMBER4]. In the EVO model are used 3 slots for MIs. WM of EVO can not contain more than 3 MIs at once.

At this point I will introduce the first process accessing the WM. Such processes are named agents [BAARS 88]. Only agent can change the state of GW or memory. Each agent will be marked with light yellow color. The generic schema of WM and agents is shown in the Figure 8.

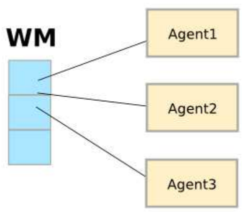

Figure 8: WM and agents.

Agents in EVO do not implement in detail the functionality described in [BAARS 88] (competing, coalitions, ...). They are left on the high level of decomposition. The only property of the agent is to access any component of the model and the possibility to change it, no other details are implemented.

This first agent is named Attention Agent. Its target is to transfer MI from the sensory buffer to STACK. In this case is WM empty, but this is not the normal case. So another task of Attention Agent is to decide which old MI will be replaced and if it can be replaced. The Attention Agent processing is shown in the Figure 9.

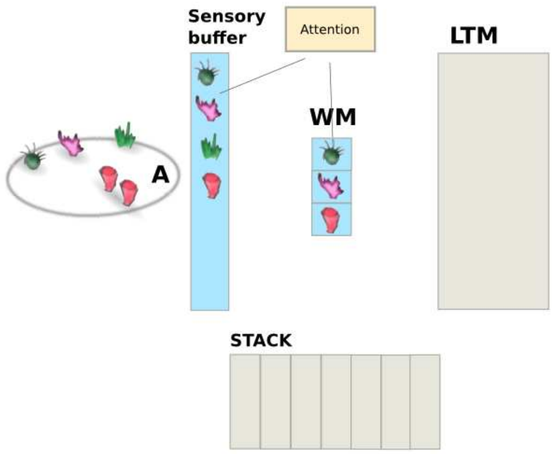

Figure 9: EVO at the position A.

EVO now moves at the point B. The new situation is shown in the Figure 10. The content of WM at the point B is different, but before it is changed, the content of WM is shifted in STACK. This is done by Stacking Agent. This process follows the fact, that whatever is conscious in WM, it can be stored in the memory.

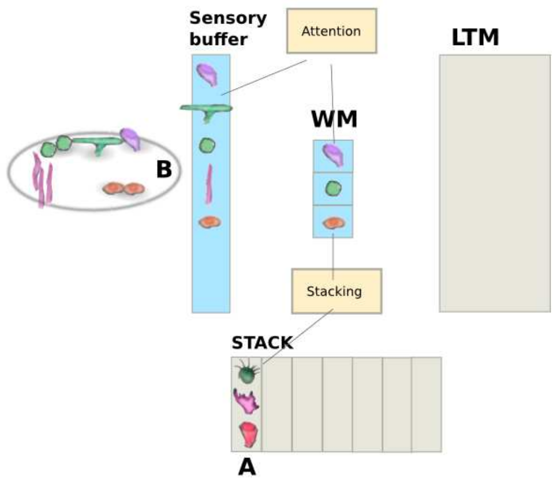

Figure 10: EVO at the position B.

Discrete processing is used in the cognitive cycle of this model. As the WM is shifted in STACK, the WM is emptied and it is prepared for new MIs. The functional equivalent is continuous fading of MIs in WM which corresponds more with the reality. For the purpose of this article is the discrete operation enough.

The used internal structure of STACK has no support in an observation. It is the best guess, how STACK can be structured. The only guide is the simplicity, STACK is just a sequence of the snapshots of WM.

An exceptional situation is at the point C. This is shown in the Figure 11. WM contains MI of the Beast. This activates the Activity Agent. It changes the direction of the EVO movement to the point D.

