Optimality Theory and other theories of the mind: A system architecture comparison

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PREFACE

I love language. I love the intricacies of its structure, its ability to communicate ideas and the beauty of a good utterance.

I've been fascinated with the ease with which we understand certain ideas, and the difficulty we face when trying to interpret others since I became an adult. And I am not alone; as can be witnessed if you leaf through any psychology text book, major philosophical work or check out your local bookstore. We are fascinated by it, as we should be. It surrounds our everyday life, when watching the TV, listening to the radio, surfing the internet or, most importantly when talking to other people.

For me the different languages are the ultimate expression of communal artwork. We talk about statues as being permanent, but it has nothing on language. The languages we are using now may not sound like the languages of our ancestors, but it is the same work of art, continually changing as new artists lay their linguistic brushes at its tapestry. In the end this is why, even though I started out with the natural sciences, mathematics and computer technology, I had to study theoretical linguistics.

Art is about communicating ideas, and within language you find the tools to express all of them. In addition to being artwork in and of itself it is also a tool with which we are able to create smaller pieces; like poems, novels or scientific journals. It permeates through our every action. This is the tool with which we have crafted our modern human life. It lends itself to cooperation, not just between people trying to do simple tasks, like making a good meal or a jacket. It lends itself to cooperation across centuries, or millennia, helping us forge theories of ethics, mathematics, physical reality and the human condition.

Language might be the single most important invention, tool and artwork humanity has ever produced, and I think exploring its structure, processes and effects is both important and a personal privilege.

Still, it was hard to figure out what sort of thesis I should write. Every aspect of language fascinates me, from the biologically explained production of simple features in phonetics to the process of understanding abstract ideas in pragmatics. But the theory that has fascinated me the most the last five years has been Optimality Theory. The simple architecture of it hides a powerful potential for explaining seemingly chaotic phenomenon in a structured fashion. And after learning it I could see its use in so many of the subjects I had immersed myself in in the past. It popped up as a possible solution when discussing ethics, meta-programming and economics. And psychology, the study of the mind.

It is the core of my understanding of linguistics; as it is a human phenomenon created by us, the underlying system for its creation should lie somewhere within us. In 2009 I was online listening to a talk called "Unlocking the Secrets and Powers of the Brain" financed by Discovery Magazine. It dealt with modern cognitive psychology and had experts from different cognitive sciences talking about their fields. In it there was a description of how they viewed the process of choosing instrumental actions based on our surroundings that matched very much my idea of how Optimality Theory works. The idea of trying to merge the system of Optimality Theory with that of Cognitive Psychology was too appealing to ignore.

This is thus my first attempt at analyzing the various theories using common terminology in an attempt to fuse them together where possible.

I hope you, the reader, can find something in this thesis illuminating. I know I have learned a lot from writing it.

- Karl-Erlend Mikalsen

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Chapter 1: Introduction

Every scientific enquiry aims to create understanding of some subject, and a very good start for a venture is clarifying what the end goal of that venture is.

This end goal is not necessarily a given certainty for linguistic enquiries. This should be no surprise however. With a diverse field that encompasses enormous amounts of data and interpretations, such questions of scientific philosophy might simply not be a priority.

But still, the question is important and should be answered. It is of special importance for this thesis, as the answer to the question needs explanation for the hypothesis to be relevant: What is linguistics trying to explain?

One of the descriptions one can find of theoretical linguistics is that it is a field where one tries to describe language and its variations. It is also the field where one tries to find common patterns in diverse languages or the field where one tries ones best to correctly describe in a systematic fashion how language acts. It is also the field of study where one tries to use language as a phenotype for the patterns of the mind, using analysis of language patterns to understand the process of language processing and understanding in the human brain. [1]

At first glance these diverse descriptions might seem to be pointing towards the same goal. The last one however stands out with a different end goal than the others. It does not just describe different possible systems for language production, but also opens up the possibility of finding out exactly what process or processes our brains utilize for our specific language production, prying into the inner workings of the brain.

This thesis will examine possible differences and similarities between different models of cognitive and biological psychology and linguistics; particularly Optimality Theory. This thesis aims to accurately describe the various models and search for convergences, if any such exist.

[1] Kager argues, in Optimality Theory (1999) on page 26, that a formal grammar should not be equated with its computational implementation, and I am forced to agree. The formal grammars of linguistics fall short of any such goal, but I would venture that it can still give insights into the problem, and I will argue for this view in this introduction. Not only can language be seen as a phenotype for the workings of the mind, but the interpretations of linguistic systems that linguists create based on the data at hand can also describe possible interpretations of more esoteric data from brain scans. Cognitive Neuropsychology can tell us that "depictive representations are created in early visual cortex" (BA17, BA18, V1 & V2) [Eysenck & Keane (2010:111)], but it cannot (yet) tell us what happens in these areas to create these representations.

1.1 THE PROBLEM

In classes and in linguistic textbooks, the description of language and how one can systematically describe it in a manner uniform for all languages take precedence. That this should in turn describe how we actually produce language is not necessarily true. The first is trying to accurately describe how a phenomenon acts through physical descriptions, and the other extrapolates from this and other data *why* this phenomenon acts as it does.

The statement that language is tied to the brain is proven; damage to various parts of the brain can give rise to diverse language problems such as expressive aphasia [Benton (1965), Musso et al. (1999), Siegal & Varley (2007) amongst others], or Specific Language Impairment [Joanisse & Seidenberg (1998)]. But this does not necessitate that any systematic account of the behaviour of language is a good description of the inner workings of the mind. Language could indeed be used as a phenotype for mental processes, but it does not need to show us more of the mind's structure than what brown-coloured eyes show us about the structure of DNA.

A problem with trying to deduce a system from scraps of information, none of which are directly about the system itself, is that of arbitrary complexity. That is, the complexity of the system is not given.

If told that there are some numbers in a row, 1, 2 and 3, what should the fourth number be? It could simply be 4. Or it could be that we're inside the Fibonacci sequence and the next number is 5. Or it could be a list of prime numbers (including 1) which would also make the next number 5, but for a completely different reason. Or it could be that we're seeing the first three numbers of a postal code. The next number is "H".

The point is that just seeing the numbers does nothing but hint at the underlying structure, and simply choosing the structure that seems to be the simplest or most efficient is in no way a guarantee for being correct. Simply studying language data can lead to several different systems that could account well enough for the data at hand. One could simply add layers of complexity to include data that is otherwise not supported. This can lead to several working conclusions that contradict each other.

Taking this into account, simply finding an efficient way to process language still has value in and of itself - not only as an attempt to find novel systems for information processing, but also for the development of speech production and analyzing software, spell-checkers or effective syntax for programming languages..

But it is clearly also in our best interests to find out how the mind pieces together information. Language can make for a good path to come to such understanding, maybe even the best path (with the possible exception of creating a complete connectome [Sporns (2005)]). If we can agree that language utterances are processed in the brain then the production of speech is the closest thing we have to a direct phenotype to some structure of the mind. The words we use, their internal and external structure, when and how we use the words we use; these are all direct consequences of the structure by which they are created.

With the example of the problem of deducing the next number in a sequence, we saw that even testing of a hypothesis to check for predictive power is in no way a guarantee for being on the right path. Both the Fibonacci sequence and the prime number sequence came to the same conclusion. But further testing would have shown clearly that there are differences and that only one hypothesis could be right. Enough rigorous testing strengthens the theory, making it more likely to be true.

But are modern linguistic theories actively describing this mental structure, or is it simply creating *a* structure, useful for computing language or for creating learning algorithms but little else?

There are ways of lessening the impact of this science-philosophical pitfall. If Optimality Theory is to be a theory of how a portion of the mind processes information, we can compare it to other theories that aim to do the same.

1.2 THE HYPOTHESIS

The hypothesis for this master is based in part on a talk given by Dr. Rebecca Saxe [Saxe (2009)]. She was describing how people with damage to a specific part of the brain had problems *not* using whatever was in front of them, a condition called Utilization Behaviour. She talked about how she thought the brain was making decisions about what to do. First, we create a list about possible actions to take. Then that list is shortened to one, optimal action, which is then promptly started.

This sounded to me to be very much how Optimality Theory proposes that we solve linguistic problems. Could it be that Cognitive Psychology (To which Dr. Saxe adheres) and Optimality Theory had come to the same conclusions?

If two independent theories can come to approximately the same conclusions about how the mind processes information then this should strengthen both theories, making it likelier that they are right. This is of course taking it as a given that the mind has a basic structure uniformly used for processing various types of information. By this logic, if there are cognitive theories unrelated to Optimality Theory that, while exploring in a novel fashion different aspects of the human mind and comes to conclusions convergent with those of Optimality Theory, then this strengthens both this other theory *and* Optimality Theory.

My hypothesis is this: The brains various levels of cognition are, if separated into modules, still structurally similar. Thus different theories describing the workings of these various levels of cognition should share similarities.

1.3 OVERVIEW

Chapter 2 is given in its entirety to a presentation of Optimality Theory. As it a goal for this thesis is to compare different psychological theories' descriptions of how the mind processes information with that of the Optimality Theoretical approach, it is necessary to describe Optimality Theory in terms suitable for a cross-field examination.

Using only the internal terminology of Optimality Theory one could not possibly hope to compare it to any other theories. The language barrier would keep them at an arm's length. To quote Nietzsche: "...language which understands and misunderstands all action as conditioned by an actor, by a 'subject'..." [Nietzsche (1996:30)] Nietzsche here rails against the language for not being rich enough to include his thoughts about the oneness of the action and the actor; there is no separation he says, between the lightning and the flash, but he struggles with the language which needs the divide. There is a necessary divide between the word and the thought; one word has different meanings, and one meaning can have different words. As such finding clarity in the meaning of the expressions used so they can be used in a uniform fashion is a goal in itself.

This exploration of Optimality Theory will also mean that non-linguists more experienced in the diverse non-linguistic fields presented here can partake in criticism, and as such two short and simple examples of Optimality Theory in use have been included.

In chapter 3 the theories other than Optimality Theory are presented as understood by the author.

One of the subchapters of chapter three is that of Cognitive Psychology. The other two theories presented here, Motivational Psychology and Connectionist Theory are not in direct opposition to this and both use and are used by cognitive theorists.

Although the theories which will be presented have very general headers they are, of course, consisting of individual theorists diverse understandings of the theories in question. As such, by Motivational Theory one might specifically mean one of several different theories, like Incentive Theory (Adler 1924), Drive Theory (Freud 1962), Need Theory (Maslow 1943) or Self-Determination Theory (Deci 1975 and Rigby 1992)]. In this thesis however broader monikers have been used, based mainly on the descriptions of Reeve (2009), Eysenck & Keane (2010), Sternberg (2009) and Rumelhart (1986)/McClelland (1986).

In chapter 4 we will look at some comparisons between the presented theories and Optimality Theory. The divisions done in chapter 3 into Motivational Psychology, Connectionist Theory and Cognitive Psychology are kept for chapter 4 for ease of reference. Following chapter 4 there is a short conclusion.

I hope this thesis illuminates the possibility of more cross-field cooperation towards the common goal of the humanistic sciences: To understand the human condition.

Chapter 2: Optimality Theory

2.1 A SHORT HISTORICAL INTRODUCTION

Optimality Theory was originally a phonological theory proposed by Alan Prince and Paul Smolensky in their 1993 paper *Optimality Theory*.

To see how it aimed to change phonology we can look at the definition of a phonological theory preceding their paper by only 3 years:

“A theory of phonology is built of three parts: it is a theory of the nature of phonological representations; it is an inventory of levels of representation, and a characterization of each level; and it is a theory of phonological rules, the statements that relate representations on each level.” [Goldsmith (1990:331)]

Of these three partitions of the definition of what a phonological theory is, none are used in Optimality Theory. Firstly, Prince & Smolensky (1993) does not mention the phonological representations other than in passing. Optimality Theory uses the same features as earlier phonological theories; what are changed are the grammatical rules by which they are processed.

In Goldsmith (1990) the author presents his concerns for the status of the third partition of a phonological theory. The rules are creating problems. Prince and Smolensky deal with the ”why” of the problem; with the absolute rules the theory of Universal Grammar created a need for multiple and complex well-formedness constraints on the rules in each individual language [Prince & Smolensky (1993:1)].

Universal Grammar states that individual languages draw their basic options from a limited set of universal properties, a core grammar that is innate in our linguistic modules [Kager (1999:1)].

With a growing number of rules that rely on this core grammar, explaining why most languages ignore most rules can be an arduous task. Instead Prince and Smolensky propose that phonology does away with the rules altogether and keep the well-formedness constraints. Instead of working in harmony to create the complete picture of a language, these constraints would be in constant conflict, vying for prominence, contradicting each other. These constraints should be universal for all languages, and each language would have a grammar which would determine which constraints would surface and shape the language. In addition to this there would need to be a mechanism for solving the conflicts inherent in the system [Prince & Smolensky (1993:1-2)].

Gone are Goldsmith's intermediate levels of representation between the input and output, and gone are the phonological rules. The process of phonology happens in one level, where every part of the utterance must be processed together to ensure that the tones and weight from the higher levels of the prosodic hierarchy fits with the lower levels, all the way down to the features.

2.2 THE MEASUREMENT CRITERIA

This thesis aspires to find similes to the way Optimality Theory describes the workings of the mind in other sciences dealing with the mind's ability to process information. As such, before looking into Connectionist Theory, Cognitive Psychology or Motivation Theory (which will be presented in chapter 3 and discussed in chapter 4) we need to properly define what we are looking for. For this we need to find the abstract systemic concepts that drive Optimality Theory.

Optimality Theory is, like any good and living theory, in constant flux. As different scientists add their research and interpretations of data to the growing pool of knowledge the theory changes; and different scientists get different interpretations of what Optimality Theory is.

In order to avoid splitting Optimality Theory into different camps only two books will be used as main sources for information on Optimality Theory. These books are *Optimality Theory* from 1993 by Paul Smolensky and Alan Price, and *Optimality Theory* from 1999 by René Kager.

In addition there are several other theories that tie into Optimality Theory on some level, for example Moraic Theory, Syllable Theory and Feature Geometry; Although these might be interesting for the representation of mental objects in cognition this thesis will examine computation within cognition. Also, this thesis will focus on psychological theories unrelated to linguistics. The criteria towards which likeness will be measured will thus come directly from Optimality Theory and not these scholastic neighbours.

Thus we will need to look at the bigger picture of what Optimality Theory entails and how it claims to work on a macro scale; leaving specific linguistic details to be described in this context by others. One of these macro effects is that of Universal Grammar. Universal Grammar, or "UG", stipulates that constraints (and certain other mental structures) are inborn in humans. This is not a view particular to Optimality Theory, but a staple of modern phonology, and so while it could be interesting to note if other cognitive sciences have the same interpretation of the mind, this thesis will use three other abstract constructs to be the main descriptors of the processes inherent to Optimality Theory:

GEN

CON

EVAL

Kager (1999:19) list the following components of OT grammar:

(20) Components of the OT grammar
LEXICON: contains lexical representations (or underlying forms) of morphemes, which form the input to:
GENERATOR: generates output candidates for some input, and submits these to:
EVALUATOR: the set of ranked constraints, which evaluates output candidates as to their harmonic values, and selects the optimal candidate.

The **LEXICON** is an important and integral part of Optimality Theory. It is also linguistically specific, and so trying to find this in a non-linguistic cognitive field would be interesting, but unlikely.

Rather than tangle with the Lexicon this thesis instead extrapolates the CON partition of the **EVALUATOR**. To this author it seems natural that there should be a separation between the ranked lists of constraints and the modules that evaluate the output candidate based on these constraints.

Let us now try to describe GEN, CON and EVAL in such a manner as to be field-independent, and possibly recognizable in other theories and fields.

2.2.1 GEN

In Optimality Theory the **GENERATOR**, or GEN is what generates a list of possible outputs or candidates for some input. The input for phonology is an idealized abstract representation of a lexical word's appearance. The output candidates are then just what their names entail; they are candidates presented to be possible outputs. Freedom of Analysis [Kager (1999:20)] states that these output candidates should be as free as possible. Kager states that "Any amount of structure may be posited."

