COGNITIVE DYNAMICS OF SCIENTIFIC CURIOSITY

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COGNITIVE DYNAMICS OF SCIENTIFIC CURIOSITY

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Cognitive Dynamics of Scientific Curiosity

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Thesis Abstract

Ahmet Subaşı, "Cognitive Dynamics of Scientific Curiosity"

The aim of this thesis is to develop an integrative perspective on the cognitive dynamics of scientific curiosity which influence and bias its motivational direction, i.e. its selectivity property. This perspective analyzes both individual dynamics and the outcomes of the interactions between these dynamics. In the thesis scientific curiosity is delimited as a particular type of specific epistemic curiosity and defined as an intrinsic motivation for systematically making sense of phenomena. It is argued that the compositional capacity of human mind, which finds its highest expression in language, makes possible the creation of meaning systems through which human mind systematically makes sense of phenomena. And the systematic aspect of making sense and its relationship to this compositional capacity is discussed. After elaborating on the definition of scientific curiosity, an inquiry is made into the emergence and processes of human symbolic capacity in order to reach findings as to the cognitive dynamics that influence the direction of scientific curiosity motivation. As the most basic definitional framework, compositional dynamic is defined as the creation of and activity within a dynamic system of meanings with a core and periphery the ultimate reference point of which is potentially everything. Other cognitive dynamics that function as subdynamics of this basic motivational dynamic are defined as interest dynamic, expansion dynamic, completion dynamic, hierarchical dynamic and perfection dynamic. The thesis aims to make the following four contributions to the literature: (1) Propose a comprehensive definition of the most basic dynamic of scientific curiosity which accounts for the diffuseness of children's curiosity as well as the property of curiosity discussed under the title of 'independence from interests' in the philosophical literature; (2) hypothesize 'hierarchical dynamic' as a general selective tendency of scientific curiosity based on evidence from studies on children's questions; (3) integrate the findings of the relevant theoretical perspectives under cognitive dynamics perspective that is offered in this thesis; and (4) analyze the interaction of individually studied dynamics and the nature of the research agenda this new perspective can offer.

Tez Özeti

Ahmet Subaşı, “Bilimsel Merakın Bilişsel Dinamikleri”

Bu tezin amacı bilimsel merakın güdülenimsel yönünü, yani seçicilik özelliğini, etkileyen bilişsel dinamiklerle ilgili bütünleştirici bir perspektif geliştirmektir. Bu perspektif hem bireysel dinamikleri hem de bu dinamikler arasındaki etkileşimlerin sonuçlarını analiz eder. Tezde bilimsel merak, literatürde özgül epistemik merak olarak adlandırılan merak türünün alt kategorisi olarak sınırlandırılmış ve görüngüleri sistematik olarak anlamlandırmaya yönelik içkin bir güdülenim olarak tanımlanmıştır. İnsan zihninin, kendileri aracılığıyla görüngüleri anlamlandırdığı anlam sistemleri yaratmasını, en yüksek ifadesini dilde bulan tümleme kapasitesinin mümkün kıldığı öne sürülmüş ve anlamlandırmanın sistematik yönü ve bunun tümleme kapasitesiyle ilişkisi tartışılmıştır. Bilimsel merakın tanımının ayrıntılarına inildikten sonra, bilimsel merak güdüleniminin yönünü etkileyen bilişsel dinamiklere dair bulgulara ulaşmak için, insandaki simgesel kapasitenin ortaya çıkışı ve süreçlerine dair bir araştırma yapılmıştır. En temel tanımlayıcı çerçeve olarak, tümleyici dinamik, nihai referans noktası potansiyel olarak her şey olan ve bir merkeze ve çevreye sahip olan dinamik bir anlamlar sistemi yaratma ve bu sistem içerisinde etkinlik gösterme olarak tanımlanmıştır. Bu temel güdülenimsel dinamiğin alt dinamikleri olarak işlev gören diğer bilişsel dinamikler ilgi dinamiği, genişleme dinamiği, tamamlama dinamiği, hiyerarşik dinamik ve mükemmelleştirme dinamiğidir. Bu tez literatüre şu dört katkıyı yapmayı hedeflemektedir: (1) Çocuk merakının dağınıklığını ve merakın ‘ilgilerden bağımsızlık’ başlığı altında felsefe literatüründe tartışılan özelliğini açıklayan, bilimsel merakın en temel dinamiğinin kapsayıcı bir tanımlamasını önermek; (2) çocuk soruları hakkındaki çalışmalardan gelen kanıtlara dayanarak bilimsel merakın genel bir eğilimi olarak ‘hiyerarşik dinamik’ hipotezini ortaya atmak; (3) ilgili teorik perspektiflerin bulgularını bu tezde önerilen bilişsel dinamikler perspektifi altında bütünleştirmek ve (4) bireysel olarak analiz edilmiş dinamiklerin etkileşimlerini analiz edip bu yeni perspektifin önerdiği araştırma gündeminin doğasını irdelemek.