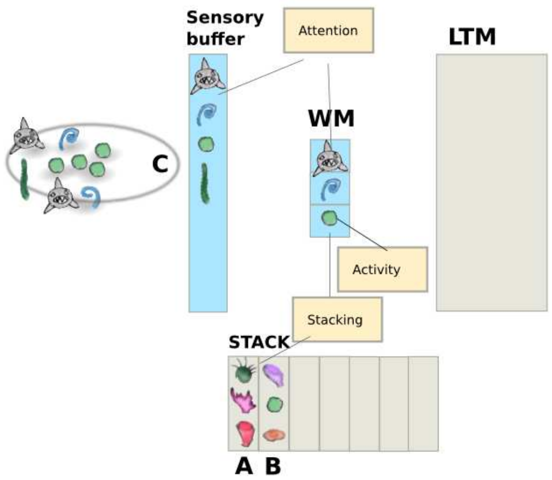

Figure 11: EVO at the position C.

EVO continues to the other point of its trace and the processes described in the text above repeat again and again. The situation at the point F is shown in the Figure 12.

At the point F is STACK almost filled with the records from the whole EVO day. Something must happen. One possible solution is the cleaning of STACK from the records, which are not found important. But EVO has a more advanced process than this. It has LTM.

5 Sleeping

Now the brain of EVO changes its mode. You can tell, that it is going to sleep. It switches off Sensory Processing, Sensory Buffer, WM and Attention Agent. It starts the Memorization Agent.

LTM is in this model an associative memory,

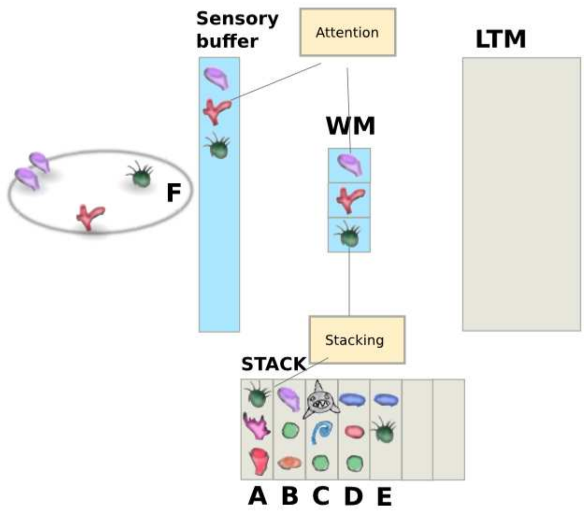

Figure 12: EVO at the position F. The end of the day.

where associations connect the MIs. The associonism is a wide term nowdays, the number of modalities is infinite. The aproach used here is similar to introductory text in [ROELFOS 08]. You must just disregard the words which are used in this article and think in the associative network with nodes which are uniformly only MIs. EVO cannot speak or hear now. It is not skilled to perform any classical associanist test (o:

Associations are created between the objects which were in WM at the same time. Being in WM at the same time ensures the spatial and temporal close relationship and this relationship is expressed by using the associations. If MIs are associated in LTM, then they occured in the same space and time in WM. This is an analogy to the Hebb approach [HEBB 49], but it is translated in the associative memory level.

Mathematically said, each slot of STACK is a subgraph of the graph in LTM. It is possible to construct a graph from its subgraphs. This is illustrated in the Figure 13

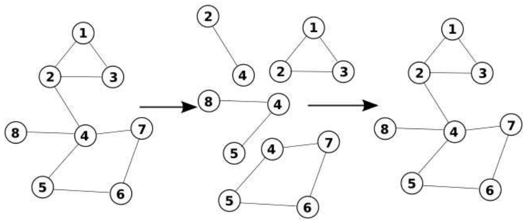

Figure 13: Decomposition graph in subgraphs and integration subraphs in graph again.

The graph in LTM is simplified for this first iteration. Even it is expected, that the associations are directional in reality, they are simplified to edges without any direction. The edges of the graph have no properties, too.

During the sleeping the subgraphs in STACK are used for construction of the graph in LTM. The processes during the sleeping are illustrated in the Figures 14 15 16.

At the end of the sleeping is STACK empty and LTM contains the experience of the previous day in the form of the graph of associations.