For non-linguistic purposes this could be any generation of a list of possibilities. First and foremost we should consider almost direct equivalents as a possible positive match with Optimality Theory. This means that any model that would generate a list of possible outcomes, or candidates for any number of problems, i.e. possible solutions, would be a direct match. Given problem-solving tasks for example, if some part of the system generated a list of possible (and largely unranked) solutions, this would be a very possible match for Optimality Theory's GEN.

Secondarily we should consider systems that generate large near-random lists of other types; For example, given the previous scenario of a problem solving apparatus, if rather than solutions you had a near-random list of problems to be solved or a near random list of obstacles for your solutions this could be compared to GEN.

One of the ideas of GEN is that it is supposed to generate a near-infinite or very large list of possible outputs which are to be compared to an input. An alternative way of representing this is saying that Freedom of Analysis, which allows any amount of structure to be posited, allows for near-random candidates. Thus the other parts of the structural architecture must take into consideration the possibility of completely irregular output candidates. For example one possible pronunciation of "car" generated by GEN could be "chafst".

2.2.2 CON

In Optimality Theory CON provides the constraints by which the possible outputs generated in GEN are measured. In Kager (1999) CON is specified to be containing "all universal constraints" [Kager (1999:21)].

These constraints are ranked from most important to least important. The ranking gives the specifics of a language, so for multilingual speakers there would have to be more than one ranking available to the structure

As with GEN, not much needs to be changed for this to apply to non-linguistic systems. CON is colloquially a list of *do not's*. Constraints generally do not check for what is *good*, but rather what is *bad*. One contrastive feature of Optimality Theory is that it as a system does not look actively for the best candidate per se, but rather weeds out the non-optimal candidates systematically until only the optimal candidate remains.

The internal ranking from most important to least important creates an opportunity to handle constraint conflict. When there is competition between these constraints we find the primus motor for choosing grammatical or correct outputs. To quote Kager: "Constraints are intrinsically in CONFLICT, hence every logically possible output of any grammar will necessarily violate at least some constraint." [Kager (1999:3)]

It would be interesting to find such internal conflict in the rule sets of scrutinized systems; or better yet, finding constraints rather than rules. If constraints are universal in OT, one should assume that other faculties of the brain would use a similar standard. Thus the appearance of an inborn set of constraints governing mental tasks, as well as ranked solution protocols would be of interest.

2.2.3 EVAL

The **EVALUATOR**, or EVAL, is where the candidates generated by GEN are measured using the constraints and their ranking provided by CON. As this is the product of CON and GEN a system that has something equivalent to EVAL would necessarily have something at least structurally similar to either one or both of CON and GEN. Such a system would in all likelihood have many aspects in common with Optimality Theory.

Another important part of EVAL is *parallelism*. The transition from input to output happens in one step without changing the input candidate. All the inputs are measured, and if found acceptable passed through to the output. A similar system of parallelism in moving from input to output would be interesting to see in other systems.

In EVAL we also find the true backbone of OT; it is an input-output correspondence system. The outputs are checked for harmony with the input. This could seem incompatible with many forms of problem-solving tasks as the input and the output could possibly have differing natures. Still, if the input and the output differ, there could be harmony between them. If the input is, say a situation, and the problem is to choose an action, that action would need to be in harmony with the realities of the situation. Thus the output must be in harmony with the input.

2.2.4 An explanation of descriptive elements

Before we look at the two examples we should get a passing acquaintance with the symbols used by Optimality Theory, and a short introduction to phonetic and phonemic representation.

There are two different types of phonological representation used; one for the input and one for the output. The input form is the maximally idealized form stored and is written inside slashes, as such: /taiger/. This is a suggested input for the English word "tiger" using phonemes relevant for the language in question. The output candidates of the word are written inside brackets and will normally (but not necessarily) feature more diacritics, for example prosodic markers: [ˈtʌɪ.gər]. These brackets are used for phonetic representations. The symbols used inside these brackets are linked to very specific sounds, and any similarity with normal letters of the alphabet does not need to mean that the sound is similar. This thesis is not aimed at explaining phonetic representation and as such the following examples will use well-known letters of the English alphabet; which is technically wrong but will hopefully make it easier to understand the functionality of the system. Some of the more usual diacritics are [:] meaning *long* or *weighted*, [ˈ] meaning *primary stress* and [ˌ] meaning *secondary stress*.

In these phonetic representations you will notice that some periods are added. These mark the transitions between syllables. The syllable is often described as being a tripartition, divided into the ONSET, the NUCLEUS and the CODA [Roca (1994:141)].

Let us look at the syllable [gər]. The NUCLEUS is the central part of the syllable and is usually a vowel. In this syllable the vowel is [ə]. The ONSET of the syllable is those consonants that precede the nucleus. For this syllable that means [g]. The CODA of a syllable is those consonants that follow the nucleus. For this syllable that means [r]. The CODA and NUCLEUS are sometimes grouped together and referred to as the RHYME of a syllable.

For natural human languages a consonant should be part of an onset rather than a coda, if at all possible [Itô (1989:222)]. This can be described with a constraint named ONS which states that all syllables should have onsets [Prince & Smolensky (1993:16)].

For simplicity's sake the exact usage of this constraint will be ignored for the following examples, as this is one of the most important and inviolate constraints. Consequentially all the output candidates chosen for the examples will have ONSETS, if possible. Please note that GEN will normally generate output candidates that violate this constraint, but that these will simply be ignored for these simple examples.

Let us quickly look at the effects of this ONSET constraint. Normally for phonologists this would be done using tableaus, multiple output candidates and rigorous testing with conflicting or otherwise interfering constraints. We will do this for the examples, but for now let us just look at the results.

Take the word “bookshelf”, roughly pronounced [bo:kʃelf]. There must be two syllables because there are two vowels separated by consonants (This is a simplification. Real languages are very, very complex and varied), so the question is, where should the boundaries between the two syllables go?

It could not be [bookʃ.elf] because you are allowed to use the syllable [ʃelf] in English. Therefore speakers would prefer to move the [ʃ] from the coda of [bookʃ] and into the onset of [ʃelf], because of the effects of the ONS constraint. It could not be [boo.kʃelf] because English normally does not allow for the syllable [kʃelf]. Or more precisely, it does not allow for the onset [kʃ].

Thus the final syllable output is [book.ʃelf]. The complete explanation of why syllables behave this way, as described with Optimality Theory could easily fill a thesis in itself, and so for the following examples will ignore the possibility that the syllables are formed in any other way than those presented.

The examples will also feature vowel insertion. This is when a vowel that is not present in the input is inserted into an output. These vowels are also called epenthetic vowels. The process of finding the right epenthetic vowel can be arduous, complicated and lengthy. Instead, as with syllable boundaries, we will ignore this aspect for the following examples.

2.3 THE FIRST EXAMPLE - CONSONANT CLUSTERS IN JAPANESE LOAN WORDS

To give an example of how GEN, CON and EVAL works we will look at syllable structure in Japanese.

In this example we will assume that the speaker is a Japanese national trying to say the English loan word “excite”$_{\text{INF,}}$ created by the stem **excite**. (This example can be found in Webb (1992:15)) The input of the word is /eksait/, as a Japanese speaker would hear an English speaker say it. This, the input, is not necessarily optimally well-formed phonologically, especially for someone wanting to use the word in Japanese. Thus GEN tries to give a range of possibilities. Usually, the scope is assumed to be near-infinite. These possibilities are called *output candidates*. This example will use the following output candidates: [ek.sait], [e.ki.sai.to], [ek.sa.si.to], [ek.sai], [e.ki.sa.si.to] and [e.sai.to]. GEN will also create any other possible output that you could imagine. For example [e.ki.sa.si.to.to], [ek.ki.sai.re.no.to], [xbl.rgf] and [tooth.paste] should all in theory be possible output candidates and EVAL should be able to remove these obviously ill formed candidates.

After GEN has created the output candidates EVAL is activated to check the well-formedness of the output candidates to find the optimal candidate. To do so it needs to set some criteria for what constitutes a well formed candidate. These criteria are called *constraints* which are found in CON. Each language is believed to have a set ranking of constraints. These constraints are arranged from least important to most important in accordance to each other.

There are two types of constraints. One type of constraint is the faithfulness constraints. These constraints say that what is in the input should be in the output (do not delete anything), or that something that is in the output should be in the input (do not add anything). Faithfulness constraints make sure that there is an input-output correspondence. Optimality Theory is, as mentioned, referred to as an input-output correspondence system.

The other type of constraint is called a markedness constraint. These make sure that combinations of sounds that sound *disharmonic* do not come to fruition. For example, Japanese language speakers often find consonant clusters to be disharmonic, and so they have constraints that make sure that when speaking there is almost always a vowel between each spoken consonant.

For this example the following constraints will be used[2]:

MAX-IO	Do not delete anything from the input
DEP-IO	Do not add anything to the output that is not in the input
*CODA	There should be no coda in a syllable.

MAX-IO, or maximal input-output, is a constraint type that says that what is in the input should be in the output. The output is a maximal representation of the input. This is a faithfulness constraint.

DEP-IO, or dependent input-output, is a constraint type that says that what is in the output should be in the input. The output is dependent on the input. This is a faithfulness constraint.

*CODA is a markedness constraint saying that there should not be any sounds in the coda position of a syllable.

[2] My MAX-IO constraint is modeled after Kager (1999:67), as is the DEP-IO constraint (1999:68)
The *CODA constraint is modeled after the –COD constraint in Prince & Smolensky (1993) page 34, but with a name change to converge with the other constraints. Japanese is more complex than this, and will allow certain codas to be pronounced, for example codas consisting of [n], such as in “sansei” (English “agreement” or “acidity”).

These constraints are ranked in accordance to each other. It is not necessary that a constraint be higher or lower ranked than a particular other constraint. Constraints can be ranked as equals. For this example the ranking will be:

MAX-IO , *CODA >> DEP-IO

MAX-IO is ranked highest together with *CODA, and these two outrank DEP-IO. DEP-IO is the lowest ranked.

Then the constraint rankings are tested in what is called a tableau. The tableau is a table with the constraints on the top, ranked from most important to the left to least important to the right. In the upper left corner one often finds the input. On the left side of the tableau, below the input, the output candidates are listed so the tableau looks like this:

Tableau 1: An empty Tableau

/eksait/	MAX-IO	*CODA	DEP-IO
[ek.sait]			
[e.ki.sai.to]			
[ek.sa.si.to]			
[ek.sai]			
[e.ki.sa.si.to]			
[e.sai.to]			

As you can see there are hard lines going vertically between the constraints *CODA and DEP-IO. This means that the constraint on the left side is ranked higher than the constraint on the right side. There is a dotted line between the two constraints MAX-IO and *CODA to mark them as equals. This means that MAX-IO is ranked higher than DEP-IO because there is (at least) one hard line between them.

Now we will check for violations of the constraints. For example, we have the constraint *CODA. The first output candidate [ek.sait] has the codas [k] and [t] in its first and second syllable respectively. Since *CODA says you should not have any coda at all this is violated in that output candidate. We mark this by adding a small star in the box where that output candidate and constraint intersects for each of the violations. Two stars mean two violations.

But we can see that this is not the only output candidate that violates this particular constraint. [ek.sa.si.to] also has a coda, the [k] in its first syllable, as has [ek.sai]. So we mark yet another star in that column for each of these candidates.

The next constraint, MAX-IO says that if there is something in the input, this something should also be in the output. In the output candidate [ek.sai] we can see that all of the segments have correspondents in the input. The consonant /t/ from the input does not have a correspondent in the output however. The consonant has been deleted. Thus this output candidate violates this constraint and a star is added to the appropriate intersecting box for this violation. [e.sai.to] is missing a /k/ so it too gets a violation mark:

That leaves only the DEP-IO constraint. This constraint checks to see that everything that is in the output has an input correspondent; or more colloquially "Do not add anything". We can see that [e.ki.sai.to] has an [i] and an [o] that were not in the input, that [ek.sa.si.to] has an [s] and an [o] that were not in the input, [e.ki.sa.si.to] has an [i], an [s] and an [o] that were not in the input and [e.sai.to] has an [o] that was not in the input. Marking of the violation marks we get this tableau:

Tableau 2: Violation Marks

/eksait/	MAX-IO	*CODA	DEP-IO
[ek.sait]		**	
[e.ki.sai.to]			**
[ek.sa.si.to]		*	**
[ek.sai]	*	*	
[e.ki.sa.si.to]			***
[e.sai.to]	*		*

Now, the most important constraints are to the left, so what one does is start at the left and check for violation marks. For each level of constraints we count the number of violations. If someone has more violations on a level than another surviving output candidate that candidate is "killed". If an output candidate is not "killed" it is surviving. Since the MAX-IO and *CODA constraints are on the same level these violation marks are added together for this purpose.

This is marked by adding an exclamation mark to the constraint violation marking that doomed it. This process is repeated until there is only one candidate left, the optimal candidate. For this example this makes the final tableau look like this:

Tableau 3: Choosing the optimal candidate

	/eksait/	MAX-IO	*CODA	DEP-IO
	[ek.sait]		*!*	
☞	[e.ki.sai.to]			**
	[ek.sa.si.to]		*!	**
	[ek.sai]	*!	*	
	[e.ki.sa.si.to]			***!
	[e.sai.to]	*!		*

As we can see [ek.sait], [ek.sa.si.to], [ek.sai] and [e.sai.to] all violated one or both of the two higher ranking constraints, while [e.ki.sai.to] and [e.ki.sa.si.to] do not; thus these four are killed off. We can further see that of the two surviving candidates [e.ki.sai.to] violates DEP-IO twice, while [e.ki.sa.si.to] violates it three times. That means that [e.ki.sa.si.to] is eliminated and only one candidate remains; the optimal and winning candidate. This is marked by adding a pointer to the left of that candidate, marking it as the winning candidate.

Thus, when a Japanese speaker wants to use the English loan word "excite" in Japanese he says: "ekisaito".

2.4 THE SECOND EXAMPLE – CONSONANT CLUSTERS IN DIOLA-FOGNY

COMPOUND WORDS

Now let us quickly look at another example, this time using the language Diola-Fogny. Diola-Fogny is a subsection of the Western Atlantic branch of the Niger-Congo family [Sapir (1965:1)]. It has some similarities with Japanese in that it seldom allows for consonant clusters [Sapir (1965:8)].

For this example we will look at the Diola-Fogny single-word construction meaning "they won't go", or "lɛkujaw". It is made up of three parts, "lɛt" is negation, "ku" is 3rd person plural and jaw is the auxiliary verb "go", The input for the word is /lɛtkujaw/ and the constraints we'll use will be the same as for the earlier example: *CODA , DEP-IO and MAX-IO.

We will not, however use the same ranking of the constraints as for Japanese. Instead we will rank the constraints as follows:

DEP-IO , *CODA >> MAX-IO

The output candidates we will use are [lɛt.ku.jaw], [lɛ.tɛ.ku.jaw], [lɛ.ku.jaw] and [lɛ.jaw].

Some languages treat the boundaries of words or other prosodic elements (such as the syllable, rhythmic feet or sentences) with special constraints, thus the word-final [w] could be in a special position. More on this can be found in Kager (1999:122) or McCarthy (2002:125-128). Another possibility is that the analysis is completely wrong and some other constraint excludes consonant clusters (other than nasal-nasal or nasal-consonant [Sapir (1965:8)]) from forming, which with the ONS-constraint would mean that all possible clusters in Diola-Fogny would tend to be onsets, except word-finally. It is apparent in the example that Diola-Fogny has word-final codas and we will ignore the word final [w] for this simplified analysis.

With constraint violations already marked the tableau looks like this:

Tableau 4: The second OT example

	/lɛtkujaw/	DEP-IO	*CODA	MAX-IO
	[lɛt.ku.jaw]		*!	
	[lɛ.tɛ.ku.jaw]	*!		
☞	[lɛ.ku.jaw]			*
	[ku.jaw]			**!*

The first output candidate violates *CODA by having a coda in the first syllable, the [t] in [lɛt]. The second output candidate has added vowels between the violating coda consonants to avoid violating *CODA, but this violates DEP-IO which is highly ranked in Diola-Fogny. Thus both the first and the second output candidates are "killed".

The third and the fourth candidates solve the problem by deleting the violating coda consonants. The third output candidate deletes just the first syllable's coda consonants while the fourth candidate deletes the entire first syllable in addition to the consonant. Although MAX-IO is the lowest ranked of the three constraints in the example, violating it three times still means that the fourth candidate is less optimal than the third candidate, and as the second violation mark is noted under MAX-IO we can see the exclamation mark being written, meaning that the fourth candidate is excluded and the third candidate wins.

