Is Global Workspace a Cartesian Theater? 
How the Neuro-Astroglial Interaction Model 
Solves Conceptual Issues

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The Global Workspace Theory (GWT) proposed by Bernard Baars (1988) along with Daniel Dennett’s (1991) Multiple Drafts Model (MDM) of consciousness are renowned cognitive theories of consciousness bearing similarities and differences. Although Dennett displays sympathy for GWT, his own MDM does not seem to be fully compatible with it. This work discusses this compatibility, by asking if GWT suffers from Daniel Dennett’s criticism of what he calls a “Cartesian Theater”. We identified in Dennett 10 requirements for avoiding the Cartesian Theater. We believe that some of these requirements are violated by GWT, but not all, hence there is partial incompatibility with MDM, and it is nonsense to answer if GWT is or is not a Cartesian Theater. However, by asking such question we conclude that the issues around this discussion involve fuzzy claims about degrees of consciousness and we show how the Neuro-Astroglial Interaction Model (NAIM) is fit for solving such conceptual issues.

Key words: Consciousness; Cartesian Theater; Global Workspace; Multiple Drafts; Neuro-Astroglial Interaction Model
1. Introduction

Bernard Baars is a psychologist who proposed the Global Workspace Theory (GWT; Baars, 1998). The theory proposes that consciousness is a functional workspace that broadcasts information widely across the brain. Baars (1997) further claims that such global workspace can be understood metaphorically as a working theater. Daniel Dennett (1991) is a philosopher that criticizes a model of consciousness he calls “The Cartesian Theater”, replacing it with his own theory, the Multiple Drafts Model (MDM; 1991; or “fame in the brain”, 2001). Dennett claims that there is no central theater ‘where it all comes together’, no finish line for the onset of consciousness, and that consciousness is accomplished by a society of specialized neural assemblies influencing behavior.

GWT has influenced many works on consciousness, making Franklin, D’Mello, Baars & Ramamurthy (2009) characterize it as the ‘current leading cognitive theory of consciousness’. Recent papers about the GWT have taken more of a scientific (as opposed to philosophical) direction, with more evidence being taken into account (Baars, 2002; Edelman, Gally & Baars, 2011). Also, other models have adopted aspects of this theory (Dehaene, Kerszberg & Changeux 1998; Dehaene & Changeux, 2011) and some researchers proposed the implementation of the theory in machines (Franklin, D’Mello, Baars & Ramamurthy, 2009; Madl, Baars & Franklin, 2011). Dennett’s theory had some repercussion in the following years including criticism (Block, 1993, 1995; Tye 1993) and support (Rosenthal, 1993). Somewhat more recent papers have been criticizing Dennett’s proposal of abolishing a finish line for the onset of consciousness (O’Brien & Opie, 1999; Christie & Barresi, 2002; Schneider, 2007; Todd, 2006; 2009). Both theories have received much attention and continue to be listed in most introduction to consciousness guides (Blackmore, 2005; Velmans & Schneider 2007; Zelazo, Moscovitch & Thompson, 2007).

At first glance, the two theories seem to be conceptually opposed, regarding the existence of a central processing instance; however, there are also many similarities between them, since MDM is complemented by a serial processing modality named “The Joycean Machine” (Dennett, 1991).
Rockwell (1997) presented a contrast of these two theories arguing that despite Baars’ attraction to the theater metaphor and Dennett’s complete opposition to the idea, the two researchers did not have much quarrel with each other. This seems to be true, since in an interview by Blackmore (2005), Baars mentions that Dennett changed his mind about possible conceptions of the theater, so that there would be no problems with his views. However, as Schneider (2007) points out, it is not very clear which claims Dennett could really dispose of to make some versions of the theater model accepted in accordance to MDM. So although Dennett shows some appreciation to GWT, his own model does not seem very compatible with it. This works makes a deeper analysis of the theorists’ claims, in order to verify such compatibility, by asking if GWT suffers from Dennett’s criticism of the Cartesian Theater. This reveals a problem on the claims about degrees of consciousness in such theories. We propose that the Neuro-Astroglial Interaction Model (NAIM) (Pereira Jr. & Furlan, 2010, Carrara-Augustenborg & Pereira Jr., 2012) can help solve such problem.

2. Is MDM Compatible with GWT?

Dennett’s (1991) MDM is - as emphasized by him - just a sketch, a path towards the construction of a theory of consciousness. Given this declaration, could there be a way for him to incorporate other theories to his model as means of strengthening it? Dennett (2001) proposed something similar. He proposes compatibility, or at least, certain resemblance of his model with GWT (Baars, 1988), or its adapted version proposed by Dehaene, Kerszberg & Changeux (1998). Even earlier, Dennett (1991) mentioned the following:

In his book A Cognitive Theory of Consciousness (1988), the psychologist Bernard Baars summarizes what he sees as a “gathering consensus” that consciousness is accomplished by a distributed society of specialists that is equipped with a working memory, called a global workspace, whose contents can be broadcast to the system as a whole … It is a version of that emerging consensus that I have been gingerly introducing, ignoring some features and emphasizing others. (p.257)
In some respects, these theories are compatible. Both emphasize massive parallel computations as basis for unconscious processing. Both conceive consciousness as an organizing system, which functions serially, and in a limited fashion helps the orientation of specialists for problem solving. Despite the similarities, there seems to be some conflicting core claims.