6 Activity Next Day

On the next day STACK is empty and it is prepared for new events. The new events are picked up in

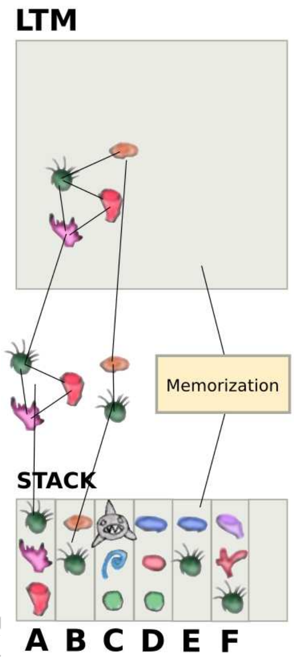

Figure 14: Sleeping A.

the same way as it was in the previous day and they are released during the sleeping again. This process repeats again and again each day. EVO becomes more and more experienced.

On the next day EVO can appear at the place X. The situation is illustrated in the Figure 17.

If nothing happens, then EVO will continue in the direction marked 1. The Beast is hungry today. But EVO has LTM and Memory Agent. Memory Agent will:

1.) correlate the MIs which correspond in LTM and WM. See the Figure 18.

2.) give attention to MIs around the MIs from the point 1.)

3.) transfer some of the MIs from the point 2.)

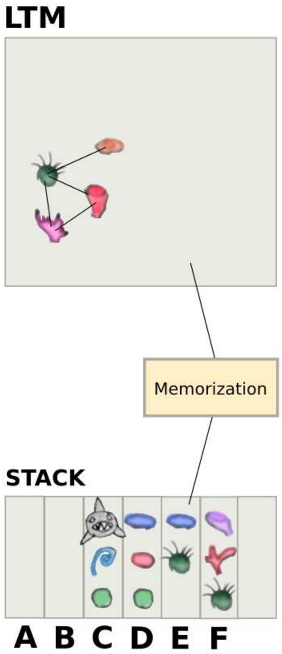

Figure 15: Sleeping B.

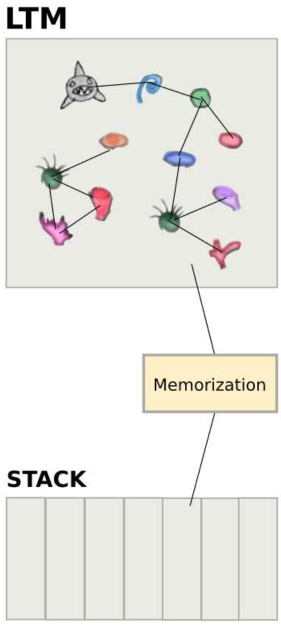

Figure 16: Sleeping C.

in WM.

The state of WM now is the same as the state at the point C in the previous day. The Activity Agent will perform the same reaction and EVO will select the trace 2 instead of the trace 1. This situation is illustrated in the Figure 19. EVO has a big advance against the predators with the fixed customs.

This is the conscious analogy to the classical conditioning which is done by using this model. Its other analyse for reasoning is over the scope of this article. It is targeted only on the conceptual cooperation of the basic components.

7 Overview

All the agents expected in this article are summarized in the Figure 20. It is visible, that the Attention and Memory Agents work concurrently and so there is their synchronization needed. The image also shows the division in day and night agents.

The complete model can be compared with the original Baars model again. The new comparison is shown in the Figure 21. It is visible, that the current model has implemented only the implicit attention. The explicit attention is left unimplemented for now.

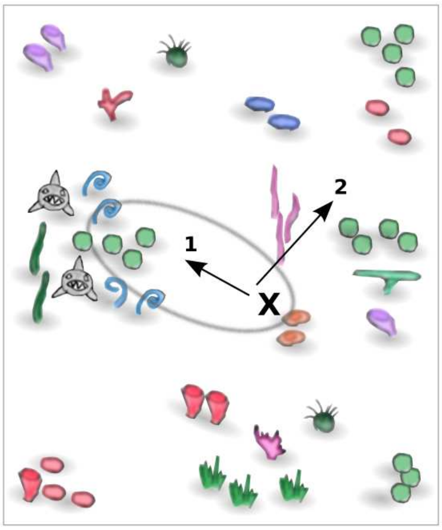

Figure 17: The situation in the next day.