The third candidate is the optimal candidate, and so when a speaker of Diola-Fogny says “they won’t go” it is pronounced “lɛkujaw” according to this tableau.

We can see that Japanese and Diola-Fogny both tend to avoid consonant clusters, but have different solutions to the problem. But using the same three constraints we can describe both these different solutions by rearranging the ranking of the constraints.[3]

2.5 OPTIMAL MODEL

When summarizing GEN, CON and EVAL’s effects into a complete and coherent model for cognition one could say that Optimality Theory stipulates that when processing data, be it output, input or even purely internally we first create a massive list of possible interpretations of the data. After the list is completed (either by creating “enough” possibilities according to some preset number, or by allocating a certain amount of time or energy to the task and stopping it when this energy or time is up) the possible explanations are processed by checking against a list of constraints. After the processing is done, the non-optimal candidates are discarded and the optimal candidate exits as the result of choice, either creating a percept, or a neural command for action or memory.

When extrapolating from OT in this way it should be easier to examine other theories of mental information processing to see if there are GEN, CON or EVAL correlates.

[3] As with Japanese this is a simplification. Diola-Fogny allows consonant clusters in some cases and can solve other similar problems with epenthesis, all depending on the input. There are many other constraints here in play; and neither DEP-IO, * CODA or MAX-IO are necessarily needed to explain this more complicated picture as the solution could rely on such varied factors as weight-to-stress, the sonority sequence, boundary issues from using compound words and so forth.

Chapter 3: Psychological Theories

3.1 CONNECTIONISM

Connectionism, or connectionist networks, describes the psyche in terms of elementary units or nodes connected together [Eysenck & Keane (2010:23)].

The theory spiked in popularity during the middle of the 1980's, although the ideas of the theory are much older [Rumelhart, McClelland & the PDP Research Group (1986:X)]. Rumelhart et al.[4] , working with Connectionism under the name Parallel Distributed Processing, draw upon the differences between the human mind and the processing power of computers in order to explain how our brains work. After all, where computers can calculate millions of equations each second they do not appear to be intelligent, and although most of us cannot calculate even simple three digit two factor multiplications humans are certainly more intelligent than current computers.

The difference does not lie with "software" alone, reasons Rumelhart et al., but must have to do with the hardware as well.

"In our view, people are smarter than today's computers because the brain employs a basic computational architecture that is more suited to deal with a central aspect of the natural information processing tasks that people are so good at. […] we will show through examples that these tasks generally require the simultaneous consideration of many pieces of information or constraints. Each constraint may be imperfectly specified and ambiguous, yet each can play a potentially decisive role in determining the outcome of processing. […] we will introduce a computational framework for modeling cognitive processes that seems well suited to exploiting these constraints and that seems closer than other frameworks to the style of computation as it might be done by the brain." [Rumelhart, McClelland & the PDP Research Group (1986:3-4)]

Rumelhart et al. wants their theory to be an alternative to "traditional" cognitive theories.

"It is often useful to conceptualize a parallel distributed processing network as a *constraint network* in which each unit represents a hypothesis of some sort (e.g., that a certain semantic feature, visual feature, or acoustic feature is present in the input) and in which each

[4] The in-text reference to Rumelhart et al. refers to both Rumelhart, McClelland & the PDP Research Group (1986) and McClelland, Rumelhart & the PDP Research Group (1986). These two books are volume 1 and volume 2 respectively, written as one work.

connection represents constraints among the hypotheses.” [McClelland, Rumelhart & the PDP Research Group (1986:8)]

3.1.1 The Constraint Network

The constraints in a constraint network can be contrary to each other, for example, there could be a hypothesis that says that whenever feature B is present feature A should be present. There could also be a hypothesis that whenever feature A is present feature B is *not* present. These two hypotheses would represent constraints that contradict each other [McClelland, Rumelhart & the PDP Research Group (1986:9)].

These constraints should be able to have varying strength, as should the input. If the input gives evidence of feature A and/or feature B’s presence, it gives a positive input to the relevant constraints. The absence of the feature is a negative input. Strong evidence of presence or absence of input means that there is strong input.

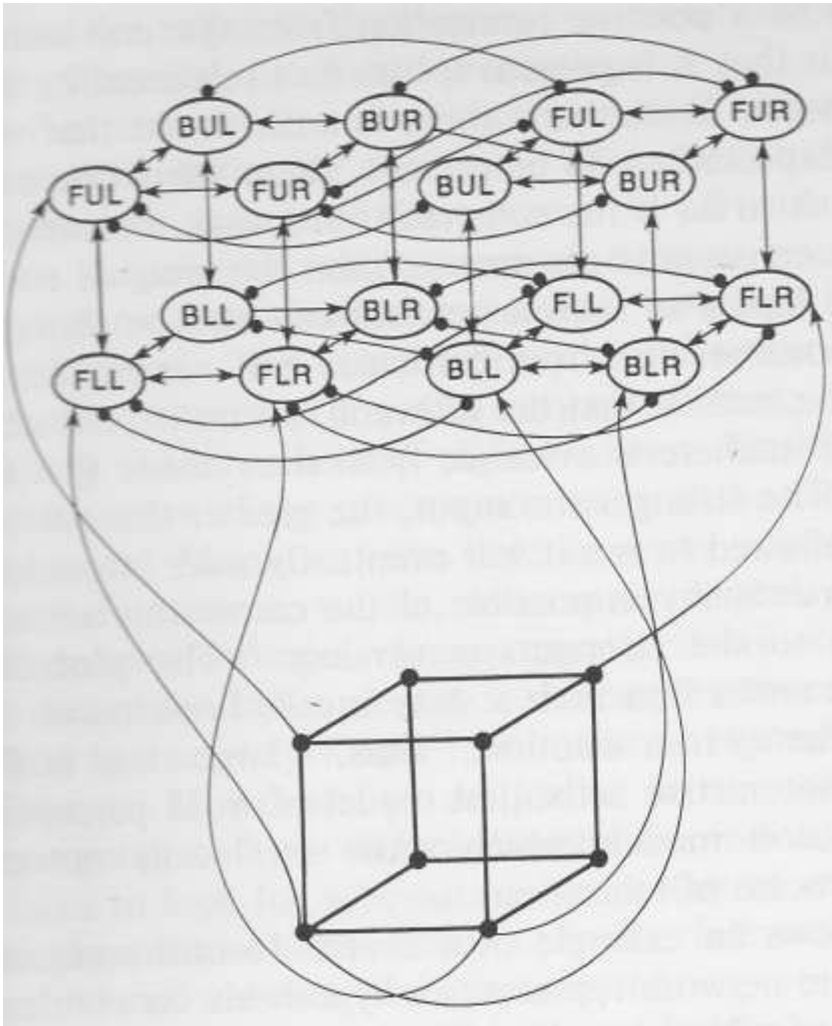


Image 1:The Necker Cube solution from McClelland, Rumelhart & the PDP Research Group (1986:10)

If allowed to run enough iterations as many of the constraints as possible will be satisfied and the constraint-system, or the constraint network, is said to settle into a state called relaxation. This means that the system has come to a solution [McClelland, Rumelhart & the PDP Research Group (1986:9)].

Rumelhart et al.’s chosen example for this is the perception of the Necker cube, a cube that in Necker’s own words lead to a “sudden and involuntary change in the apparent position of a crystal or solid represented in an engraved figure” [Necker (1832:336)]. It is a rhomboid shape where you have two choices as to what side you can perceive to be at the front; the classic cube can either be facing slightly down and to the left or up and to the right.

Note that Rumelhart et al. does not intend for this to be an explanation of the Necker-cube illusion. This is a demonstration of the system in action describing the solution for a problem [McClelland, Rumelhart & the PDP Research Group (1986:9)].

For this example Rumelhart et al. concentrates on the perception of the spatial relationships between the corners. Each corner gives a visual input that leads to a positive input for one of two constraints, each such constraint giving negative feedback to the other seeking input from the same corner if given positive input. So, take the corner in the upper right of the above picture. It can either give positive input to the constraint looking for that corner to be the back upper left corner of the cube *or* it can give positive input that it is the front upper right corner of the cube. But because the input is weighted to be either or and since the constraint gives a weighted feedback to another constraint you cannot have both constraints in such a dual constraint system being positive, and the input cannot (in this case) be ambiguous.

Each such constraint also gives positive feedback to three other constraints that correspond to the same perceived cube, and negative feedback to a fourth constraint corresponding to the other perceived cube.

For most cases, with repeated checking for input the system will settle in a relaxed state of either one or the other of the two possible perceived cubes [McClelland, Rumelhart & the PDP Research Group (1986:11-17)]. But since the negative feedbacks are weighted higher (to create an equilibrium with the positive feedbacks which are more numerous) extreme inputs can create a rare position of four constraints for each perceived cube coming to an equilibrium of positive, creating the perception of an impossible cube.

The total effect of the system is that a simple network of 16 constraints can account for both possible percepts when it comes to Necker-cubes. You could also treat these as two separate competing networks.

In fact, for a complete overview of the mind, according to this theory, every single unit would have to take part in multiple constraint networks, as every unit can be said to be of the "mind" network which is the complete network that creates a whole which is your mind. In this massive mind network every conceivable concept would in fact make some sub network capable of reaching a relaxed state, and most units would partake in multiple such networks.

Take, for example Rumelhart et al.'s example of room recognition [McClelland, Rumelhart & the PDP Research Group (1986:23-36)]. In this example the unit network consists of 40 objects which may or may not be in certain rooms, and these units interact with each other to either enforce the probability that another object is in the room based on what object the active unit represents, or weaken the possibility of a unit triggering if the two objects seldom are in the same room. For example a television is seldom in the same room as a toilet, but is often in the same room as a window. The input given then forces an interpretation on the part of the experiencer as to what sort of room he is in, based on which units are active when the network comes to a relaxed state. But to see this in the larger context one must take into account the nature of the input to the system. One can discuss what the minimal sensory input that we can perceive is, but this is the purview of theories of Perception (and will be handled in the subchapter on Perception and Gestalt theories). Instead it is important to note that the input for this last example certainly is *not* the minimal sensory input we can perceive.

The unit television is not a unit at all; rather it itself is made from patterns of other units that have to combine in different patterns before they can combine into patterns totaling all things we think of as "televisions". Different subpatterns within the larger pattern correspond to different televisions. This multitude of options of patterns over units would have to be reproduced for every possible item in the real world, totaling millions upon millions of units all of which would be to some degree connected with each other [McClelland, Rumelhart & the PDP Research Group (1986:174)]. In addition to there being different subsets of patterns that culminate in the different abstract patterns that represent televisions, different types of televisions will have different impacts on other related units. Some television sets belong in living rooms while others belong in caravans. This means that in the example of room recognition some televisions might correlate with patterns that have some sort of refrigerator in them, while other television patterns will not [McClelland, Rumelhart & the PDP Research Group (1986:25)].

In addition the television does not necessarily belong to only this larger pattern in charge of finding out what type of room you are in. We would also expect to find it in patterns dealing with movies, TV-series, general entertainment, news, technology, history and so forth. So either each such pattern has its own version of the television, or there is a general television pattern that is called upon for multiple purposes. The latter option would seem more elegant and economical, without that necessitating its validity.

If thinking in schemas the television would have the function of slot-filler in a schema, and the particulars of that television would represent the characteristics of that slot-filler.

3.1.2 The stable pattern

Let us now return to the idea of the stable pattern.

"The stable pattern as a whole can be considered as a particular configuration of a number of such overlapping patterns and is determined by the dynamic equilibrium of all these subpatterns interacting with one another and the inputs. Thus, the maxima in the goodness-of-fit space correspond to interpretations of the inputs or, in the language of schemata, configurations of instantiated schemata. In short, they are those states that maximize the particular set of constraints acting at the moment" [McClelland, Rumelhart & the PDP Research Group (1986:20-21)].

The goodness-of-fit function takes into account that the system moves from a state satisfying fewer constraints to a state satisfying more constraints [Rumelhart, McClelland & the PDP Research Group (1986:13)]. This is summed up in an equation:

$$G(t) = \sum_i \sum_j w_{ij} a_i\,(t) a_j\,(t) + \sum_i input_i(t) a_i\,(t)$$

The G(t) indicates that this is the global amount of goodness-of-fit at time *t*. The w_{ij} is the weight of the connection between unit *i* and unit *j*, the $a_i(t)$ is the activation of unit *i* at time *t* and $a_j(t)$ is the activation of unit *j* at time *t*. $input_i\,(t)a_i(t)$ is the degree to which the unit *i* satisfies its input constraints [McClelland, Rumelhart & the PDP Research Group (1986:11, 13)].

This means that the equation says that the overall goodness-of-fit for a network is the sum of the connection strength between each possible pair of units in the system multiplied with the activation of each such pair plus the degree to which each unit in the network satisfies their input constraints.

Thus for each possible pair, if the weight of the connection is positive, the goodness-of-fit is maximized by each unit being as active as possible. On a scale of 0 to 1 both units in a pair should push towards 1 if the connection is positive. If the connection weight is negative then at least one of the units should be 0 to maximize the goodness-of-fit, as otherwise their contribution to the goodness-of-fit is bound to be negative.

For each single unit, if the input constraint is positive then that unit should push towards maximum value to increase the goodness-of-fit, or decrease the value towards 0 if the input constraint is negative [McClelland, Rumelhart & the PDP Research Group (1986:14)].

This means that the entirety of the sum of the goodness-of-fit takes into account every single unit in the limited system, takes into account that units connection to all connected units and their states, takes into account each unit is ability to meet its constraint's input criteria and does this for each run-through of the system. Each time the system "runs" it will only go up as input strength increases, and the different units either enforce each other or keep their connection's effect on the goodness-of-fit at zero. The system's total goodness-of-fit thus increases until it hits a roof, a maximum, at which it stays. This peak is then a result.

In Rumelhart et al. these peaks are shown in faux 3d patterns where the spikes are clearly shown [McClelland, Rumelhart & the PDP Research Group (1986:15, 28-33, 35), Rumelhart, McClelland & the PDP Research Group (1986:428-429)]

3.1.3 Problem solved

This take on the brain, that it is made up of interconnected units forming massive complex networks of constraints, explains many different aspects of the human experience. For example, the addition of extra constraints based on possible inputs will mean that peaks are reached faster as there are more units to give positive feedback to other related units; thus with training we complete mental tasks faster. It will also, interestingly enough, mean that minimal familiar input will lead to an interpretation that we are dealing with a familiar experience, even if we are not; a mistake we often make. More importantly it will lead to the familiar conclusion when this is correct.

Take for example the famous THE CAT illusion from Selfridge (1955:92):

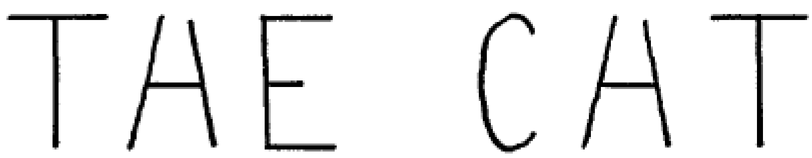


Image 2: THE CAT illusion from Selfridge(1955:92)

We have no problems perceiving the two identical letters as H and A respectively, but some mechanism must make it so. The two letters are truly identical in shape, so the shape does not enter into it. Rather, the surrounding letters must make the interpretation probable. Also, upon realizing the illusion one can feel doubt about the interpretation, telling us that there is no rule set in stone at work here, there must be a certain amount of malleability in the structure allowing either interpretation but preferring one until further input can make the other probable. Also, even though the two letters in question are unlike anything we've seen before we reduce their meaning to something familiar rather than seeing them as new novel orthographic letters.