Schneider (2007) points to three major conflicts of the two theories. The first regards the content of consciousness. According to Dennett (1991), the content of consciousness depends on probes in the parallel activity of the multiple drafts, which are accomplished only by individuals bestowed with language. For GWT (1988), not all conscious content needs to be probed in a voluntary manner, even though that is also possible. One could argue that such distinction results from Dennett’s terminology. If we consider the multiple drafts part of the process as consciousness, the probing necessity ends. By adding a virtual machine for consciousness, as he describes, probes are necessarily required. However, it seems to be more than just terminological, when in the chapter “Our consciousness their minds” Dennett (1996) clearly considers the virtual machine addition as the only legitimate form of consciousness.

The second point of conflict mentioned by Schneider (2007) refers to the centralist character of the global workspace, characterized as a central, non-modular system where content from different sense modalities are united and integrated to influence planning. This idea resembles a central system as introduced by Fodor (1983), to which Dennett is clearly in opposition. We agree this is a point of tension. However, maybe the tension shatters if we conclude that planning in reality is not realized by the global workspace, but by the whole brain, being only broadcast through the global workspace (which is more coherent with Baars [1988]).

We believe the third point of conflict mentioned by Schneider (2007) is the most problematic one. It refers to the notion of a finish line for consciousness. It is the most problematic since this is the major aspect of Dennett’s criticisms to traditional models of consciousness. GWT seems to require such a finish line for consciousness, which is the moment when the content is broadcast. The message necessarily needs to be broadcast in order to be a part of consciousness. In light of this, at first glance, it seems easy to conclude that GWT is a Cartesian Theater, making it incompatible with
MDM. Since this is the major point of conflict, and is not as simple as it might sound, it will be assessed throughout the paper.

Schneider (2007) did well in identifying the main points of conflict between the theories. Beside these, we found three additional points of conflict through our analysis. The first refers to the evolution of consciousness. Since Baars (1988) points to an evolutionary old brain anatomical structure (Extended Reticular-Thalamic Activating System) for the basis of consciousness, it is easy to conclude that Baars understands it as a function shared by many animals, at least all mammals (see Baars [2005]). Dennett (1991) makes it clear that consciousness is too recent to have evolved biologically so he delegates this role to cultural evolution – the diffusion and installation of memes. In the chapter “Our consciousness, their minds” (Dennett, 1996) he makes it clear that there is a gap between humans and other animals when it comes to consciousness, because of meta-cognitive capacities. Baars (as mentioned in Edelman, Gally & Baars [2011]) might understand this as a distinction between primary consciousness (related to visual awareness and other percepts) and higher-order consciousness. However, there seems to be no kind of gap between the two kinds as there is in Dennett’s theory, where the installation of a cultural virtual machine is necessary. I think it would be safe to say that “higher-order” consciousness is also a function of the same system, the global workspace.

A strong point of conflict is the integration of information. Consciousness in GWT has a central information integration role of specialists which are spread throughout the brain. Dennett (1991) claims that the observer’s point of view is spread throughout the brain. It may be that the Joycean Machine has such integration role, but that does not sound too convincing. It would be more coherent to claim that this machine reads selected parts of the drafts scattered throughout the brain, with much being lost in the process. After all, there is no place where all information is united to form consciousness experience. A problem with this is that a model of consciousness based on language and higher order thoughts is not able to account for the phenomenon of “binding”. Perceptual binding seems to be completely independent from language, thoughts or voluntary control and is probably present in animals.
This point of conflict leads us to a final one. Would it be correct to claim that unconscious specialists cooperate and compete for the same reasons in both theories? Again, it does not seem to be the case. In GWT, competition and cooperation occur as means of accessing the global workspace, in order to form an integrated and coherent conscious experience which will influence the work of others specialists in the brain. Competition and cooperation in MDM will not grant the winner any “privileged state”, the winner gets to directly influence behavior, instead of informing specialists about his interests of action.

In sum, there seems to be six main points of conflict between the two theories, the most problematic being those that might link the global workspace to a Cartesian Theater, precisely the main point of criticism in the book *Consciousness Explained*. But before we discuss this issue, it is crucial to understand what Dennett means by a “Cartesian Theater”.

### 3. The Concept of a Cartesian Theater

Daniel Dennett was accused of attacking a straw man, in other words, of criticizing a model of consciousness to which no serious philosopher or scientist subscribes (BLOCK, 1993, 1995; TYE, 1993; BAARS, 1997). Before the criticism, Dennett (1991) had already tried to explain why he did not attack a straw man. We think it is safe to say that philosophers, neuroscientists and psychologists did not understand or discard Dennett’s criticism, since many still have models that fit his description of a Cartesian Theater.¹

¹ In some ways, Dennett and Baars are misunderstanding Descartes, as the philosopher notes: “We need to recognize that the soul is really joined to the whole body, and that we cannot properly say that it exists in any one part of the body to the exclusion of the others. For the body is a unity which is in a sense indivisible because of the arrangement of its organs, these being so related to one another that the removal of any one of them renders the whole body defective. And the soul is of such a nature that it has no relation to extension, or to the dimensions or other properties of the matter of which the body is composed: it is related solely to the whole assemblage of the body’s organs. This is obvious from our inability to conceive of a half or a third of a soul, or of the extension which a soul occupies.
He mentions the Cartesian Theater in various moments throughout his book, making novel claims about its identity and what he is in fact against in each moment. Dennett (1991) suggests a first definition:

The Cartesian Theater is a metaphorical picture of how conscious experience must sit in the brain. It seems at first to be an innocent extrapolation of the familiar and undeniable fact that for everyday, macroscopic time intervals, we can indeed order events into the two categories “not yet observed” and “already observed”. (p.107)

Yet, Dennett (1991) claims to be against a view called Cartesian Materialism, described as:

…The view you arrive at when you discard Descartes’s dualism but fail to discard the imagery of a central (but material) Theater where “it all comes together.” … Cartesian materialism is the view that there is a crucial finish line or boundary somewhere in the brain, marking a place where the order of arrival equals the order of “presentation” in experience because what happens there is what you are conscious of. (p.107)

These indications highlight four initial points which he might be against. First, that consciousness is localized in some specific region of the brain. Second, that there is a place related to the finish line in the brain, marking the onset of conscious experience. Third, that there is a place in the brain where information and the senses are integrated to form consciousness. And fourth, that it is possible to establish a specific moment in time to distinguish pre-experience from post-experience (in this case, this claim does not mention to the brain). We agree that, in some way, all of these

Nor does the soul become any smaller if we cut off some part of the body, but it becomes completely separate from the body when we break up the assemblage of the body’s organs” (Descartes, 1649 [1989] §31). The term “Cartesian” here then might not be very truthful, but we will use it to refer to what Dennett means, not Descartes.
meanings are related. However, the fact that not all of these claims imply one another might be a major source of confusion. Perhaps it is possible to claim, for example, that this anatomic structure related to consciousness does not integrate information, or that it does so, but experience is not there localized. Also, if we posit a functional center to the cognitive model, but one which is spread throughout the thalamic-cortical complex (a sort of functional center which might be in a distinct neural network depending on the moment, such as Edelman, Gally & Baars’[2011] Dynamic core) would Dennett stand against it? If he was only in opposition to Cartesian Materialism, than maybe it would not be a problem. Yet he seems to oppose many other ideas which are related to a Cartesian Theater.

Some theorist might adopt a finish line in the brain for the occurrence of consciousness experience and not claim that this center has central executive functions. That also seems to be another aspect of the Cartesian Theater, as Dennett explains “… even the most sophisticated materialists today often forget that once Descartes’s ghostly res cogitans is discarded, there is no longer a role for a centralized gateway” (Dennett, 1991, p.106). This is also related to the so-called novelty of the Multiple Drafts Model: that a stimulus is discriminated only once, needing not be – in contrast to Cartesian Theater Models – sent to some center for a final discrimination.

Dennett (1991) does not attack only Cartesian Materialism, a specific place in the brain for consciousness. In another moment, he makes a claim which is perhaps overlooked by those that claim he is attacking a straw man:

There is, it seems, an alternative model for the onset of consciousness that avoids the preposterousness of Descartes’s centered brain while permitting absolute timing. Couldn’t consciousness be a matter not of arrival at a point but rather a matter of a representation exceeding some threshold of activation over the whole cortex or large parts thereof? On this model, an element of content becomes conscious at some time t, not by entering some functionally defined and anatomically located system, but by changing state right where it is: by acquiring some property or by having the intensity of one of its properties boosted above some threshold. (p.166-167)
Dennett (1991) calls this a “mode of action” model, which seems to be different from a Cartesian Theater, but is in reality just one of its many disguises. We believe that in this moment, he reveals his most novel criticism, that what makes a theory a Cartesian Theater is really the claim that certain discriminations in a moment in time “T” in the brain are immediately correlated to certain experiences in the same time “T” in consciousness, a claim that any identity theorist must adopt. As he makes clear:

The idea that consciousness is a mode of action of the brain rather than a subsystem of the brain has much to recommend it ... Moreover, such mode shifts can presumably be timed by outside observers, providing, in principle, a unique and determinate sequence of contents attaining the special mode. But this is still the Cartesian Theater if it is claimed that the real (“absolute”) timing of such mode shifts is definitive of subjective sequence. The imagery is slightly different, but the implications are the same. (p.166)

As he puts it, many researchers subscribe to a disguised version of the Cartesian Theater. So, perhaps the main point of opposition to the Cartesian Theater is in corresponding some brain discrimination in millisecond to experiences in the same moment. In this case, we could hardly take this criticism as being directed towards a straw man.

But if we take these ideas too seriously would we not arrive at the claim that any neural correlate of consciousness implies a Cartesian Theater? Possibly, since Dennett (2009) argues that:

Another area of philosophical naivete’ in the cognitive science of consciousness concerns the quest for the Neural Correlate of Consciousness (NCC). It has seemed obvious to quite a few scientists aspiring to solve the mystery of consciousness that there has to be an NCC, the necessary and sufficient conditions, characterized in terms of locatable neural activity, for conscious experiences. How indeed could there not be one, if materialism is true? … There need not be anything mysterian or anti-scientific about the observation that the quest for the
NCC is probably a wild goose chase. (p.234)

After such claim it is easy to acknowledge that Dennett does not attack a straw man. He probably accepts such idea because he understands consciousness as a virtual machine that reads some selected multiple drafts. His strong functionalism shines through, since the virtual level seems almost to obtain a dimension of its own, not reducible to specific brain locations. As Rockwell (1997) notes, Dennett understands consciousness as an emergent property of the system as a whole, so that looking for the correlates of consciousness would result in a category mistake.