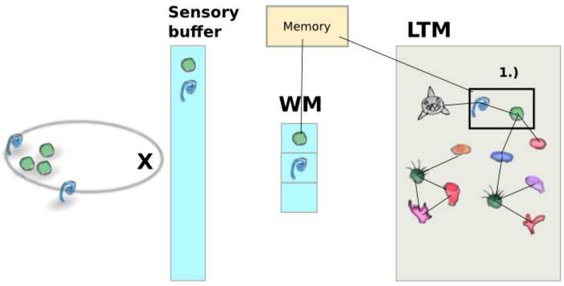

Figure 18: Memory Agent.

8 Context

It is easy to include in the model the idea of the Context, described in [BAARS 88]. In this explanation the non-hierarchical Context is used, but it is easy to extrapolate this concept in a hierarchical Context.

The context in this model is preheating a part of LTM graph which is for EVO actual. In this preheated area the parts are included which are

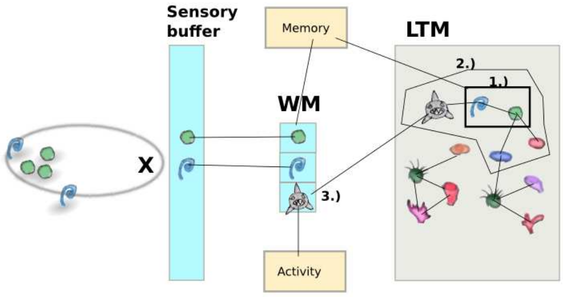

Figure 19: Memory and Activity Agents.

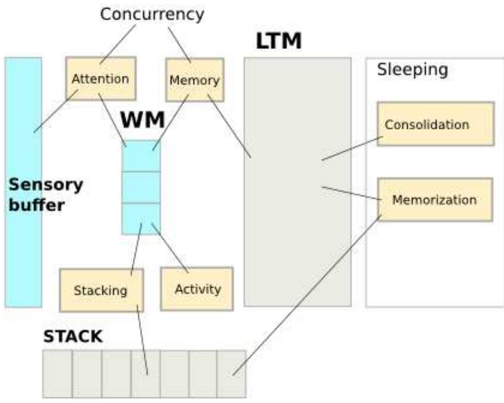

Figure 20: Model overview

near the nodes corresponding to the actual situation. This effect is illustrated in the Figure 22.

Preheated MIs in LTM have higher probability, that they will be activated in WM.

This preheating has two effects:

1.) Avoiding distant MIs saves energy. Energy savings are very dominant in the brain architecture.

2.) If distant MIs are excluded from activity, the probability of mistake is lower. This is a functional enhancement.

The Figure 23 illustrates the bad context, rela-

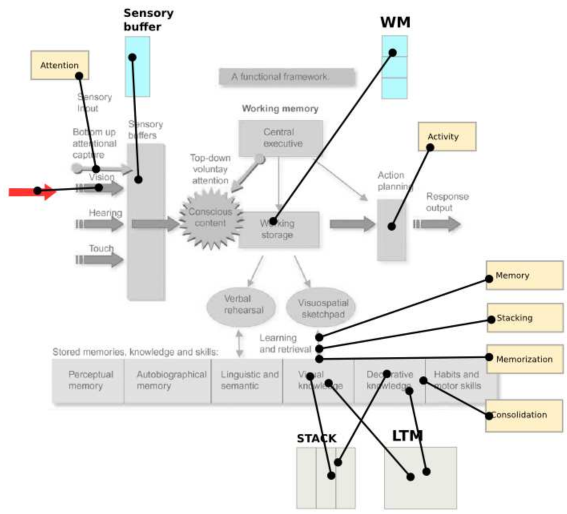

Figure 21: Corelation with the model from the Figure 1

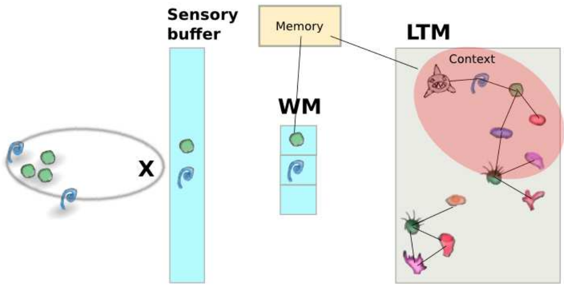

Figure 22: Context.