This also allows for cost-effective and slightly faulty memory being accounted for, in that Rumelhart et al. propose that memory is stored in the form of an array of connection strengths between certain units. When the memory is activated the units connected to the memory get activated, and some patterns might be sympathetically activated [Rumelhart, McClelland & the PDP Research Group (1986:30-32)]. Similarly we can see learning functioning in the same way. Some new units must necessarily be formed, but much can be done just by doing connection strength adjustments [McClelland, Rumelhart & the PDP Research Group (1986:21)]

3.1.4 Sum of the parts

The totality of it is a highly complex system with intricate and certainly opaque rules; each unit has its own individual set of rules that gets meaning only in correspondence with other units. To formulate exactly what it entails we can turn to this beautiful summation by Donald A. Norman of the PDP structure:

"… here we have an adaptive system, continually trying to configure itself so as to match the arriving data. It works automatically, prewired if you will, to adjust its own parameters so as to accommodate the input presented to it. It is a system that is flexible, yet rigid. That is, although it is always trying to mirror the arriving data, it does so by means of existing knowledge, existing configurations. It never expects to make a perfect match, but instead simply tries to get the best match possible at any time. The better the match, the more stable the system. The system works by storing particular events, but the results of its operations are to form generalizations of these particular instances, even though the generalizations are never stored directly. The result, as has been illustrated throughout the chapters of this book, is that although the system develops neither rules of classification nor generalizations, it acts as if it had these rules. […] It is a system that exhibits intelligence and logic, yet that nowhere has explicit rules of intelligence or logic [Norman (1986:535-536)].

Especially the last part of this quote resonates well with how the mind *must* work. After all, if there was a system *with* intelligence and logic in it then it would not need added layers of complexity to produce intelligence and logic. If intelligence and logic are the products, then it does not also need to be in the system producing itself. That is why reducing a number to its devisors stops at prime numbers; to reduce the prime you would need the prime to produce itself, which would (in most cases) be pointless.

The apparent flexibility of the system, its ability to proceed even when facing lacking data and the non-reliance on perfect matches are strengths that are shared with Optimality Theory.

3.2 Motivational Psychology

Motivational psychology is the science of what motivates us. The question of what motivation is and where it comes from is ancient, but the field came under scientific scrutiny only a hundred years ago. At that time it was a small side-branch of psychology until interest skyrocketed in the early 1990's.

Since then the advent of biological psychology has led to a much greater understanding of how the brain works, and motivational psychology can now go into molecular detail when answering some questions of the field.

Although motivational psychology tackles a part of the human mind not normally associated with language, some theories of motivational psychology have some startling similarities with Optimality Theory. The terminology is, of course, different.

3.2.1 What is Motivational Psychology

Motivational psychology is the science of motivation. It asks important questions such as: what is motivation, what is emotion and how can one be motivated? [Reeve (2009:1-2)] Motivation is normally seen as something desirable, a positive. We want to be motivated, especially by "positive" factors such as love, desire, curiosity and fun. But motivational science also takes into account undesirable motivational factors such as fear, hunger, thirst and anger.

Motivational Psychology primarily looks for answers to two questions:

- What causes behaviour
- Why does behaviour vary in its intensity [Reeve (2009:5)]

Each of these questions of course gives rise to new questions. For example, why does behaviour start? Why does behaviour change?

The study of motivation is as old as philosophy. Plato is quoted to have said that “Human behaviour flows from three main sources: desire, emotion, and knowledge.” But as all other fields of study it has changed much since the ancient Greeks, often changing with whatever the era’s view on the nature of soul was. Notable “grand theories” of motivation in the last 24 centuries have been will, instinct and drive.

Now, as science moves away from such notions as explanatory forces, multiple other explanations have been tested. Since the 1970’s there has been some agreement in the field pointing towards four motivational factors rather than one grand explanation: needs, cognitions, emotions and external factors. These four are seen as working together to motivate us [Reeve (2009:42-43)].

3.2.2 Range of motivations

According to Reeve we have, at all times, a multitude of motivations. We should not think of it as having a single motivation on which we’re acting at the moment. Instead motivations should be seen as a dynamic force, rapidly changing to suit our ever-changing environment.

“It is helpful to think of motivation as a constantly flowing river of needs, cognitions, and emotions. Not only do motive strengths continually rise and fall, but people always harbour a multitude of different motives at any one point in time. Typically, one motive is strongest and most situationally appropriate, while other motives are relatively subordinate. The strongest motive typically has the greatest influence on our behaviour, but each subordinate motive can become dominant as circumstances change and can therefore influence and contribute to the ongoing stream of behaviour.” (Reeve 2009, page 15)

If we assume that the output of the motivations is our behaviour, we can see the motivations compete for influence over the output, much how Optimality Theory’s constraints fight each other for prominence; but where Optimality Theory’s constraints are relatively fixed the relative strength of a motivation changes with the situation.

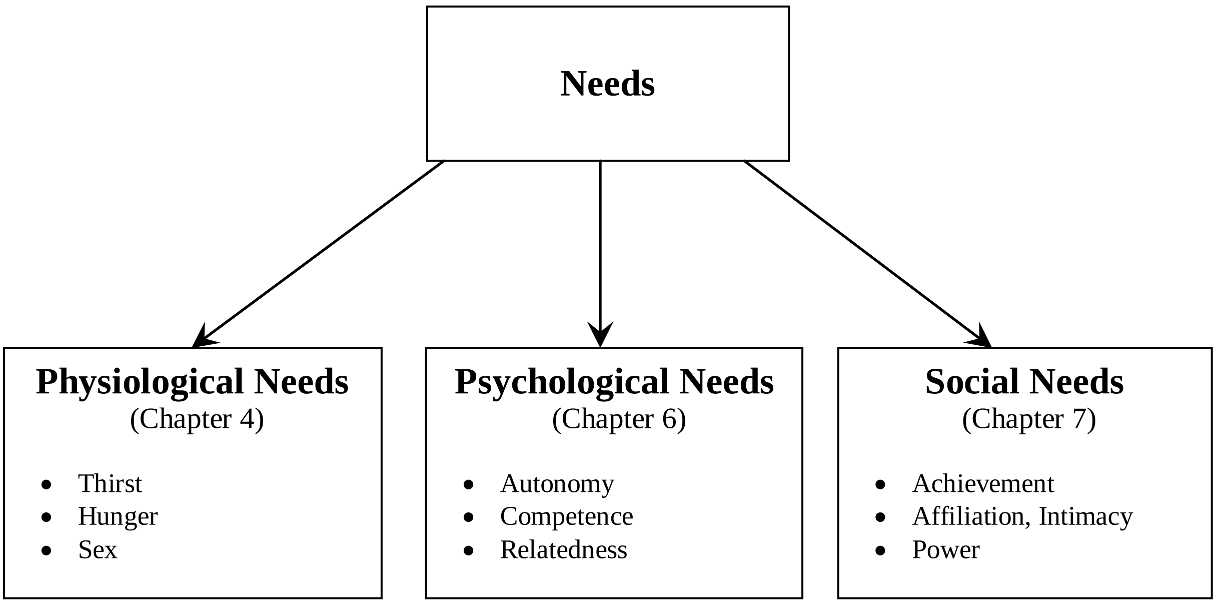
Reeve (2009:15-16) gives an example for how these competing motivations work:

”As an illustration, consider a typical study session in which a student sits at a desk with book in hand. Our scholar’s goal is to read the book, a relatively strong motive on this occasion because of an upcoming examination. The student reads for an hour, but during this time, curiosity becomes satisfied, fatigue sets in, and various subordinate motives – such as hunger and affiliation – begin to increase in strength. Perhaps the smell of popcorn from a neighbour's room makes its way down the hallway, or perhaps the sight of a close friend passing the door increases the relative strength of an affiliation motive. If the affiliation motive increases in strength to a dominant level, then our scholar's stream of behaviour will shift direction from studying to affiliating."

Thus, as the need for food or the need for affiliation becomes stronger no external input is needed to change the output. Instead it seems like the motivations themselves shift in strength, or in Optimality Theoretical terms, shift their ranking.

3.2.3 Hierarchy of needs

Let us take a closer look at the needs. According to Reeve (2009:78) there are different types of needs, which can be organized in a need-structure, as shown in this figure (recreated from Reeve (2009:78) :



It is important to note that we're not talking about the well-known Maslowian pyramid [Maslow (1943), Maslow (1954)] here, but rather the emergent results from testing Maslow's pyramid against facts. And these tests show that Maslow's pyramid is both inaccurate in depicting what needs we have, and what needs we subjectively feel the strongest [Reeve (2009:423)].

A need is defined as “any condition within the person that is essential and necessary for life, growth and well-being.” [Reeve (2009:77)].

The division between physiological needs and the other two is simple enough; the needs of our bodies fall into this category. The difference between the psychological needs and the social needs is more opaque.

Reeve (2009:78) explains that the psychological needs, such as autonomy, competence and relatedness are part of the basic human condition and, as such, is inherent in everyone. As a contrast social needs, such as, achievement, affiliation, intimacy and power, vary from person to person and arise from unique personal experiences. Which social needs we manifest are dependent on the state of our social environment during our upbringing, the social situation we live in and our social goals for the future.

Rather than coming and going like our physiological needs do, these social and psychological needs are forever somewhat active in our consciousness, ready to rise up and gain salience if there are factors in our surrounding environment that we believe capable of satisfying them. That is, it is always nice to be in good company, but you mostly feel the need for such if in a situation where those needs can be met.

These needs require fulfilment, and if met they will foster well-being. Not fulfilling your needs will likewise be felt as “damage”. Fulfilling the physical needs will hinder damage to the body through hunger, thirst and the like. Fulfilling psychological needs will lead to personal growth and adaption. Fulfilling one’s social needs will lead to healthy interpersonal relationships.

We have a plethora of feelings dealing with needs; for example hunger, thirst and pain for physical needs; frustration, melancholy and boredom for psychological needs and aggression, embarrassment and loneliness for social needs, to name a few of the negative ones, but these are not the needs themselves, but rather projections of them. Reeve’s (2009:8) clearly define emotions and needs as separate entities, each capable of motivating us to action.

This separate entity *needs* could then be separated into more than just the three groups physiological, psychological and social. Equally important is the distinction of “in-born” and “learned”. Furthermore, the needs can also be distinguished into the two groups “deficit” and “growth”, or “validation-seeking” and “growth-seeking” [Reeve (2009:436)].

We are still not Maslowian terms. Rather the theories focus on the more modern humanistic approach of individualistic thinking. This means that for the purposes of this description the terms are used to describe individuals rather than personality partitions, and also paired up with the idea that psychological needs are inborn.

A person that is described as “growth-seeking” would necessarily have a different structure to their need hierarchy than a person that is “validation-seeking”. Assuming a ranking of the needs, as has been hypothesized earlier for motivations [Reeve (2009:15)], of which needs is a subgroup, the “validation-seeking” individual must have high-ranking needs that force them to conform to outside-stimuli. Rather than focusing on growth, which would be the output of high-ranking psychological needs, the validation-seeker has high ranking social needs. This difference between the output conforming to the situation and the output conforming to the input can also be seen in linguistics with faithfulness and markedness constraints, if one is willing to twist one’s understanding of the latter slightly.

The markedness-constraints all force the output to conform to our idea of what harmonic language should sound like. That the output conforms to this common idea of language is more important than that the output conforms to the input. In contrast, the faithfulness constraints force the language to conform to our inner abstract representations of what we want to produce. Could this mean that the difference between markedness and faithfulness constraints are homogenous with the difference between “inborn” and “learned” needs?

In truth, both faithfulness and markedness constraints combine to create our image of a “harmonic” language. But another thought that could make the equality of the motivational growth/validation and the linguistic faithful/marked contrasts more plausible is if markedness constraints were to be learned rather than inborn, such as Reeve tells us social needs are; given that social needs are what are responsible for the validation-seeking behaviour.

That there *are* inborn linguistic constraints or a Universal Grammar is certainly a stance that is well-founded [Kager (1999:1)], and if one agrees with Kiparsky or Blevins there are constraints that are learned rather than inborn [Kiparsky (2006:220-221)] [Blevins (2006:117-120)]. In short, part of the constraint catalogue does seem to be inborn, and part of it possibly (probably) not. But is there room to define faithfulness constraints as more “inborn” than the markedness constraints? Is it an easier sell that we do not have the markedness constraint “no [ʘ] in the coda.” (ʘ is the sound you make when you drag your lips apart creating a “smattering” noise, colloquially known as a “clicking sound”, used in Khosian languages[Traill (1985)]) than to state that we’re not born with the faithfulness constraint “do not delete ʘ”.

The easiest solution could be to ignore the possibility of a comparison of the groupings of the constraints. Alternatively one could say that it is only the social needs that do not fit within the constraint architecture.

We can make the following description of the difference between markedness constraints and faithfulness constraints in order for these to have meaning beyond the field of phonology:

Faithfulness constraints deal with the well being only of internal factors to the mind, making sure the idealized input and the idealized output are faithful to each other.

Markedness constraints deal with external factors, such as whether something is difficult to do (hard to pronounce for phonology) or makes outcomes difficult to predict (difficulty of creating contrast for the listener in phonology), or similar considerations to factors external to the system itself.

Similarly the needs can be classified as either dealing with internal factors, for example staying true to an idealized version of who one is and what one should do. Conversely, other motivational factors could rely on the difficulty of a task, or the problems of predicting the outcome of an action.

Within this structure the division between needs being physiological, psychological or social are not important. Still the apparent presence of learned constraints means that an absolute comparison between needs and constraints fail.

There is also the question as to whether social needs exist at all, or if social experience is just changing the interpretation of the state you are in and your definition of a good or bad outcome, rather than change your need structure [Weiner (2006:66)]. That is, you could have the same needs, but your definition of what satisfies the need for affiliation, autonomy, competence or relatedness might differ. Also, given that we are highly social animals, hard wired both for caring about others and for our social position [Batson (1990:344 & 337 respectively)], it should not be a hard sell to say that social needs are as inborn as the other needs, but that their realizations are changed based on our perception of reality, which in turn is based on our culturally biased understanding of our social bonds. This thought is older than Batson. Cooley said that taking the mantle of leadership “...is not so much forced upon us from without as demanded from within." [Cooley (1902:319)] The need to lead, the need for power; this social need is with us from birth. Could not the need for affiliation, intimacy and social status also be treated the same way?

3.2.4 Emotions

This thesis will not claim to fully explain the full complexities of the theories discussed herein, but just quickly present them at their most abstract levels to look for superficial similarities. This will have to go doubly for the study of emotions, as "the concept is going to elude a straightforward definition" [Reeve (2009:299]

Emotions are not a simple group of units. They are as diverse as to be subjective, biological, purposive and social phenomena that influences perception, cognition, coping, creativity and more [Izard (1993:73-74, 86)]. They are of course biological in their nature, stemming from neural processes [Izard (1993:71)]. They can arise in response to social situations and can likewise be used to inform others of how you are interpreting the current social situation through your body posture, facial expressions and voice quality [Izard (1993:77-78, 83)]. They are, however well communicated, by ourselves and only by ourselves, and often strongly colour our perception of the status quo. Finally, emotions can obviously motivate us to action, creating a motivational desire to act out against perceived injustice (anger), finding nourishment (hunger) or striking up a conversation with an attractive stranger (lust) [Izard (1993:73)] [Reeve (2009:229)].

"Emotions are short-lived feeling-arousal-purposive-expressive phenomena that help us to adapt to the opportunities and challenges we face during important life events. [...] Defining emotion is more complicated than a "sum of its parts" definition. Emotion is the psychological construct that unites and coordinates these four aspects of experience into a synchronized pattern. [...] Emotion is that which choreographs the feeling, arousal, purposive, and expressive components into a coherent reaction to an eliciting event." [Reeve (2009:301)]

This partitioning of the need "hunger" and the emotion of hunger into two separate parts mean that there is no straightforward equation with constraint mechanisms and motives, as long as emotions remain a motive. But this problem is solved by removing emotions from motives:

Fridja (1986:336) discusses the role of negative and positive emotions in terms of creating concern for something, or the disposition to like or dislike something. These "concerns" are, according to Fridja, equitable with motives if "awakened" by an emotion.

Oatley and Jenkins (1992:60) classify Fridja's "concerns" as needs or goals. They further state that emotions is what drives us to action (1992:59-61), and " [...] emotions are usually elicited by evaluating events that concern a person's important needs or goals" [Oatley & Jenkins (1992:60)]

If we keep them to needs we can see that Reeve's comments on just Fridja (1986) and Oatley and Jenkins (1992) can lead us away from using emotions as motives in themselves: "Positive emotions signal that 'all is well', reflect the involvement and satisfaction of our motivational states, and evidence our successful adaption to what is going on around us; negative emotions act as warning signals that 'all is not well', reflect the neglect and frustration of our motivational states and evidence our unsuccessful adaption to what is going on around us. (Fridja, 1986; Oatley & Jenkins, 1992)" [Reeve (2009:303)]

If emotions are not motives, but something that modifies the motives then they are not constraints per se, if by motives we mean constraints. With emotions removed from the possible list of motives then the duality of them (or quadrality) is a non-issue; and motives can be compared to constraints. But the role of emotion is no less important for the model.