All implications of the Cartesian Theater concept discussed so far were related to a localization of consciousness in the brain or a finish line for consciousness. However, there are more implications related to the centralization of power for various cognitive functions; homunculi related to the audience watching the play: The central observer, central intender, central planner, central understander, central meaner, and the self. All of these homunculi refer to the centralization of some specific cognitive function, like comprehending a sentence or planning what we really want to say. However, nothing stops a theorist from agreeing that language, vision, and comprehension are realized by parallel distributed activity which lacks a boss, and yet posit a central executive for planning or the formation of self. In this case, the theorist would be adopting certain characteristics of a Cartesian Theater for some functions, while not for others.

In sum, we think it is safe to say that Dennett (1991) is not opposed only to Cartesian Materialism, but to many other implications of the Cartesian Theater. So we organized a list with all the requirements for a theory to avoid the Cartesian Theater (following Dennett’s descriptions):

1. Consciousness cannot be localized in any specific place of the brain.
2. There cannot be a finish line (place) in the brain, marking the onset of conscious experience.
3. There cannot be a place in the brain, related to consciousness that integrates all information of the brain or all conscious experiences.
4. We cannot mark a specific moment in time to distinguish pre-experience from post-experience (this claim does not mention the
5. There cannot be a central executive module as proposed by Fodor.
6. A stimulus does not need to be discriminated twice, since it is not sent anywhere else for further discriminations.
7. There need not be a mode of action in the brain that corresponds to consciousness.
8. A discrimination in a moment in time “T” in the brain cannot immediately correlate to certain experience in the same time “T” in consciousness.²
9. There need not be Neural Correlates of Consciousness.
10. There cannot be unexplained homunculi bosses to deal with functions such as language, vision, planning and the self.

We identified a total of 10 requirements for a theorist to avoid the Cartesian Theater. However, the main one seems to be number 8. Even though the other nine requirements cannot be reduced to this one, it incorporates the main part of the criticism which is not directed towards a straw man. We believe that the source of confusion over Dennett’s claims happened since not everyone realized the attack was stronger than it seemed to be, and because not everyone agrees that all those 10 requirements need to be met.

4. So is Global Workspace a Cartesian Theater?

Baars (1997), in his paper “In The Theatre of Consciousness”, emphasizes the resemblance of his proposal to the theater metaphor. He compares the global workspace to the stage, attention to the spotlight, the audience to unconscious processors and people behind the scenes to contexts which influence the actors (the content of conscious experience). Could we then conclude that Baars believes that the global workspace is a Cartesian Theater? Not so fast. Baars (1997) claims precisely the contrary:

Daniel Dennett and Marcel Kinsbourne have criticized one conceivable

² Is distinct from 2 because it works for the “mode of action” hypothesis as well, while 2 does not.
theatre model, the ‘Cartesian Theatre’ in which conscious experience ‘comes together in a single point in the brain’, much as René Descartes thought consciousness might be located in the tiny pineal gland. Descartes was looking for just one dimensionless point where the singular soul might connect with the brain. Dennett and Kinsbourne claim that the Cartesian Theatre cannot work, and I believe they are right. It makes no sense. There is no single point in the brain where ‘it all comes together’. But no one in science today suggests a Cartesian Theatre. Certainly none of the cognitive theatre models that have been proposed since the 1950s suffer from these defects. (p.229-300)

As is made clear by this, Dennett’s criticism of the Cartesian Theater is rarely understood to its full meaning; Baars clearly accuses Dennett of attacking a straw man. However, as we have seen, this does not seem to be the case. Baars seems to have in mind only two of the requirements listed above, namely 1 a 3. So there are still eight requirements that might not be met, possibly classifying GWT as a Cartesian Theater. It is important to note that there is no rigid criterion for determining how many of these requirements need to be met in order to avoid the Cartesian Theater.

Baars (1988) meant to unite four traditional hypotheses about consciousness in his theory: the activation hypothesis, the novelty hypothesis, the tip of the iceberg hypothesis and the theater hypothesis. Except for the novelty hypothesis, the rest of them are linked in some way to the Cartesian Theater in Dennett’s account.

In the case of the tip of the iceberg hypothesis, Dennett (1991) explains:

Ray Jackendoff … argues in the same spirit that the highest levels of analysis performed by the brain, by which he means the most abstract, are not accessible in experience, even though they make experience possible, by making it meaningful. His analysis thus provides a useful antidote to yet another incarnation of the Cartesian Theater as the “summit” or “the tip of the iceberg.” (p.278)

It is possible for GWT to incorporate only some aspects of this metaphor which are not problematic. For example, the claim that conscious processes
are only a small portion of what is really going on in the brain, in contrast to a sea of unconscious processors. Since this is the case, he would not be setting the tip of the iceberg as the boss; much to the contrary, he uses it to claim that unconscious processes scattered throughout the brain have a greater potential than consciousness.