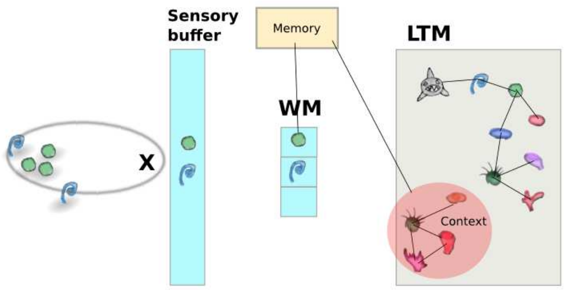

Figure 23: Bad Context.

tive to the situation in the previous text. This is the drawback of context usage. This situation must be detected and the bad Context must be cancelled.

The mechanism of cancelling of the bad Context is simple in EVO model. If there are some continuous disproportions between LTM and WM, then the Context is cancelled.

9 Magic 4

Each model should have some explains and what would be better for this purpose in GW model than the magic mystery of 4 [COWAN 00 NUMBER4]. In this model 3 slots are used which is the possible limit of WM, too [COWAN 00 NUMBER4].

What will happen with the model behaviour, if this property is changed. Let's say it changes to 7. It is not too much. 7 was for years the expected limit of WM [MILLER 56 NUMBER7]. This change does not seem too big, but the subgraph of WM is changed significantly. It is illustrated in the Figure 24

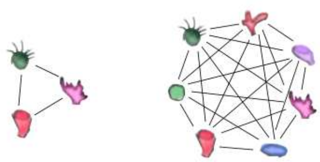

Figure 24: Subgraphs for 3 and 7 slots in WM.

The subgraph for 7 slots is much more complex. If the complexity of graph is the number of nodes plus the number of edges, so the complexity is increased from 6 to 28. This will influence the graph in LTM. Its complexity will increase and it can be expected that this over-complexed LTM will not be so clever.

This is only a general idea. The competition of EVO3 and EVO7 in the software simulation can proof the result without doubts. [2]

10 HM Simulation

EVO can simulate the well known amnesiac HM [SQUIRE 2010 HM]. Just imagine removing STACK from the schema. EVO will not have an updated LTM by new experience forever. It will change in analogy of HM.

This behaviour is natural for any architecture based on the active consolidation hypothesis [RASH 13 SLEEP]

The same effect as the removing STACK has the removing Stacking or Memorization Agent. In next iteration of EVO will be STACK virtually translated in LTM interface and used in the same way as LTM. This enhancement excludes the Memorization Agent from HM deduction.

This HM analogy undoubtedly identifies the location of one EVO component in the real human brain. STACK or Memorization Agent is the hipocampus or its part.

[2]To guess the absolute winner of this competition, I bet on EVO4 in the accordance with the mean value in [COWAN 00 NUMBER4].

11 Comparison With the LIDA Model

EVO has the same roots in GW model as LIDA [BAARS 07 IDA] system has. It would be reasonable to compare them, but this is over the scope of this article. Generally LIDA is much more complex. It is also more strict in the interpreting [BAARS 88] or [BAARS 97 THEATER].

EVO is simple and targeted on the educational tasks. The EVO functionality is so simple, that many simulations can be done without running a software. The simulation can be done only by the imagination in mind, as it is presented in this article.

12 Conclusion

This article introduces the model of the Global Workspace theory. The key principle, which is formulated in this article is interconnection WM and LTM using the graph from the subgraph construction. This is illustrated in the Figure 14

The model is simple, especially in this first iteration. Even some possible extensions of this model are known at this time, they were not included here. Especially the STACK and LTM consolidation potential is not used here.

One of the targets of this model is to create a minimalistic base which can be used for explaining of the more complicated concepts. The new concepts can be draught like extension slots in this model. It is not needed to setup the model basic conditions over and over.

Even the model is simple, it is possible to explain some global workspace and memory issues using it. It reasonably explains the magic 4. The model clarifies the basic interaction between WM and LTM and it explains the most of the contextual issues in easy manner.

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