If we are to accept Fridja, Oatley and Jenkins' treatment of emotions they must somehow change the constraints. One option is to take Fridja at his word and say that certain needs are turned on or off, or "awakened" through the usage of emotions. This would make emotions a separate structure that directly influence CON without *being* CON. Another option for Fridja's interpretation is to say that as each language has its own constraint ranking, so does each emotional state. Thus the need ranking for anger and the need ranking for hunger would be two different rankings. Since emotions are not as clear cut in their mental existence as different languages can appear to be, but rather overlapping and rapidly changing, such an interaction would be difficult to give account of and thus not explored further in this thesis.

Another option is to take Reeve, Oatley and Jenkins' at their word and say that emotions give us a feeling of good or bad to tell us if we're pursuing a line of action that support our current needs. This would remove the need to influence CON. Instead the change of emotional state signals the need to check with our needs to see if we have to change actions.

Language has natural "checkpoints" where CON and EVAL has to be consulted. Every time we hear a speech sound (or perceive a similar linguistic communication attempt, e.g. sign language [Sandler & Lillo-Martin (2006)] or whistling languages [Meyer (2008), Rialland

(2005)] or write [Eysenck & Keane (2010:334)]) and every time we produce language the use of GEN, CON and EVAL would be prompted.

Since we're living and experiencing a continuously changing world that continually gives us cues for action we cannot expect our brains to run a "check" for our needs for every such cue. Instead we could suggest that emotions are prompted by a secondary source looking to see if one or more needs are satisfied or neglected to a degree that would require us to check to see if we need to change actions. Emotions are, however, much like our perception of the world constantly being checked up on by a continuously working neural system [Izard (1993:84)].

Thus, the emotions only prompt the use of a Motivational Theoretical version of phonological Optimality Theory's GEN, CON and EVAL, an external force that drives the structure, "forcing us to action", rather than influencing any one nuance of it.

It is also worth noting that the extent to which we feel emotions, what emotions we feel and their relative strengths are themselves adjusted through sensory inputs and subject to hierarchical constraints [Izard (1993:82, 84-85)], and as such could very well be included into this thesis with its own examination to see if they could fit into an Optimality Theoretical framework.

3.3 COGNITIVE PSYCHOLOGY

To quote Eysenck and Keane " [Cognitive Psychology] is concerned with the internal processes involved in making sense of the environment, and deciding what action might be appropriate. These processes include attention, perception, learning, memory, language, problem solving, reasoning, and thinking. We can define **cognitive psychology** as involving the attempt to understand human cognition by observing the *behaviour* of people performing various cognitive tasks." [Eysenck & Keane (2010:1)]

As we can see Cognitive Psychology is a vast field able to include a massive array of different theories. As such, comparing it to a single theory, such as Optimality Theory, is folly. In this subchapter we will take a closer look at some parts of some theories to try to gauge how they handle information processing and problem/solution processing.

In addition to Cognitive Psychology we will take a closer look at cognitive neuropsychology. Eysenck & Keane explain the difference between Cognitive Psychology and cognitive neuropsychology as such: Cognitive neuropsychologists study the brain as well as behaviour; using PET scans, fMRI and any other technological wonder they can get their hands on they try to see our brain in action. Some research by cognitive neuroscientists is also done on monkey brains, as cutting into these while they think is ethically less problematic than doing so in humans [Eysenck & Keane (2010:41)]. Further insight into the difference will be given shortly.

Cognitive Psychology has some limitations, which should be mentioned.

1. Behaviour by subjects as tested in a laboratory does not necessarily copy behaviour displayed in non-laboratory settings.
2. Task performance does not necessarily take into account the complexity of cognitive processes.
3. Cognitive theories have often been described in verbal terms, which can be vague.
4. Some experiments yield only results for specific paradigms and cannot be carried over to slightly different paradigms.
5. Much of the research done within Cognitive Psychology has been focused on a few relatively specific theories, covering only a narrow range of cognitive tasks. Since each theory has its own internal system architecture, there is no one overreaching architecture for cognitive theories. The existence of such an architecture would make testing this thesis' hypothesis a much simpler task, and would for cognitive psychologists make the work of joining the different theories into one whole theory of psychology easier, if at all possible. [Eysenck & Keane (2010:5)]

Some cognitive architectures have been proposed, for example Anderson’s Adaptive Control of Thought-Rational (ACT-R) [Anderson et.al. (2004), Eysenck & Keane (2010:22-27)] model, but no such propositions have caught on in the scientific community [Eysenck & Keane (2010:5)][5].

It is because of this fifth limitation that this thesis will have to take into consideration the more specific theories and prod them for information about possible underlying structures.

[5] This is getting close to an **either-or fallacy.** There is not a choice between the perfectly “right” cognitive architecture and a “false” architecture. There are different choices which are “okay”, and choosing one of these and modifying it as one goes along could yield adequate results.

3.3.1 The scope of cognition and cognitive neuropsychology

The functional specifications of neurons are largely understood. This “neuron code” show how individual neurons receive and transmit impulses. As such the larger structure of the “brain code” is now more in focus for researchers. This “brain code” is concerned with the mechanisms by which large groups of neurons work together to transmit and process various information such as visual stimuli, cognitions, emotions and percepts [Cook (2002:vii-x), Torey (2009:3)].

Although by no means a field of study that should not at least give rise to curiosity from linguists and cognitive psychologists, the neuron code is not the main focus of this thesis. Instead, this thesis aims to examine abstract systems able to describe the flow of neural impulses as parts of a bigger system.

In this enterprise the brain code itself will not do. The information gained from researching the brain code would undoubtedly be part of a complete understanding of the human mind; and only the physical reality of the functioning of the brain as a complete system could be used as the basis for a true understanding of the human mind [Cook (2002:ix)].

For the purposes of this thesis the abstract entities that are to be compared would be on a meta-level in comparison to the brain-code, similar to what Zoltan calls the "mind code" [Torey (2009:4)].

The field of cognitive neuropsychology deals with the neuron- and brain-codes, and while Cognitive Psychology certainly deals with the brain code it also describes this meta-level of cognition.

There is, however, no clear distinction at work here; everything at the meta level would in the end rely on the actions of single neurons working in a chorus, and in similar fashion how single neurons interact with each other is only given purpose for the larger organism in view of the macro effects that all neurons have when working together in a network. The mind code must be completely reliant on these biological structures; unless we ascribe some parts of the human consciousness to metaphysical resources.

In summation there are three active levels with fleeting boundaries:

- The neuron code: describing the actions of single neurons, or small clusters of neurons.

- The brain code: describing the actions of larger clusters of neurons, or long chains of them working in tandem on larger computational problems, using our knowledge of the neuron code
- The mind code: a description of the workings of the human mind using abstract structures built upon our understanding of the brain code.

3.3.2 Cognitive Neuropsychology

Describing the abstract models for Cognitive Neuroscience is a daunting task as the field does not use many abstract models. The third limitation to cognitive science does not at all apply to the field of cognitive neuroscience. It is a field of biological chemical precision. As such penetrating the meaning of the various numbers, tables, diagrams and abbreviations would require more time and space than this mere thesis allows. Thus the verbal descriptions of two experts in the field will make this venture possible:

> " [...] what differentiates human brains from other species is the huge, enormous size of our prefrontal cortex.... one of the most interesting things about all that extra cortical real estate is that you'd think that what all that prefrontal cortex would do for us is allow us to do all these wonderful things like paint and make music and speak and build churches and cities and schools and have systems of justice. But at an anatomical level one of the most distinguishing characteristics of it is, it is full of inhibitory circuits. The highest density of $GABA_A$-receptors in the frontal cortex is in humans. It is an inhibitory neurochemical. So much of what makes us human is inhibiting action. And that's counter intuitive, because you'd think of all the things we can do. But really, the story of humanity is we're not doing a whole lot of stuff."
>
> - Daniel Levitin interviewed by Discovery Magazine February 26th, 2009

> "Basically, most of the major ways [the brain] works is by generating all the possible responses to a situation, and then inhibiting the ones you do not want. We sort of think of it as if we only generate the one; we only generate the one right answer. So we do not have to worry about the wrong answers to a situation. So, here's a mundane example: When there is a cup in front of me or a comb in front of me, most of the time I do not drink from the cup and most of the time I do not pick up the comb and comb my hair. Especially I do not comb my hair if it is in an inappropriate context like this and I do not drink from the cup if it is somebody else's cup. And so you might think that we only generate the plan for how to reach for the cup and drink from it if that's something we've

decided to do. But it turns out, actually, our brains' are constructing our representations for all the possible actions for all the possible objects in front of us. And then clamping them down. And you can see that because in patients that have lost some of the inhibitory controls, because they have had damage to their frontal lobes you get what is called Utilization Behaviour[6]. You get people who, literally any time you put a comb in front of them they'll start combing their hair. Just because there's a comb they'll use it. If you put a glass they'll drink from it."

- Rebecca Saxe interviewed by Discovery Magazine February 26th, 2009

As we can see a basic function of the brain, according to cognitive neuroscientists, is that it works very hard to inhibit incorrect responses to stimuli, both when it comes to interpretation of those stimuli and responses to these stimuli. This holds true for the minutiae details of the biological brain as can be seen in the above interview with Dr. Levitin, but it can also be seen in the more abstract description of what powers our behaviour as can be seen in the interview with Dr. Saxe.

When considering what it is that makes humanity great, how many would consider the feat of not acting on our brains' responses as important? The intuitive answer would surely be that we can come up with genius ideas for manipulation of our surroundings. But apparently, according to cognitive neuropsychology what really sets us apart from other mammals is that we come up with several solutions and then inhibit all but the apparent best option.

There are several important axioms that should be paid attention to when we are dealing with Cognitive Neuropsychology.

The first is *modularity*, the assumption that the mind can be partitioned and that different partitions deal with different problems.

The second is *anatomical modularity*. Not only do Cognitive Neuropsychologists postulate that different parts of the mind processes different inputs, but these different abstract modules are anatomically bound to specific places in the brain [Eysenck & Keane (2010:17)].

Part of the thought of the idea of modularity is that each module should only respond to particular types of stimuli. This axiom has of course been contested, but the loss of very specific cognitive abilities in patients with localized brain damage does give it much credibility.

[6] Also known as Bilateral Magnetic Apraxia or Hypermetamorphosis

The third axiom is the *uniformity of functional architecture across people*. This means that the postulated anatomically fixed modules do not change position or function based on cultural or inherent traits. If this axiom failed, says Eysenck & Keane, cognitive neuropsychologists could not diagnose or treat patients based on their apparent ills. This axiom holds for all of Cognitive Psychology.

The fourth axiom is *subtractivity*. If a module sustains damage or is destroyed this adds nothing to the system. Such damage can only reduce the system. As you would with removing constraints in Optimality Theory you could create apparent new structures because of the reduction of complexity. But, says this axiom, this is only a faux understanding of the inherent loss in the system. This means that someone with brain damage does not grow new modules to make up for the loss of an old one. Eyesenck and Keane state that the axiom of subtractivity "is more likely to be correct when brain damage occurs in adulthood and when cognitive performance is assessed shortly after the onset of brain damage.” [Eysenck & Keane (2010:18)]

Under the heading of modularity, Cognitive Psychology can predict where certain processes take place in the brain. For example, when it comes to form processing the brain activates the areas V1, V2, V3, V4 and the inferotemporal cortex. V4 is also active in colour processing, and the inferotemporal cortex is activated for mostly all complex visual stimuli, and possibly facial recognition [Eysenck & Keane (2010:42, 93)]. Motion processing for direction is however almost completely located in the V5, or MT (middle temporal), although this is also processed in V1-V4. Orientation processing also occurs in the same, but with different distribution [Eysenck & Keane (2010:46].

As we see, cognitive neuropsychology has tremendous detail about where in the brain different processes take place. However, there does not appear to be any consensus as to how these modules modify or process the data they receive, and so no real description of such is given.

There can be little doubt that understanding the neuron an d brain codes would be a great tool for a complete understanding of how our brains work, and cognitive neuropsychology does give some predictions about how things might work based on relative activity in certain areas. For example, it gives a claim for how we read text (which will be reviewed later under the header Orthographic Processing) and how we partition visual sensory inputs into both recognition modules and response modules [Eysenck & Keane (2010:55)]; so when you see something one module will try to find out what it is while another is trying to figure out if you need a quick response.

3.3.3 Executive Control

Executive Control is a complex structure which has multiple distinct components. For Cognitive Neuropsychology it is a structure that is said to monitor and detect conflict between competing representations or responses, select the correct response and inhibiting the incorrect responses [Saxe, Schultz & Jiang (2007:286)].

Executive Control can best be described as the control executive processes hold over other cognitive functions, and executive processes is well-defined in Smith & Kosslyn:

" […]*executive processes* [which] manage your other mental events, allowing you to pause before you speak and to inhibit yourself from saying the wrong thing, and which enable you to act on your decisions" [Smith & Kosslyn (2007:2)]

…or from Eysenck & Keane [2010:218]:
"**executive process:** processes that organise and co-ordinate the functioning of the cognitive system to achieve current goals."

In Eysenck & Keane executive control is compared to "working memory" [Eysenck & Keane (2010:168)]. Further, it can be said that "cognitive control is needed for actively maintaining the distinction between targets and distractors [sic]" [Lavie (2005:81)]. This is from a section on perception and what happens to unattended visual stimuli.

We can see that executive control can enter into a more general description of mental processes, and that it covers many bases.

3.3.4 Orthographic Processing

The study of orthographic processing explores the human mind's ability to "read", or to visually recognize speech sound or speech pattern stimulus. As the ability to read has become increasingly critical for everyday life in the western world research into why some people have difficulties using this medium proficiently is a matter not only of personal growth but for the notion of equality of education.

First and foremost it is interesting to note, for a phonologist, that the areas of the brain connected to phonological processing are activated when we read; [Eysenck & Keane (2010:334)] when we read we 'hear' the words. But in addition to this, cognitive psychologists find that when we read a word, areas associated with its *orthographic neighbours* are activated. Orthographic neighbours are words that with reference to a particular word can be created by changing a single letter. That is, if we read the word "seem", areas associated with the words "stem" and "seam" will be activated [Eysenck & Keane (2010:338)]. Eysenck and Keane do not mention if orthographically neighbouring pseudo words (words that are pronounceable but that do not carry any meaning, like "mave" or "tiem") are activated.

This does not mean that the accessing of the phonological system is important for word recognition; it could very well be that the system is only 'piggybacked' onto the process as word meaning is accessed. Some evidence suggests that this is the case, and that the accessing of the phonological module happens after the read word is recognized [Daneman, Ringgold & Davidson (1995:896)].

The exact process of word recognition and lexical retrieval seem to suffer from the same malady as other parts of the cognitive sciences. There is a good description of what happens, where it happens and what other processes play a part; what there is not is a general idea of *how* it happens. Grainger & Jacobs (1996) introduce their article on the Multiple Read-Out model with the presuppositions that when a skilled reader moves their gaze over written text each word goes through a set of elementary operations which compute a form representation of the physical signal, a percept, and match this percept with abstract representations stored in long term memory by looking for the best candidate for identification. [Grainger & Jacobs (1996:518)]

3.3.5 Colour Processing

One of the problems when it comes to colour processing is colour consistency. To what extent is 'red' 'red'? And does the brain check to see if what you think is red is red? One of the most important clues for our brain is a local contrast. The object in question is compared to the immediate background. If the background is changed, this can change our perception of the object in question. You also have a global contrast, which takes into account all seen objects.