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CONTENTS

The important thing is not to stop questioning. Curiosity has its own reason for existing. One cannot help but be in awe when he contemplates the mysteries of eternity, of life, of the marvelous structure of reality. It is enough if one tries merely to comprehend a little of this mystery every day. Never lose a holy curiosity.

Albert Einstein

CHAPTER 1: INTRODUCTION

The Aim of the Thesis

The aim of this thesis is to develop an integrative perspective on the cognitive dynamics of scientific curiosity which influence and bias its motivational direction, i.e. its selectivity property. This perspective analyzes both individual dynamics and the outcomes of the interactions between these dynamics. The method is first to delimit and define scientific curiosity in relation to the categorizations that have been made in the literature and then to make an analysis of the emergence and processes of human symbolic capacity from infant pointing to children's questions in order to reach findings as to the cognitive dynamics that influence scientific curiosity. Finally, the results are theoretically discussed and evaluated together with the existing theoretical perspectives in order to come up with an integrative perspective. The thesis aims to make the following four contributions to the literature:

(1) Propose a comprehensive definition of the most basic dynamic of scientific curiosity which accounts for the diffuseness of children's curiosity as well as the property of curiosity discussed under the title of 'independence from interests' in the philosophical literature;

(2) hypothesize 'hierarchical dynamic' as a general selective tendency of scientific curiosity based on evidence from studies on children's questions;

(3) integrate the findings of the relevant theoretical perspectives under cognitive dynamics perspective that is offered in this thesis; and

(4) analyze the interaction of individually studied dynamics and the nature of the research agenda this new perspective can offer.

Background of the Problem

Delimiting Scientific Curiosity

As the subject matter of a number of psychological and philosophical investigations, curiosity has generally been considered in terms of the two categories - epistemic curiosity and perceptual curiosity (Berlyne, 1960). According to the categorization proposed by Berlyne (1960), curiosity is subcategorized as diversive curiosity and specific curiosity where with the former Berlyne refers to a general type of sensation seeking and with the latter to desire for specific information. According to this well established categorization of Berlyne, the type of curiosity that is associated with scientific and philosophical activity falls under the category of specific epistemic curiosity. However, although specific epistemic curiosity is usually exemplified by a scientist's investigation of a problem, its definition can also include cases where the specific details of a personal matter or practical questions about specific issues also constitute instances of epistemic curiosity. Therefore, the term 'scientific curiosity' needs to be delimited as a subcategory of specific epistemic curiosity for the sake of clarity before its cognitive dynamics, i.e. its selectivity property, is discussed.

Defining Scientific Curiosity

In the literature the definition, situational determinants, and motivational nature of curiosity have been extensively discussed. This thesis endorses the widely accepted views that curiosity is an intrinsic and primary motivation and it is also appetitive and aversive, meaning that it is a desire that demands satisfaction and induces aversive feelings in case of deprivation. There is, however, still the question of the underlying cause of curiosity, which is fundamental to giving a comprehensive definition of it. Loewenstein (1994) notes that "the remaining question – the cause of curiosity – is inherently unanswerable" but, nevertheless, expresses his belief that "the need for sense making discussed by Kagan and others provides a plausible account of the underlying cause of curiosity" (p.87). According to this definition, curiosity is fundamentally an intrinsic motivation to know in order to make sense. Therefore, sense-making is the ultimate goal of curiosity motivation and the fundamental force that determines its direction. And to establish a theoretical framework for the cognitive dynamics perspective to scientific curiosity, this definition will be elaborated.

The Selectivity of Curiosity

In the opening words of 'A Theory of Human Curiosity' D. E. Berlyne (1954) remarks that although few phenomena have been the subject of more protracted discussion than human knowledge, little attention was paid to the motivation underlying the quest for knowledge. According to Berlyne's (1954) theory, the exploration of human beings qualitatively differs from the exploratory behavior of other animals.

> In the case of rat, for example, there appears to be a drive which is aroused by novel stimuli and reduced by continued exposure to these stimuli. Its reduction reinforces exploratory activity, i.e. activity, such as approaching and examining the stimulus-objects, which increases stimulation of the animal's receptors by them. Now, similar exploration is undoubtedly elicited by strange objects in adult and especially infant human beings. But in an animal as well endowed for learning and remembering as the human adult, exploration is bound to leave a stock of permanent traces in the form of symbolic representations ('pure stimulus acts' or 'cue-producing responses'), which are manifestations of what we call 'knowledge' (p. 180).