The activation hypothesis was also criticized by Dennett (1991). Such criticism was present when he mentioned mode of action models of consciousness. If consciousness is correlated with an exceeding of some threshold, and if the theorist claims that such moment “T” corresponds to an event “T” in consciousness, the model will still be a Cartesian Theater.

Another problem for this hypothesis is that it leaves open how the brain as a whole knows that such threshold was exceeded. As Dennett (1991, p.166) tries to explain: “The objective simultaneities and sequences of events spread across the broad field of the cortex are of no functional relevance unless they can also be accurately detected by mechanisms in the brain”.

Following Dennett’s (1991) words, it does not seem plausible that there is some form of the theater metaphor which does not fall to the problems linked to the Cartesian Theater, as Baars (1997) tried to argue. If there are still any doubts that Dennett does not attack a straw man, the following declaration will certainly solve the problem: “As it happens, all of our unified models of mental functioning today are theatre metaphors; it is essentially all we have” (Baars 1997, p. 307).

Rockwell (1997) noted that Baars made great correlations of the theater metaphor to consciousness phenomenon, explaining, for instance, the paradox of a limited working memory capacity given the enormous processing capacities of the brain as whole. Because of that, Dennett’s (1991, p.108) characterization of the theater as “the most tenacious bad idea bedeviling our attempts to think about consciousness” seems like a bit of an overreaction.

Rockwell (1997) also argued that many of the specific problems between the two theories might result from the difficulty of working with metaphors, causing confusions between the claims of each theorist. Should that be true, the best strategy then would be to verify which ones of the 10 requirements are met by GWT. Although many metaphors are in use, they are just for ease of understanding. We believe the theories are not limited to these
metaphors; many straightforward claims can be extracted from them.

Baars (1988) agrees with the first requirement: “Consciousness cannot be localized in any specific place of the brain”, but disagrees with requirement number 9 “There need not be Neural Correlates of Consciousness”. He claims that information related to consciousness must go through the Extended Reticular-Thalamic Activating System to be broadcast. This seems to be a problem for Dennett (2001, p.222) when he says that: “If, as Jack and Shallice … point out, Baars’ functional neuroanatomy has been superseded, this shows some of the progress we’ve made in the intervening years”. Perhaps Baars has accepted some of the criticism, since he has adopted a slightly different neuroanatomy (Edelman, Gally & Baars, 2011).

The third listed requirement reads “There cannot be a place in the brain, related to consciousness that integrates all information of the brain or all conscious experiences”. Baars (1997) denies that there is a specific point where information is united. Although conscious experience needs to be integrated in the global workspace, this corresponds to the Dynamic Core, which has no fixed location (Edelman, Gally & Baars 2011). Anyhow, this integrative character of consciousness is a main function of the global workspace. The senses, and any other conscious type of information, must be united and can be related in the global workspace, together forming a single coherent integrated experience (Baars 1988, p.350). It might be an open question whether this Dynamic Core biology of global workspace violates this third requirement, but in our opinion, it does not.

Considering requirement 4 “We cannot mark a specific moment in time to distinguish pre-experience from post-experience” there seems to be a finish line for the onset of consciousness, the broadcasting moment. Conscious events are clearly defined. This broadcasting moment might also be associated with requirements 2, 7 and 8, making global workspace a mode of action model of consciousness bearing a clear finish line and a corresponding time of brain and consciousness. This is so because in this model there still is a sense in which the interpretation of conscious experiments of milliseconds could be Orwellian or Stalinesque. The question, “which content was being broadcast at time ‘T’?” is still plausible to ask.

For these aspects, it might be plausible to sustain that Dennett must infer
that the global workspace is a Cartesian Theater. However, Baars (1988) does not easily commit himself to the idea of a moment for consciousness. He mentions the Snowballing Effect:

The neurophysiology suggests that broadcasting may not be an instantaneous event, but a “snowballing” recruitment of global activation, supported by many systems, that may feedback on each other. For example, Libet’s work indicates that for cortical activity to become conscious may take as long as a half second ... This is much longer than a single broadcast message would take, and suggests a circulating flow between cortical and sub-cortical areas, building upon itself until it reaches a threshold. Thus we must not take the broadcasting metaphor too literally: a relatively slow accumulation would accomplish much the same functional end. (p.131)

Even though this comment might make his theory look a bit more similar to Dennett’s proposal, the snowballing effect still results in a threshold of activity that must be exceeded in order to be related to consciousness. The exceeding of the threshold still results in a complete moment for consciousness, which is unreal for Dennett.

Requirements 5 and 6 respectively state that “There cannot be a central executive module as proposed by Fodor”, and that “A stimulus does not need to be discriminated twice, since it is not sent anywhere else for further discriminations”. In GWT stimuli are discriminated first by unconscious specialists and only after a detection of relevance are they sent to a central facility to be globalized. If not, then there would be no competition to access this global workspace, the channel would be direct. However, global workspace is no executive boss, destined to do all the work or to pass down all the orders. Broadcasting occurs precisely so that all unconscious systems can try to solve the problem. Anyhow, the problem of double discrimination of the same stimulus might remain. However, it may be that there is no new discrimination of this stimulus but rather just some automatic broadcast when it arrives at the global workspace.