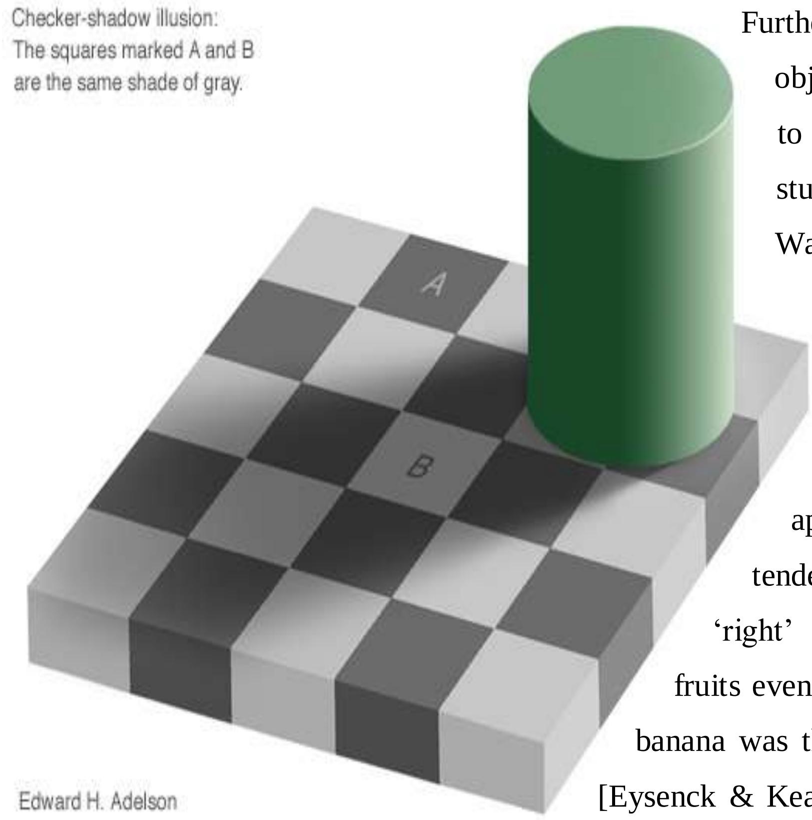


Image 3:The Checker Shadow Illusion by Adelson (1995)

Furthermore, our perception of an objects colour is changed according to our expectations of its colour. In a study done by Hansen, Olkkonen, Walter and Gegenfurtner (2006), they showed observers an image of different kinds of fruit, and asked the observers to adjust the image until the fruits appeared to be grey. The observers tended to observe the fruits as being the 'right' colour, and so would adjust the fruits even if they started out grey. The grey banana was thus adjusted to have a bluish tint [Eysenck & Keane (2010:61)]. To see that colour and in this instance shading does not give absolute inputs take a quick look at the presented figure created by Adelson (1995). The squares A and B are actually the same shade of gray; but the surrounding visual inputs force us to see B as a lighter shade of gray than A. Such illusions are not uncommon, and they all prove one thing: the world we perceive is not the world as it exists, but the world as it is interpreted. We might bump into a table but we feel a percept.

3.3.6 Perception Theories: Perception and Cognitive Psychology

To say that there is a clear distinction between the theories of perception that will be presented on the coming pages and Cognitive Psychology or cognitive neuropsychology would be false. Perception theories in themselves constitute a rich field of knowledge, and the theories described here all cater in some fashion to Cognitive Psychology. Some of them also use details from cognitive neuropsychology to tie the abstract systems to biological units.

3.3.6.1 Gestalt Theory

Gestalt theory states that when we observe the world we create percepts. A percept is an abstract representation that can receive focus. Further, these percepts are whole perceived images.

Take for example the classic image that is either a rabbit or a duck [Jastrow (1899:312)]. You can easily switch between seeing a duck or a rabbit, but you cannot see both at the same time. Gestalt Theory argues that this is because you're creating a complete percept of either the duck or the rabbit rather than 'seeing' the whole picture [Sternberg (2009:92-100)]. Thus the percept of the duck/rabbit hybrid is not available to your consciousness because this percept does not exist. Perhaps with training you could create a new complete percept which would be the whole picture; but this would not be a duck or a rabbit. It would be a percept of something completely new.

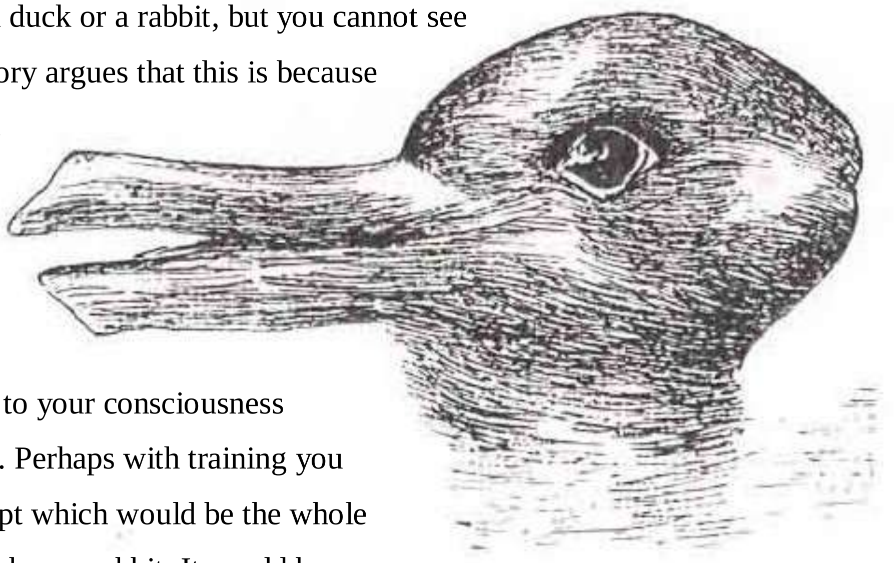


Image 4:The rabbit/duck illusion from Jastrow(1899:312)

Gestalt theory consists of several principles, most of which can be grouped into the Law of Prägnanz. This law states that a percept is an organization of the disparate elements you see into the simplest form needed for coherence. There are also the gestalt principles of symmetry, perception, proximity, similarity, continuity and closure. These are used to explain why we perceive the world as "a coherent, complete, and continuous array of figures and background" [Sternberg (2009:93)]

The gestalt principles are very simple, and seem to hold true despite their age, but the theory is clearly only descriptive. It tells us how we perceive the world but does not touch upon why we perceive the world in this way. Its founders had, of course, no knowledge of the minute details of the brain, its chemical composition or cellular structure, and could not build upon the yet nonexistent neuron code or brain code.

To find theories that attempt to explain why we perceive the world the way we do, we have to access literature of a more recent date.

3.3.6.2 Pattern-Recognition

Farah (1992) proposes that there are two separate systems for recognizing patterns, each with different purposes and functionality.

The first one specializes in creating a percept based on decomposing a perceived object into smaller parts. The understanding of what this percept represents is based on these various parts. This system is important for recognizing symbols and useful for recognizing normal objects. It is however of little or no importance when it comes to facial recognition.

The second system creates a percept based on the interpretation of complex and indivisible parts. This second system is important for recognizing faces, useful for recognizing normal objects and of little or no importance when it comes to recognizing symbols [Farah (1992:169)].

This explains the dual nature of visual agnosias[7]. Some visual agnosics have problems with recognizing both faces and objects but can read just fine. Other visual agnosics have problems with letters and objects but can recognize faces just fine. There are however no visual agnosics who have problems with recognizing faces and letters while still having the ability to recognize objects.

Farah thus theorizes that the face is not split into many smaller parts, and this leads to a more complex and specialized system for recognition

Other theories claim that this second system recognizes anything in which we have special expertise. This second system is located in the fusiform gyrus in the temporal lobe, and damage to this area can lead to problems such as autism and prosopagnosia [Sternberg (2009:100)]. This pattern-recognition theory is a function of the brain code, and although interesting thus not a focal point for this thesis.

3.3.6.3 Bottom-Up versus Top-Down

Farah comments on where the perception processes happen, but like other cognitive psychologists she spends little time discussing how these two separate systems create a percept. We will now take a closer look into theories that deal with models for what happens during the perception processes.

Sternberg (2009:102) divides these theories into two categories: Bottom-Up and Top-Down. The bottom-up theories aim to describe how the higher processes are controlled or manipulated through lower-level stimulus. The top-down theories aim to describe how the lower-level stimulus is controlled or manipulated through higher-level functioning.

[7] Visual agnosia is the inability to recognize objects through visual stimuli. This can be specific, such as the inability to recognize faces, the inability to recognize objects or the inability to recognize words or letters.

3.3.6.4 Bottom-Up theories

Bottom-Up theories start their descriptions, and build their understanding of our perception systems from the bottom-up; thus the name. Starting at the very small, the minutia of what we perceive, they try to use what they find to be atomic to explain how we build our percepts. This opens for a systematic approach that tells us how we build a complete percept through a system of interpretation based on input consisting of the smallest perceivable units.

3.3.6.5 Template Theory

Template Theory claims that we create abstract mental templates that we match possible patterns against. These templates are highly detailed and an exact match is required for recognition. Sternberg seems to discard Template Theory because such a system would fail to accommodate the myriads of sensory inputs we process every day that cannot possibly match a pre-existing template perfectly; especially since this would require a perfect 3D mapping of every single known object. Template Theory has therefore largely given way to the similar Prototype Theory.

3.3.6.6 Prototype Theory

"A prototype is a sort of average of a class of related objects and patterns, which integrates all the most typical (most frequently observed) features of the class." [Sternberg (2009:103)]

The prototype is similar to the template, but is less rigid and less detailed. Where the Template Theory would not be able to account for recognizing **A** and $\mathscr{A}$ as the same letter, this problem is solved with prototype matching.

Each prototype has a set of attributes. For example FRUIT could have the attributes *contains seeds, is sweet, grows on trees* and *is round*. When an object is perceived it is then prodded for criteria. The likeness of the object to various prototypes is tested based on the degree to which the features match these criteria. The attributes of the prototype are weighted for importance, so not all criteria need to be met. Each likeness of the attributes is weighted, and if enough "weight" is given then the object passes a threshold after which it is classified as belonging to the group of objects that fits into that prototype [Hampton (1995:686)]. Objects that pass the threshold with a certain amount of weight are classified as being undoubtedly in that category, while objects with very little or no weight are classified as clearly *not* belonging to that category. And then you have some objects that fit in between, which explain the inherent fuzziness of object classification; we are not always certain.

Connectionist Theory also gives a good account for a possible Prototype Theory interpretation. In this case the prototype itself would necessarily not exist other than as possibilities within a network of units.

3.3.6.7 Feature Theory

Feature Theory disagrees with Prototype Theory, proposing that we try to match features from possible patterns with stored features.

One level of representation contains units that represent a specific feature. Whenever a unit is feature can be found in a perceived something it "shouts out".

Another level of representation contains units that represent a set of features, linked to an abstract concept. Whenever one of the units in the set is detected by the first level of representation this unit on the second level "shouts out".

A third level listens for the yells of the second level and picks the unit that shouts the loudest or most frequently and use this units representation of the perceived something to be this perceived something.

3.3.6.8 Structural Description Theory

Biederman [Biederman (1987)] proposes that we build our percepts up with pre-existing 3-D geons (geometrical ions) that when combined create larger objects, much like how polygons create 3-D images in modern computers. But where the modern computer typically builds up everything from one specific polygon, structural descriptorists use a small number of different geons to create complete percepts.

Biederman proposes that much like how language is built up from a small number of primitives with less than ten contrasts, so is also object perception built upon a similar small set of primitives [Biederman (1986:145, Sternberg (2009:110)].

"The ease with which we are able to code so many words or objects may thus derive less from a capacity for coding continuous physical variation than it does from a perceptual system designed to represent the free combination of a modest number of categorized primitives based on simple perceptual contrasts." [Biederman (1986:145)]

3.3.6.9 A Top-Down Theory of perception: Constructive Perception

The Bottom-Up theories (especially Prototype and Feature Theories) of perception can predict the effects of certain stimuli. These theories do however have problems when trying to account for the effects of higher cognitions, such as expectation and context, and cannot readily explain why some perceptual stimuli are ignored. They also have problems with the configural-superiority effect [Bar (2004)].

The Top-Down theory of Constructive Perception works well as an answer to these problems by using the higher cognitive status as part of a baseline for what we can observe.

According to Constructive Perception's adherents the process of perception involves the creation and testing of various hypotheses regarding percepts. These percepts are based on three different parts: The first part is what sensory inputs we receive. The second part is using what knowledge we have stored in memory; The third part is what we can infer using high-level cognitive processes [Sternberg (2009:112)].

The second and third parts fill in errors, omissions or obscured information from sensory data, trying to make sense of conflicting data. In addition these processes can project assumed actions of external agents based on the sensory data.

Constructive Perception is also known as *intelligent perception*.

3.3.7 Neither bottom-up or top-down

The bottom-up and top-down theories can at first glance seem to be contradictory, working from the opposite assumptions about the brains processing systems. But both the bottom-up theories and constructive Perception Theory have predictive power. Further, seeing as how Constructive Perception fills gaps in the bottom-up theories at the higher cognitive levels we can assert that we need both approaches [Sternberg (2009:114)].

Constructive Perception includes the processing of the input in the model, and this processed input must be synthesized into the percept. The processing of the bare input must happen in a systematic fashion, and here for example Feature Theory or Prototype Theory can be important tools.

The problem with using only one approach is that they are both linear descriptions of an apparently non-linear process [Eysenck & Keane (2010:3)]. They are simply too simple. Lately much more focus has been given to the idea of parallel processing, where different parts of the brain work in parallel to solve a single problem. Eysenck & Keane (2010) use someone learning to drive a car as an example. At first it is hard to shift gears, pay attention to pedestrians and oncoming traffic and steer accurately at the same time because each process requires too much focus. But after some practice you can do it all while happily singing along with the radio and planning dinner. Clearly the brain will at any given time use several modules.

Some take the idea of parallel processing to the point of doing away with the self, and in some cases describe the notion of attention as nothing but a clever self-imposed illusion.[8] The idea is that several modules in the brain work on their separate problems without communicating with each other is experienced by us as if we were thinking only one thing at a time.

Evidence of this can be found in patients with for example split brain[9] where (after teaching the right hemisphere of the brain to communicate) we can see that both halves work independently and simultaneously.

As with different linguistic theories this means that some perception theories could be seen as different parts of the whole, rather than oppositions. While Prototype Theory and Structural Description Theory mostly contradict each other, both can be seen as representing part of the structure for Constructive Perception. Although one module creates possible percepts based on the visual input, this does not mean that it cannot receive instructions of some sort from another module; for example favouring one possible percept in the case of expectation.

[8] Oxford's A Very Short Introduction to Consciousness by Susan Blackmore is a fine read and highlights many interesting questions, both psychologically and ethically.

[9] Split Brain Syndrome is damage either partial or total to the Corpus Callosum, often effectively splitting the brain in two or otherwise limiting the two halves' ability to communicate with each other.

Chapter 4: Discussions

4.1 CONNECTIONISM

4.1.1 Why compare Optimality Theory to Connectionism

There is one major problem in including PDP in this paper, and that problem is one of scope, or level. Motivational Theory, Cognitive Theory, Perception Theory; these are all theories that work within the “higher” levels of cognition. They include bits and pieces of information about neurons, brain modules and such; but the phenomena they describe are abstractions on the total effects of these “lower” systems.

Optimality Theory works on these “higher” levels, taking abstract entities and modeling or processing these through means of other abstract entities. This creates a real problem for a meaningful comparison. But although the scope of Connectionism is different the goal is similar; in a meaningful way show how the brain processes information.

There is also the importance of historic relevance when it comes to Connectionism. This is the bed from which Optimality Theory grew. One of the founders of Optimality Theory, Paul Smolensky, was one of the prominent members of the PDP research group when they wrote the 1986 books Parallel Distributed Processing, volumes 1 and 2 [Rumelhart, McClelland & the PDP Research Group (1986:xx)].

Comparing Connectionism with Optimality Theory thus serves a dual purpose. First, it highlights Optimality Theory’s already existing connection with psychology. Second, the comparison is of interest both when it comes to comparing Optimality Theory with a psychological theory to test the hypothesis of the paper and as a measuring stick to see how far Optimality Theory has moved from its roots.

4.1.2 Finding comparable parameters

At first glance one can see the similarities with OT very clearly: Taking the input from a source the system parses it through various constraints until it finds an answer.

But these constraints do not at all work like the constraints of Optimality Theory. They are part of a highly complex structure rather than the linearly hierarchical structure of constraints in OT’s CON. And possible answers are not generated; rather only the optimal answer, found in the peak of goodness-of-fit is generated. And where is the EVAL structure?

To find GEN one has to look hard and the comparison is neither simple nor good. In Optimality Theory GEN creates a long list of candidates; possible answers to a problem. The problem is the input and the solution is the output. Connectionism does not create lists like these of any kind. Instead there is a malleable system of units connected to each other, turning each other on or off depending on which input they are given.

But in this system of interconnected constraints we might be able to see a partial resemblance to GEN's list of possibilities.

Rather than creating a list, the totality of possible outcomes of the interconnected constraints *is* the list. Every possible peak is a possible answer. The constraints then interact with each other in such a way as to build up to the best goodness-of-fit maxima it can get based on the input it is given; finding the solution with the "minimum amount of conflict or discrepancy." [Norman (1986:545)]

This does not mean that there is, in fact, a list. The manipulation of output candidates found in OT means that the generated list probably is an actual abstract artifact; this cannot be said of Connectionism's possible goodness-of-fit peaks. Also, the GEN as presented in Optimality Theory should be able to produce any conceivable line of phones, while in Connectionism each set of constraints have a given and finite set of possibilities.

The constraints of Connectionism are slightly different in scope than the ones in Optimality Theory. Not surprising since the theory deals with every part of the mind rather than just the linguistic modules.

The constraints in Optimality Theory do, however, check for an input-output correspondence, something that is impossible if there is no output candidate to check against. This does not by any means mean that the constraints of Connectionism are unidirectional, only looking at an input. As complex units in a complex network the unit can and probably has multiple connections, some strengthening it, others weakening it. But where an Optimality Theoretical could check for a labio-dental feature in a coda and try to 'kill' those output candidates that proved to have such a feature a similarly aimed Connectionist constraint would, if activated, send negative signals to the unit representing the labio-dental feature in the coda-segment.

The intercommunication between different constraints with varying connection strength's mean that you could create a hierarchy of signal strength; but this would not be a unidirectional constraint hierarchy other than by chance; it is much more complex than that.

There is also the nature of the constraints to consider. Some of the constraints used in Optimality Theory have complexities that in Connectionism could best be described through the interaction of several constraints. Although this might not be so different from certain types of Optimality Theoretical constraints that can show evidence of being constructs of smaller scoped constraints. For example the MAX-IO constraint described in chapter 2.3 The First example - Consonant clusters in Japanese loan words. Now, this constraint is much wider in scope than those in actual use in Optimality Theory. Instead it is often used for more specific target features, such as MAX-IO(nasal), making sure that nasal features are not deleted. The constraints are not necessarily atomic in scope, just because they are treated that way. We know so little of how the brain actually processes information that to speculate in the atomic or non-atomic nature of such a specific feature is currently folly.

An important similarity between the two different constraint types is their inherent conflict. In the television example the television cannot both be small and big; if one of the constraints have a positive input value the other is naturally not going to be activated. As such not all input constraints can get positive input values; it is simply not possible. This is in line with Optimality Theory.

Let us revisit the problem of finding an equivalent to the EVAL structure. The system runs as many iterations as it needs until the whole system hits a peak. It does not necessarily have to end there; repeated iterations will not change the output of the system once it has hit the peak, but for the exampled presented in Rumelhart et al. this seems to be the case. But what is it that oversees the goodness-of-fit? What is it that tells us whether a task is done well or not? There simply does not seem to be an evaluation mechanism built into the structure.

There could very well be such a structure; the theory has room for it. This would have to be a separate near-autonomous structure that evaluates the outputs based on its own criteria set by its own constraint structure. This is especially necessary for longer chains of complex actions, where modifications to the sequence have to be made in cases of errors or faulty reasoning [Norman (1986:541-542)].

Such an extra structure is already stipulated to be probable by Rumelhart et al. for dealing with planning [McClelland, Rumelhart & the PDP Research Group (1986:42)].

In addition to a model of the observed world that updates as we get new sensory input Rumelhart et al. makes probable an internal model of the world that is changed by internal input; a place for experimentation and planning. To find out if a given action will lead to a good result the planned action is run in the internal world-construct where we can test to see if we get the expected results, given what we know about the world.

You could either modify this internal world-construct to act as a evaluator to check if our actions are leading to optimal results, or if they deviate from the expectation built up by previous test runs or one can build a third world-construct whose only job is to keep up with the current plan and check our performance in the real world against the expected performance from the internal world. Either way we get an evaluator for our actions.

This evaluator does not have much in common with EVAL however. For one it does not have the prerequisite constraint rankings to check the output against, and there is no list of possible outputs available for a well-formedness comparison.

The principle of everything happening in one level is also lacking. Using Optimality Theory the output candidates are created, the constraints are checked against and the outputs are evaluated. In Connectionism the input is measured and then run through one constraint base multiple times to find an optimal candidate, and then it is executed while being continuously checked against internal expectancy of the outcome. There is an apparent direct route from input to output, but according to Rumelhart et al. the action is first planned in the internal world-construct before it is executed, adding a second process before the output can be executed. It is however an input-output correspondence system, it generates one to get the other.

4.2 Motivational Psychology

Reeve's outlying of the abstract structures of needs, motivation and action are surprisingly easy to compare to the basic structure of the Optimality Theory system.

First of all, that there are numerous motivations ready to respond to possible scenarios means that there has been generated multiple possible responses to the status quo. But what is put into the meaning of "motivations" here?

Reeve writes about these motivations not as needs, but as the observed actions taken to satisfy the needs [Reeve (2009:15)]. This means that given a certain situation, multiple possible responses are given and the best one is picked. This creation of multiple possible responses does mimic some aspects of GEN. What lacks is any hint about the randomness of the possible responses, or the amount of responses created. Still, as this might just be a lack of detail the similarities to GEN are striking. As such, the output candidates of the Optimality Theory system for Motivational Psychology will be the actions taken by the person in question.

What is elsewhere referred to as the motivations can also be fitted into the Optimal Theory system. As mentioned in 3.2.4 Emotions, there is a divide between the needs and the emotions. For argument’s sake this thesis will assume that emotions are not part of the need hierarchy and are indeed a separate structure. However, these emotions either "wake up" certain needs, or increase their standing in the need hierarchy.

As there are several output candidates ready to be acted upon some force has to keep the inactive ones at bay. Reeve calls these "subordinate", indicating a hierarchy. For the output candidates the term sub-optimal or non-optimal will mean the same. They are the output candidates that are not acted upon.

But for such a hierarchy to be meaningful there cannot be any strict rules regarding the output. If there were such rules then using the rules to generate the output would lessen the computational burden on the brain by magnitudes. Rather, there must be a non-absolutist solution where many different outputs can come to fruition given different circumstances. As such there must be a structure that uses some criteria to choose the best candidate. Reeve indicates that the winning motivation is the "most right". EVAL however works after the principle of "least wrong".

Still, the output candidate that satisfies the most important needs is the one which is chosen and dictates our behaviour. For Optimality Theory this could be a problem, as there is really no construct for finding inherent goodness in an output candidate. This can be solved, in a systemic fashion. the Boolean question "satisfied" or "unsatisfied" can be put on its head. As would be done for phonology, the system thus marks violations of constraints rather than giving certain output candidates a "plus" point.

This does make sense, as the system should find its optimal candidate not by choosing the best candidate, but inhibiting the other candidates. It saves computational power as some candidates quickly become inhibited to the point of being ignored, and rather than checking all needs for every option you can check only the most important needs and proceed down the need-hierarchy until you have only one remaining candidate. This system of using constraints to choose one option from many *is* EVAL.

We can see that GEN, CON and EVAL can have their place in a motivational theoretical system for predicting behaviour.

4.2.1 An example

To see how closely the descriptions of Motivational Theory and Optimality Theory resemble each other we can look at an example. Reeve himself gives such an example on page 15 of Understanding Motivation and Emotion which has been referred to on page 37 of this thesis, and this example will be the basis for this venture.

For this example the motives will be used as constraints. Reeve mentions CURIOSITY, HUNGER and AFFILIATION in his example. For purposes of this example "senser" will refer to the one who senses, feels and is motivated. For this example the senser will be the student from the original Motivational Theoretical example, trying to read a book.

CURIOSITY	Satisfied if the output behaviour teaches the senser something
HUNGER	Satisfied as long as the senser is not hungry.
AFFILIATION	Satisfied as long as the senser is in a social setting

When the study session begins the ranking is as follows: CURIOSITY > HUNGER / AFFILIATION.

It is impossible to say whether hunger or affiliation is higher than the other, as neither is part of the output.

Then, the senser smells food. The HUNGER motive increases in strength. The smell is from a neighbour's room, reminding the senser of his AFFILIATION motivation. AFFILIATION increases in strength. But it is not visible on the ranking until the CURIOSITY motivation is weakened by its satisfaction. The ranking becomes this: HUNGER / AFFILIATION > CURIOSITY. As HUNGER and AFFILIATION now outrank CURIOSITY the senser changes his output behaviour to mirror the shift in motive strength. He visits his neighbour and eats popcorn, allowing the output behaviour to satisfy both HUNGER and AFFILIATION motivations.

Let us see how this fits Optimality Theory using a tableau.

The top leftmost cell normally filled with the input in Optimality Theory is so far empty, as we have not discussed a correlated term for motivation. You could say that the entire situation that the senser is in is his input, and the output possibilities are all possibilities entailed by this input. The situation would necessarily be too complex to sum up in a single cell. For order's sake the cell will have the text "situation" in it. The current situation is the one depicted by Reeve.

This situation will have a similar connotation to the output candidates as it would have with Optimality Theory, but not the same. The GEN of Optimality Theory and Freedom of Analysis means that "Any amount of structure may be posited". Instead, for motivation, the outputs should be modelled after what is possible within the situation, making it less "free" than Optimality Theory's GEN would allow. An option for this is to have the motivations check only for how much satisfaction is possible for each output in the input. So even if a possible output states that you should eat half an ox, the output would violate the HUNGER motivation if eating half an ox is not possible given the input. Alternately there could be a separate constraint checking for feasibility of action, chance of failure or cost of failure. For this simple example we will however stick to the above constraints.

We also see another difference in the wording here with the motives. The motives will not be checked for violation, per se, but for lack of satisfaction. The wording does not necessitate a break with the thought of constraint violations in OT, but only reflects that a different field of study has used different wording. Here the term violation will be used to mean that a motive has not been satisfied.

The ranking of the motives used here is the same as in the beginning of Reeve's example.

The output candidates are more complex and so named only O1, O2 and O3, and need more description:

O1: Read the book

O2: Go hang out with friends and have a snack

O3: Go hang out with friends and read the book

The tableau ends up looking like this, before violations are marked

Tableau 5:Empty motivational tableau

/situation/	CURIOSITY	HUNGER	AFFILIATION
O1			
O2			
O3			

O1 clearly does not satisfy HUNGER or AFFILIATION, and so a violation mark will be placed in both.

O2 does not satisfy CURIOSITY, for this particular input.

O3, although at a surface level good, will, for this input violate CURIOSITY as the senser knows that he will not be able to read the book if hanging out with his neighbour. It also violates HUNGER. This makes the tableau look like this:

Tableau 6: First student motivation tableau

	/situation/	CURIOSITY	HUNGER	AFFILIATION
☞	O1		*	*
	O2	*!		
	O3	*!	*	

For O2 and O3 there is also an exclamation mark in the box marking a violation of CURIOSITY, since a violation of this higher ranked, stronger, motivation kills off these output candidates. This leaves O1 as the only surviving output candidate, and so O1 reflects the senser's actions.

After an hour the actions of the young student change. Oatley & Jenkins (1992) say that the emotions change the rankings of the needs. As such we can try to modify the rankings to illustrate the change in emotional state. The senser is tired, his curiosity has subsided and he is hungry and wants some company or action. He gets the new ranking HUNGER / AFFILIATION > CURIOSITY.

Based on this modified ranking we can construct a new tableau to see if we can predict a new outcome:

Tableau 7: Student motivation after Oatley & Jenkins re-ranking of needs

	/situation/	HUNGER	AFFILIATION	CURIOSITY
	O1	*!	*	
☞	O2			*
	O3	*!		*

As we can see, the same motives are violated for the same output candidates, but now O2 is the winning candidate as this only violates CURIOSITY, now a weaker motive. The senser changes his behaviour to match the new ranking of motives.

A different description would be given if Fridja (1986) is to be used instead. The emotions are used to switch the needs on or off. As such we can, instead of re-ranking the needs turn CURIOSITY off, as it is satisfied enough. That gives this tableau:

Tableau 8: Student motivation after Fridja need repression

	/situation/	HUNGER	AFFILIATION
	O1	*!	*
☞	O2		
	O3	*!	

As with the Oatley & Jenkins (1992) re-ranking strategy O2 is the optimal output candidate.

We have here seen the effects of rearranging or removing the constraints based on emotional states; which is needed when the constraints are fixed. Boersma (1997) suggest the addition of a stochastic element in the ranking of the constraints. Rather than having the constraints ranked according to each other in a hierarchy the constraints are given values. When a constraint is violated its value is checked and its impact on EVAL is treated according to this value. These values are then manipulated by a stochastic element, temporarily making the constraints more or less important, giving the structure more flexibility than what is allowed for with fixed constraint rankings. It can be visualised as if the constraints, rather than being dots on a line are partially overlapping smudges.

Given such an interpretation of the notion of constraint rankings, emotions could be treated as fixed rather than stochastic elements: either temporarily increasing or decreasing the importance of a constraint.

As with phonological tableaus these short and small ones hide an extreme complexity. For this example there is given only three different output candidates and only three needs are used as constraints. For such a model to actually work it would have to include all needs (or all active needs) and a plethora of different possible outputs, some outrageous and some which are well-fitting, but in the end only one candidate should come to fruition. Not that that is necessarily necessary as one can easily see the possible outcome “indecision” if no output candidate was to make itself the only viable one. This could happen if the output candidates were to closely matched or if the need hierarchy for some reason is under or over excited; that is, either too few needs are active or too many needs are ranked very high.

It is important to note that for an actual working model the output candidates would have to get validated by some higher cognitive process, so the output from the motivational system tells us what we *want* to do, and prompts a cognitive process that can extrapolate on the outcomes of that process, which could prompt a new run of the motivational system based on this new information. The answer from that run would have to be subject to this higher cognitive structure, which could prompt a new run of the motivational system and so forth until there is an outcome [Izard (1993:85)].

We can see that although there is not a flawless comparison, the similarities between the abstract construct systems of the two theories share striking similarities.

Both generate a list of possible responses to the input, and both have a list of constraints with different importance for the evaluation of the output candidates.

One notable difference is in the nature of the evaluation, although, as earlier stated this can be a problem of wording rather than concept. Where Optimality Theory looks for the “least bad” candidate, Motivational Theory looks for the “best” candidate.

4.3 COGNITIVE PSYCHOLOGY

The main focus of the thesis is not on the biological processes of the brain, but some aspects of Cognitive Neuropsychology deserve closer inspection.

The comments made by Daniel Levitin and Rebecca Saxe at the symposium “Unlocking the Secrets and Powers of the Brain” in November 2008 create a torrent of effects that cannot be overlooked at the brain or mind levels. Especially Rebecca Saxe’s comments about the effects in patients with Utilization Behaviour especially highlight the possibility that both GEN and EVAL reach well beyond linguistic modules[10].

Levitin's description of what makes humans stand out as a species here on Earth, our ability to inhibit parts of the neural network, points towards a general tendency of the brain to over generate stimuli; stimuli which then need to be whittled down until only the relevant ones remain. If GEN or similar exist there would have to be processes in the brain on a neural level that stop the non-optimal solutions from coming through and confusing our speech patterns.

That being said, the neural inhibitors are not absolutes. They are chemical elements that decrease the possibility of a signal coming through by hyperpolarizing the affected neuron, lessening the chance of a successful action potential in that neuron. In other words, the neuron's ability to communicate with its neighbours is diminished, not absolutely removed.

The principle of *uniformity of functional architecture across people* is taken seriously by Optimality Theory. Not only the larger swooping generalizations, but the specifics of the constraints are assumed to hold for all people.

Other than this we can also see through some of the biological descriptions of the paths that information takes through the brain that the assumption that the processing happens in a semi-linear fashion, as with form processing, could be substantiated in OT. If the path a phonological representation has to take is "through" the constraints, then each constraint would weaken or inhibit those that violate it, making that output candidate less likely to be expressed; although not killing it completely, so even a weak candidate can win if the other candidates are weaker.