The tenth and last requirement is that “There cannot be unexplained homunculi bosses to deal with functions such as language, vision, planning
and the self”. This does not seem to be a problem for GWT, since the homunculi are dissolved in neural networks that process in parallel and can follow the solution of Homuncular functionalism.

Dennett (1991, 2001) says he proposes a version of the consensus mentioned by Baars (1988) only ignoring and adding some characteristics. However, precisely how a union with a theory that seems to violate some of his requirements for a theory to avoid the Cartesian Theater is far from clear.

Since GWT meets some of the 10 requirements but not others, it is nonsense to answer if it is a Cartesian Theater or not. We believe the source of confusion is not in metaphors but in the claims of degrees of consciousness, which are unclear in both theories. Baars probably does not think consciousness is an ‘all or nothing phenomena’, but that is not what GWT leads us to, probably as a result of his contrastive analyses method, which compares fully conscious phenomena to fully unconscious ones. As for the MDM it does not explain how a virtual machine is supposed to organize global information and how that could happen spatially or temporally. How and why consciousness has various degrees is not explored in any of the two theories.

We now propose a new solution to this problem of degrees which might make the best of what both theorists intended to propose, eliminating issues and adding novelty which is plausible with recent evidence.

5. The Solution of NAIM

The neuro-astroglial interaction model (NAIM) is a recent proposal which is being developed based on recent knowledge on the workings of glial cells for cognition and emotion. For a more straightforward exposition of this model we suggest further reading (Pereira Jr. & Furlan, 2010; Carrara-Augustenborg & Pereira Jr., 2012; Pereira Jr., dos Santos & Barros, 2013). The point here is to show how this model is the only one (of the three analyzed in this paper) which tries to explain why and how there can be degrees of consciousness. This explanation is weakly mentioned in the GWT proposal, and is highly fuzzy in the MDM.

The history of Cognitive Science has shown us an increasing courage to
tackle problems Behaviorism tried to avoid, such as the mind itself, and functions such as language processing, different types of memory, and visual coding. In 1988, Baars mentioned that Cognitive Science had been overlooking conscious phenomena and gave a great account of how they could be addressed. However, Cognitive Science had still been overlooking the importance of affective states for the production of conscious states. In contrast to GWT and MDM, the consideration of affective states is one major difference that the NAIM brings for understanding consciousness. Affective states can be understood here as emotional, but also as qualitative ones, expressed as ‘the feeling’ of something.

In the last century, astrocytes (a type of glial cells) were commonly understood as having the passive role of supporting metabolic processes, bearing no important role for cognitive or affective states. Neurons have been at the center of attention in the study of the brain. This is such the case that brain sciences came to be known as neuroscience. Recent evidence has started to make the name sound somewhat implausible, as if scientists were considering only half of the brain, missing out on a unique and important half. It was found that astrocyte complexity and amount increased with primate evolution (Banaclocha, 2007). Also, genetic studies determined that the greatest differences in brain gene expression in comparing humans and mice are in glial transcripts (Miller, Horvath & Geschwind, 2010).

Two of the most important (for our purposes here) of these scientific evidences are that astrocyte play fundamental roles in consciousness and learning. Thrane, Thrane, Zeppenfeld, Nanhong Lou, Qiwu Xu, et al. (2012) through calcium imaging in wake mice found that anesthetics (commonly used to induce sleep-like states) suppressed calcium transients in astrocytes. Interestingly, these anesthetics inhibited synchronized widespread calcium waves. This suggests a relation of these waves to the formation of wake states.

According to Xiaoning Han, Michael Chen, Fushun Wang, Windrem, Su Wang, et al. (2013) human astrocytes are larger, more complex and propagate calcium waves faster than mice astroglia. These researchers inserted human glial progenitor cells in neonatal mice. When mature, these animals had both mice glial cell as well as human astrocytes working functionally together. Areas with human glia exhibited a significant
enhancement of synaptic transmission regulation. There was an increase in synaptic plasticity. Behavioral tests showed improved performance in learning and memory tasks. More flexibility in learning is well-known to be associated with consciousness.

The NAIM claims (Pereira Jr. & Furlan, 2010) protoplasmic astrocytes function as ‘local hubs’ which are connected to a group of neurons. These astrocytes can release their own chemical messengers as they establish communication with pre- and post-synaptic neurons, forming tripartite synapses. The job of these local hubs is to integrate information from thousands of synapses into calcium ion waveforms. The whole active network of astrocytes functions as a ‘master hub’ that integrates the results of local hubs in a similar fashion as the global workspace, also broadcasting the integrated information. It also mediates the interaction of metabolic signals with neural processing. The master hub can ascribe positive or negative values to the information of neurons in a comparison with bodily states, given its privileged connections with blood and synapses. Because of the integration and broadcasting, NAIM can also be viewed as an extension to the GWT, or a version of the ‘gathering consensus’ that Dennett and Baars mentioned.

According to Edelman, Gally & Baars (2011), the Dynamic Core is a mechanism for broadcasting events by reentrantly projecting neural signals throughout the cortex. The distributed neural activity that underlies conscious contents is widespread throughout the thalamo-cortical system, being accessible to neural assemblies responsible for different functions (associative learning, memory formation, behavior, planning, etc.). According to NAIM, the same neural mechanisms impact on the astroglial network, which form large calcium waves assumed to be involved in the broadcasting activity. Both are hypothetical models based on recent evidence on brain conscious functioning.

NAIM understands that neuronal networks function in a digital-like fashion (exciting or inhibiting, firing or not firing), while astroglial networks function in a wave-like manner. So while digital-like processes convey content, wave-like processes ascribe feelings to these. This ascription of feelings results in an approval or disapproval of the content which elicit feedback on post-synaptic neurons by causing membrane
potentiation or depression. This is not to say it is a function of single cells to ascribe feelings, but whole networks which constitute brain functions of an individual. Thus, the neuronal network composes generally cognitive content functions, while the astroglial network composes affective states.

While MDM and GWT both emphasize that unconscious processors compete for power, or access, for NAIM, cooperation between the affective and cognitive networks is more relevant for the formation of a conscious episode. The cognitive content does not compete with the affective one, they must find resonance to create cognitive-affective blocks which are broadcast throughout the brain. These blocks are formed when the cognitive network has high activation associated with some representation (e.g. the thought ‘I have to win this race’) and the affective one has a corresponding matching feeling in resonance (e.g. a feeling of intense desire of winning). Selection is a good mechanism when there is not a global goal in common for all the groups. Take the example of organisms in competition, where selection was first discovered. There is little or no benefit for all organisms taken together. In a macro-scale, selection seems even pointless. So inside the same organism, too much competition between functions is not as fitting as is cooperation. The consequences would be drastic if organs such as the lungs and the heart were in competition in the same sense that organisms are. In the brain, the same drastic effects would apply. It is more plausible that inside the organism, since coalitions are all working for the same purpose, cooperation does a better job of resolving conflicts.

As mentioned, GWT does not state clear reasons for why there should be different degrees of consciousness. MDM argues that consciousness is not “an all or nothing” phenomenon but does not succeed in showing how this could in fact be realized by the brain. NAIM states (Carrara-Augustenborg & Pereira Jr., 2012) that variable degrees of consciousness depend on the intensity of activation in affective and cognitive networks, and perhaps most importantly, the degree of resonance between them. Therefore, truly unconscious affective states can occur when there are calcium waves in the astroglial network that do not affect neuronal networks at all. In contrast, truly unconscious cognitive states can happen when neural groups do not interact with resonance with the astroglial network.

An event in a fraction of milliseconds that is normally not perceived
as fully conscious can be understood as exciting some local hubs but not enough to characterize a full conscious episode. Metacontrast masking interpretations can show the singularities of these three approaches to consciousness. These experiments were first made by Fehrer & Raab (1964) and there were various follow-ups (including Breitmeyer, 1984, Breitmeyer, Ro, O’Gmen & Todd, 2007).

In these experiments, generally, a disc is presented with the duration of 30msec, which is quickly followed by the presentation of a ring (in the same location of the visual field), whose internal circle has a similar diameter to the diameter of the disc as a whole. Subjects in these experiments only report seeing the ring. However, if asked to guess how many stimuli there were, they get it right that there were two with a precision that is higher than guess. MDM argues that asking if the disc was conscious at the precise moment of discrimination is nonsense. GWT, taken strictly, would have to determine if the disc was conscious or not based on the occurrence or lack of a broadcast. NAIM can state that the disc could have been perceived with a certain degree of consciousness. Also, in principle, a more detailed neurophysiological analysis could solve the riddle, which for Dennett is nonsense. This would be done by stating if, in an instant, there were groups of local hubs processing disc information. Also, the fact that if the ring is not presented than the disc is perceived as fully conscious leads us to believe that the individual at the moment had in fact some degree of consciousness of the disc.

The projects of Todd (2006, 2009), Breitmeyer, Ro, O’Gmen & Todd, (2007) and Christie & Barresi (2002) show and analyze new evidence which, they argue, is capable of distinguishing between the Stalinesque and Orwellian revisions. Todd (2006, 2009) and Breitmeyer, Ro, O’Gmen & Todd, (2007) conclude that for the phenomenon of metacontrast masking only the Stalinesque revision can be true. Christie and Barresi show how both type of revisions can be true depending on the task. Todd (2009) has argued that this phenomena must have a Stalinesque reading (the disc did not make it to consciousness), because the Orwellian contrast (tested by letting the disc become conscious by differences in time exposition) has different experimental functional results. NAIM would account for Todd’s analysis of recent evidence, since a functional difference would still be
possible between fully conscious events and others with less consciousness, since there can be a functional difference for local hubs activities and master hub activity.

One could argue that this solution is the same found if we take the snowballing effect of the GWT seriously. Perhaps so, but this effect is sort of an isolated claim from the rest of the model, it is never explained how it should go along with the rest. A contrasting claim, which is essential to GWT is that contexts (unconscious specialized processors with privileged access to consciousness) along with other unconscious processors account for processing everything that is not at the moment in the theater of consciousness. Take the classic example of driving a car, unconscious processes would be doing the monitoring of changing gears. For NAIM, there are different degrees of consciousness, and changing gears would not be done unconsciously, but by smaller degrees of consciousness. This makes the snowballing effect mentioned by Baars not just a side note to be forgotten, but a crucial part of the theory, which is incorporated in the model. In this respect, NAIM is closer to MDM.