The other three axioms used for cognitive neuropsychology, *modularity, anatomical modularity* and *subtractivity* do not necessarily clash with assumptions in OT. Since OT is a linguistic theory its contents could well be fitted into a single linguistic module. Subtractivity deals directly with the creation of modules, but how far should this be taken? It is well known that some people with aphasia can relearn their old language skills, while for others the damage seems permanent [Musso et al. (1999)].

But cognitive neuroscience also tells us that the connections between modules are complex, and similar tasks happen in several of them. Some singular tasks happen in several of them and culminate in a single node, such as with form perception. Furthermore, with form

[10] Psychological module; not to be confused with Linguistic Modularity

perception, it would seem like the process happens in different levels before culminating in an answer in the inferotemporal cortex. Does this differ from how Optimality Theory treats language? Would phonology be analogous to form perception in scope? If so, how many levels or partitions of phonological processing are there in the brain, and should this be represented somehow in the OT-structure? There should at least be three; the creation of output candidates in GEN, the inhibition of bad candidates through CON and the evaluation of the winning candidate in EVAL.

4.3.1 Cognitive Psychology and Executive Control

If we look at some of the abstract terms used for describing executive control we can see some similarities with Optimality Theory.

Executive control deals, in part, with the monitoring and detection of conflict between stimuli and responses, and the selection of proper responses at the cost of the ignored or suppressed ones. It does more though. It organizes thoughts and lets humans act on what feel like decisions we make. In short it is exactly what its name implies, the *executive control*.

Although Optimality Theory lacks such a broad-sweeping abstract construct it does have partitions of it apparent in its structure. The choosing of proper responses to stimuli at the cost of the improper responses can be recognized as EVAL, which when fed the representations and the measuring criteria can subjugate the less-than optimal responses and feed the unsubjugated responses to its next destination, be it a semantic or pragmatic understanding of a concept, or to the production of speech sounds.

The detection of conflict between representations can also be seen in Optimality Theory. Let us quickly look at output-output correspondence [Kager (1999:257, 263 ++)] and sympathy [Kager (1999:387-392)].

Output-output correspondence forces the output to be faithful to itself in cases of reduplication, which at least minimally forces Optimality Theory to encompass some motor for intra-response monitoring. But sympathy forces it to a new level as an output candidate has to be faithful to a different output candidate; one response must be faithful to another, competing, response. This goes past just inhibiting unfavourable responses, and instead requires an active monitoring of possible connections between the possible responses before validation occurs. But the wording is different from Saxe et.als description of executive control in a crucial part. Whereas in Optimality Theory using sympathy results in faithfulness between outputs (responses), Saxe et al. (2007:284) specifically state that executive control looks for conflict. How much this is just a poor choice of wording or a result of detailed analysis is hard to grasp from the context.

4.3.2 Orthographic processing

When we read a word, the claim that orthographic neighbours are also activated can be of particular interest. It is especially interesting considering the claim that phonological processes are active while reading. It would appear that in order to understand what word one is reading one first has to consider all words that kind of look like the word you are reading. The mind thus generates a list of words that look very similar to the word you are looking at (or touching for the blind).

It is hard *not* to draw a comparison with GEN, but there is a key difference that is of some importance. There is no mention in the Eysenck & Keane (2010) about anything that could resemble Freedom of Analysis, which is after all a key element of Optimality Theory GEN.

That being said, the lack of mention does not mean anything as the text does not go into rich detail on the subject, and the activation of various, near-random other words could be hard to spot on an fMRI or similar. But even if a test on the subject would show that there are additional options generated randomly this still would not change the claim that orthographic neighbours are activated as a rule. This still goes against Freedom of Analysis. How important is Freedom of Analysis to Optimality Theory? Strictly speaking, the definition of Freedom of Analysis, that "any structure may be posited". Kager (1999:20) does not exclude the possibility of *some* candidates being more easily generated than others, for example candidates that are very easily mapped to the input. This would still break with the existing Freedom of Analysis, but if cognitive neuropsychology has it right, changing the rules of GEN could make the grammar more in line with natural language processing.

4.3.3 Perception theories: Gestalt theory and Pattern-recognition

Gestalt theory's assessment of percepts being undivided wholes (possibly made from smaller parts; dividable into these smaller parts only at the cost of the percept) is not inherently against Optimality Theory's take on inputs or outputs. The output candidates are indeed treated by the wholes, not as parts. This is important for the system to work. Even if a syllable in one word A is "more harmonic" than a syllable in word B does not mean that word A is the optimal candidate. The whole of the candidate must fit the harmonic goodness evaluation in order to be the optimal candidate. And the Law of Prägnanz could seem to hold as well, since both the input and the output candidates are clearly constituted by smaller parts, where the smallest change can mean that a candidate is optimal or forgotten.

The division of the visual modules into two distinct parts with separate specialities can be mimicked only with difficulty in regards to phonology, although it is possible. There are certainly levels of scope in regards to phonological representation and processing, from the small changes in almost instantly produced sounds such as aspiration to a bilabial plosive to the lengthy ones spanning across many other features such as phrasal tones. But would such a division into multiple feature analysis and complex feature analysis carry over to phonology?

Aphasia can affect spoken language as well, and is called expressive aphasia. It can target the word representation rather than whole abstract meanings as described in as early as in 1769 by Johann Augustin Philipp Gesner [Benton (1965:57)]. Knowing if expressive aphasia could damage specific parts of speech could be used in an exploration of the reach of modality in the same fashion as Farah has done for visual perception.

4.3.3.1 Is OT Bottom-up or Top-down?

In its essence, phonological Optimality Theory must be a bottom-up approach to word understanding, as it deals with outputs designed for direct action rather than what we consider “high reasoning”. Such a definition would be a simplification though, as it is for the theories discussed in chapter 3. Optimality Theory does not take into account the context in which a word is understood or produced, nor does it use inference. But phonological theory does not attempt to explain the whole process. There are syntax, semantics, pragmatics and phonetics which must be included for full understanding of verbal communication, and at least some of these can use Optimality Theory [Kager(1999:341), Smolensky & Legendre(2006:161-338)]. It is a piece of the puzzle when it comes to verbal communication; the puzzle as a whole is neither inherently top-down or bottom-up, although its disparate parts can seem to adhere to one or the other. Optimality Theory can, however, be used for more than phonology, at least being able to describe syntactic processes, and possibly more.

4.3.3.2 Prototype Theory and Feature Theory

Prototype Theory can at first glance seem the stark opposite of Optimality Theory. After all, Optimality Theory can seem like a theory of details, nitpicking the differences between modal voiced and stiff voiced. But these are for idealized outputs before they meet the physical world, representing how we wish the receiver would hear our words.

In the real world there are open windows, cracking fires, loud trucks and crispy treats. Through this noise the recipient of words is still often able to understand what is said through a “best guess” scenario. This could include higher cognitive factors, such as inference. If the one speaking was not talking about Star Wars, there is no reason he should refer to his sandwich as a “Han sandwich”. But normal speech is hardly idealized either; it is slurred, staccato, interrupted by the occasional “əh”; all in all it is a miracle that anyone can understand anyone else at all. But Optimality Theory is already a “best guess” generator in itself.

Optimality Theory does not take inputs at face value; instead they are just the beginning of a process where the result does not need to be perfect. It needs to be good enough.

The nature of phonological features and their constructions into words could lend itself to some sort of prototyping where every word is a prototype in itself. But it is equally likely that there are individual words represented by units which are tasked with finding the disparate parts that make up the word. This would be a lexical representation however, and not a phonological one.

Either notion is at odds with some basic concepts of Optimality Theory. The percepts are created from a pre-generated list of options as opposed to how Optimality Theory’s GEN creates various possible candidates. The process to find the “right” answer seems rule-based rather than constraint based. The prototype that has its weight-threshold exceeded is chosen, a result that can be predicted by a simple formula. The unit that shouts the loudest is the unit that has the most matching features.

As we can see in chapter 2, Optimality Theory does not simply accept there being enough matching features. There is a matter of harmony as well; in Optimality Theory terms all options for Prototype and Feature Theories seems based on the subject of faithfulness. As there is no likeness to CON there is no likeness to EVAL.

Further, both theories check for correct features, whereas Optimality Theory checks for incorrect features. It is in many ways a system not of “best”, but of “least bad”. In many ways both theories have more in common with older rules-based segment phonologies than Optimality Theory.

4.3.3.3 Constructive Perception

As mentioned earlier Optimality Theory is not a top-down approach. It does however have some similarity with Constructive Perception.

Constructive Perception's percepts are hypothetical ones. The process starts with the production of hypothetical percepts which are then tested through a process to find out if the hypothesis is right. This one point does share some similarity with GEN which in essence does just this: create hypothetical outputs.

Chapter 5: Conclusions

5.1 General comments about the theories

Through this thesis we have taken a short look into Motivational Theory, Perception Theories, Cognitive Neuropsychology, Cognitive Psychology and Connectionist Theory.

The separate fields looking into the structure of the mind have different, elegant models that give a good account for how the behavior of the phenomenon which is their specific field of study can be described, and give predictive results for this phenomenon.

Although these different theories often describe different modules (with the exception of Connectionist Theory which describes the whole system) the different modules, being parts of a bigger structure, could still be said to have structural similarities; the hypothesis of this thesis says they do.

Using the structural partitions given by Optimality Theory as a base for the descriptions of each theory we can draw some conclusions based on the insights given from this examination.

It's a point worth noting that the only theory reviewed here that does not touch on the subject of linguistic interpretation in some way is Motivational Psychology. This can be problematic as there is not necessarily a clear divide between the linguistic theories and these other theories. However, most of the theories touch only lightly on the subject; notable exceptions are Connectionist Theory some of whose proponents have given rise to Optimality Theory, and Cognitive Psychology whose scope means it is connected in some way to every theory connected to mind code.

5.1.1 GEN

Several of the examined theories seem to have something analogous to GEN.

A notable exception, especially given the expectation of clear connection is Connectionism. Although it certainly has a multitude of possible outputs built into the system through the various possible peaks given various inputs this is in no way a creation of a *list* of possibilities. Also, the different options are not created freely, but rather exist continuously as possibilities in the system. An abstraction of a list can still be seen, almost conforming to Freedom of Analysis, in these possibilities. Still, rather than giving rise to any possible structure, the system instead can only create those outputs already existing in the system as possibilities.

Feature Theory, Prototype Theory and Structural Description Theory, all Bottom-Up perception theories, do not show such an architecture either, rather constructing percepts directly based upon perceived inputs.

Orthographic Processing does seemingly make a list of possible candidates, but the list does not have something close to the randomness inherent in GEN. The same can be said for Constructive Perception's Top-Down perception approach, which creates a list of hypothetical percepts to choose from, but without any hinting to the randomness given from Freedom of Analysis.

The case of Utilization Behaviour as described show that a construct similar to GEN can exist for certain higher cognitive levels dealing with choice, although a complete model for such choices cannot be found in this thesis. The very similar field of Motivational Theory is however given a more in-depth description, and also shows a construct very similar to GEN. It creates a list for possible outputs in order to choose the best candidate. The number of possible outputs and the freedom they are given are however not given much description, which would be needed for a more coherent comparison.

5.1.2 CON

Where the structure of GEN has some equivalent in many different theories, fewer models mention the exact manner of choosing a good output candidate. As the constraints are not generative, not validating and conflict seeking they naturally have no place in those theories where only one possible output is generated on the basis of the input. Further, many of those theories that *do* have a GEN like structure do not give specifics of the selection process.

Connectionist constraints show conflict, much like Optimality Theory's constraints. The constraints are also hierarchical and can trigger negatively given certain inputs. This is like a combination of the EVAL and the CON structures, which is not necessarily contrary to Optimality Theory. They do not however look for violations in output candidates, as such candidates do not exist in the structure. Rather they give negative feedback to possible candidates in the goodness-of-fit space based on their activation. They are also used to validate certain outputs; and in fact the system functions only because of this validation through positive enforcements.

Motivational Theory has more than one possible construct similar to CON. Emotions and Needs for example could very well fit the description of constraints.

The model works well if the needs are used in an analogous fashion with the constraints, while the emotions function as trigger mechanisms, forcing a run of the system and/or changing the active need hierarchy. The needs are however validation-seeking rather than violation seeking like the Optimality Theoretical constraints, although as the example in 4.2.1 An Example shows, it is possible to use the needs as if they were violation-seeking, albeit only for a superficial examination.

5.1.3 EVAL

Most systems that create possible output candidates would need to have some way of evaluating those candidates in order to choose one of them. Systems that do not, but rather opt to create only one possible output would still benefit from an evaluation of that output in order to ensure that there has not been an error. The evaluation mechanism of EVAL is more specific than just being an evaluator of goodness. It is not looking actively for the best candidate per se. Rather, using the violations of constraints it whittles away at the possible outputs until only one is left. Rather than looking for the best candidate it looks for the best available candidate, the optimal candidate. And it is the best because the other candidates are worse.

Cognitive Neuropsychology's description of the brain's inhibitory system lends strength to the idea of violation-based evaluation of possibility, as the non-optimal candidates are whittled down, leaving only the surviving candidate. And for Cognitive Psychology there is the Executive Control structure which shares similarities with EVAL. One such similarity is the monitoring of conflict, although the scope of Executive Control seems to be wider than that of the EVAL described in this thesis.

Another theory with a scope almost equal to Cognitive Psychology is Connectionism, which must have an evaluation system built into it. There is no *evaluator* per se, just a relaxed state that yields a single constant output. This evaluation mechanism does not take into consideration the other possibilities for the solution space, nor does it take into account constraints of any type. Rather, the system in many ways evaluates itself as it comes to equilibrium, an event that occurs without outside interference. In the case of an actual construct evaluating the system it does not need to check for anything but a steady level of activity over a set of constraints. In short, there is no need for an EVAL.

Motivational Theory must have something resembling EVAL for the need hierarchy and emotions to make sense; without this mechanism the rest of the structure does nothing. But where Optimality Theory looks for "least wrong" Motivational Theory looks for "most right". This Boolean construct is not necessarily easily changed, and using the needs as violation-seeking constraints rather than validation-seeking could seem counter intuitive. More research is needed to come to any conclusion on this subject.

5.2 ON UNIVERSALLY COMMON STRUCTURES

Although several of the theories share similarities there is little in the way of universal agreements across all fields.

Although *some* have structures similar to GEN and EVAL many do not; which is hardly unexpected. There are still two parts of the structure which can be found in enough theories to deserve a mention:

The generation of multiple possible outcomes seems to be a recurring theme for many theories. The evaluation of these multiple possible outcomes is a necessity, as the non-optimal outcome candidates need to be inhibited.

These two structural units must also be in some way part of a linear progression. The evaluation structure cannot do its job without something to evaluate; logically it follows that the generation of possible outcomes must precede the evaluation of them. As briefly mentioned on the topic of emotions, there would also have to be a starting mechanism for this structure for it to run. This could be the reception of input or it could be a timed cycle of some sort, or even a continually running process. The theories discussed in the thesis have all started with the reception of some input. Whatever the case may be for the trigger, the process must give one or more outputs in order to have relevance.

This leads to the following extremely simple structure representing what most of these theories can agree on:

First step: The structure receives a prompt to run, for example through the reception of some input.

Second step: There is a generative substructure generating a list of possible outcomes, or outcome candidates.

Third step: There is an evaluative structure evaluating the different outputs based on the input and/or some criteria.

Fourth step: The output candidates that are not evaluated to be the best outcomes are inhibited, leaving only the best output candidate, which is promptly sent out of the system as the system's output.

Due to the convergent nature of many of these elements, it can be suggested that there is some synchronicity of thought with regard to how to unlock the brain's ability to turn the apparent chaos around us into coherent mental representations.

5.3 SOME FURTHER COMMENTS

It is interesting to note exactly how much Motivational Theory and Optimality Theory have in common on the abstract structural plane. These two fields in particular could benefit from cooperation, even though the fields are so divergent in their goals as to resist most common research projects.

As should be expected there are no clear commonalities between all the diverse theories. But given that most of them had structures that showed some similarities further and deeper explorations into the exact natures of the different theories is warranted, as the possibility of finding one overarching structure common to all modules would make it easier to solve current and future riddles of the mind.

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