However, NAIM is not in accordance with MDM either, since there is also a complete moment for consciousness which is when the master hub is working fully. As shown, it has a different solution to explaining conscious events in milliseconds. Also, we could map the hubs anatomically to the astrocyte networks (violating requirement 9). It still is a mode of action model (violating requirement 7), in which a discrimination in a moment in time “T” in the brain can immediately correlate to certain experience in the same time “T” in consciousness (violating requirement 8). The novelty is that small degrees of consciousness map onto the activity of some local hubs (small degrees of resonance of cognitive and affective networks), while full consciousness maps onto the activity of the master hub. The Master Hub has the same explanatory power as GWT for explaining the “binding” of perception, while MDM fails to give a clear account of such phenomenon.

All three theories accept modular phenomena as well as global phenomena. They might accord and vary in respect to the way of explaining conscious experience changes by brain impairment. In the case of prosopagnosia, a local impairment, usually in the fusiform gyrus, MDM
could argue that since the unconscious processors responsible for face recognition are damaged, there is little or nothing the Joycean machine could probe on faces. If the patient reports no consciousness of people’s faces, then that would imply that he cannot have higher order thoughts on such information. For the GWT and NAIM, face recognition information would not reach the broadcasting moment because the damaged modular processes responsible for face recognition would not deliver their content.

In the case of blindsight, caused by occipital damage, normally defined as seeing without having the conscious qualitative visual experience, each theory proposes a different explanation. This case is even more interesting, because patients can guess correctly which objects are in the visual blind spot without reporting having the conscious experience of seeing it. The correct answer is only tapped by the experimenter’s cues. According to Dennett (1991), if the person learns when to start guessing about objects in his blind spot without the experimenter’s cue, then he will have his visual consciousness back. According to GWT, There is no visual experience because the broadcasting of information about the damaged occipital area does not occur. If the person guesses correctly, that just means the unconscious processors are handling the job without broadcasting. In this case, NAIM also provides a unique solution based on degrees of consciousness. About general blindsight patients, NAIM has the same solution as GWT. However, in the case of Dennett’s mentioned patient who can learn to start guessing by himself what is on the blind spot, NAIM can add that this information might reach resonance with local hubs, giving him a degree of consciousness over the event, but not a full conscious event as a non-damaged person should have.

NAIM accounts perfectly for the reports of Weiskrantz’s patient:

As stimulus “salience” increases, the patient may say insistently that he still does not “see,” but he now has a kind of “feeling” that something is there. In some cases, if the salience is increased still further, a point may be reached where the subject says he “sees” but the experience is not veridical. For example, DB “sees” in response to a vigorously moving stimulus, but he does not see it as a coherent moving object, but instead reports complex patterns of “waves.” Other subjects report
“dark shadows” emerging as brightness and contrast are increased to high levels. (1988, p. 189).

Dennett (1991) argues that what such patients have is just like peripheral vision, which is normal sight. However, these reports clearly favor a degrees of consciousness approach explained by NAIM, since after all, MDM also fails to account for why peripheral vision should have different ‘qualities’ than fully conscious vision. Also, the patient has a peripheral-like experience in an area where he should not have, therefore it is not precisely “normal sight”. Dennett (1991) seems at such an urge to explain that blindsight is not “magic” that he forgets his model itself cannot separate between normal seeing and a recovering blindsight patient. Again, degrees of consciousness need to be called in.

Finally, the models also present separate solutions to the philosophical problems of Qualia. According to the MDM, Qualia is an illusion. Such claim has led people to oddly characterize Dennett as the theorist who denies consciousness. He would not have written a book on consciousness if he were to deny it. He means only that we need not apply extra ontology to the “seeming” or the “feel of experience”. For GWT (Edelman, Gally & Baars, 2011) Qualia is a non-causal phenomena that emerges from the broadcasting activity, but no extra explanation is given for why the Dynamic Core should make Qualia emerge while other neuronal processes should not. In the case of NAIM, there is a physical difference that allows for the absence or presence of experience. Neuro-astroglial interactions are a different kind of physical process which might allow for qualitative process to emerge, and the degree to which they interact corresponds to the degree to which the strength of qualitative experiences occur (For other philosophical implications of NAIM see Pereira Jr. & Lehmann, 2013).

6. Concluding Remarks

A contrast of MDM and GWT by the asking the question ‘is GWT a Cartesian Theater?’ reveals that problems on how degrees of consciousness are possible have not been well addressed by these theories. NAIM seems to propose an adequate solution to the problem of degrees of consciousness
by theoretical means, as we hope to have shown, and also by accounting for recent physiological evidence on astrocytes and psychological evidence. Of course, NAIM is a hypothetical model and other models, which are also hypothetical, could account for degrees of consciousness, given the possibility of flexibility in claims. For instance, Baars (along with Franklin and Ramsoy, 2013) continues to develop his model and could make the GWT account for our suggestions, which is mainly to account theoretically for why there should be degrees of consciousness and to use this account as a true part of the theory which can explain phenomenon, rather than a part to be forgotten.

References


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