In this passage Berlyne specifies "leaving a stock of permanent traces in the form of symbolic representations" as the distinguishing aspect of the exploration of human beings. However, our explorations are not limited to approaching and examining stimulus-objects in the environment and assigning to them traces in the form of symbolic representations. If it was so, we would only be able to speak about things that we directly experience. As noted by Moch (1987), in another passage Berlyne gives a more comprehensive definition of epistemic curiosity as "exploration of symbolically representable contents aimed at increasing one's knowledge" (p.199). This is a more inclusive definition of epistemic curiosity, since human beings are capable of exploring all symbolically representable contents regardless of their being directly experienced or real. This indirect form of exploration is made possible by the human language faculty, which, as İnan (2009a) notes, "enables us to extend our knowledge, our beliefs, our thoughts, and our ontology, beyond what we actually experience in our private lives" (p.1). In Berlyne's (1960) words, linguistically mediated knowledge allows "stimuli that belong to the past or the future, or even stimuli that will never be part of the stimulus field, to make their influence felt through their internal representatives" (p.266). The exploratory possibilities opened up by language are seemingly endless and there is also a motivational basis in human beings that instigate potentially endless quest for knowledge. And this makes epistemic curiosity interesting and also theoretically problematic in certain aspects.

Petri (1996) proposes that motivations are about initiation, *direction* and intensity of behaviors. For example, when an animal is hungry, the drive of hunger initiates search for food and food is the direction of the searching behavior. In the case of scientific curiosity, the drive of scientific curiosity initiates exploratory behavior and the direction of exploratory behavior is certain knowledge. There is, however, the question of why we search for certain pieces of knowledge out of the infinite range of knowable items in the world. This question was raised by Berlyne (1954) as the question of *the selectivity of curiosity*. The studies about this question have been attempting to characterize the general selective tendencies or cognitive priorities of scientific curiosity. In this thesis these tendencies are called 'cognitive dynamics' and it will be attempted to offer an integrative perspective.

Statement of the Problem

In order to develop an integrative perspective on the selectivity of scientific curiosity, these theoretical problems have to be dealt with:

(1) How can the theoretical findings about the general selective tendencies of scientific curiosity be reformulated in an integrative framework?

(2) Are there cognitive dynamics that have not been defined and studied in the current literature?

(3) How can the diffuseness of children's curiosity and independence from interests be accommodated by this perspective?

(4) How do cognitive dynamics interact and what outcomes do they produce?

(5) What research agenda can such an integrative perspective offer?

Organization of the Thesis

The thesis is organized as follows. Chapter 2 is a literature review starting with a brief review of the history of the discussions in philosophy and continuing with a more detailed survey of psychological literature. In Chapter 3 the concept of scientific curiosity is delimited and defined together with a discussion of the implications of this definition for this study. In the fourth chapter, an inquiry is made into the emergence and processes of human symbolic capacity including infant declarative pointing, play behavior and language faculty. The purpose of these analyses is to reach findings about the cognitive dynamics that influence the direction of scientific curiosity. Chapter 5 focuses on children's questions and their changes through development in order to reach further findings on cognitive dynamics. Chapter 6 makes theoretical discussions about the cognitive dynamics that are defined and brings them together in an integrative framework called "the cognitive dynamics perspective to scientific curiosity". In the concluding chapter, the interactions between cognitive dynamics are discussed, proposals for future research are listed and last remarks are made.

CHAPTER 2: RESEARCH ON CURIOSITY

This chapter surveys the previous studies on curiosity. Curiosity has been of interest mainly to philosophers and psychologists. The issues raised in philosophy have been the definition of curiosity and its moral status. Psychologists, on the other hand, have been concerned mainly with categorizing types of curiosity, its motivational nature and its situational determinants.

Curiosity in Philosophy

The subject of curiosity does not have an intellectual history as intensive as other subjects such as knowledge and reason. The earliest discussions, conducted mainly by philosophers and theologians, were concerned mainly with its moral status rather than its psychological underpinnings. Blumenberg (1983) notes that the general trend of classical philosophers was to see curiosity as a virtue. Curiosity was construed as an intrinsically motivated desire for knowledge. Aristotle began his *Metaphysics* by stating that all men by nature desire to know and emphasized the intrinsic quality of this desire. Loewenstein (1994) states that Cicero defined curiosity similarly as a passion for learning. In the Middle Ages philosophers were concerned more with wonder than curiosity and appreciation of curiosity of ancient times was replaced by a critical stance. St. Augustine held that to wonder about natural phenomena distracts one's attention from God and described it as the lust of the mind. He also referred to it as ocular lust, which was later used by Freud. Curiosity underwent rehabilitation during the Enlightenment, though ambivalently. Hobbes praised curiosity to some extent and Hume made a distinction between a good and a bad variety. The good type was love of knowledge and the bad type was one that leads to inquisition of other's privacy. Loewenstein (1994) further notes that "Bentham referred to the 'appetite of curiosity,' Burke observed that curiosity 'has an appetite which is very sharp,' Kant referred to an 'appetite for knowledge' … [and] Feuerbach referred to the 'pains [resulting from an] unsatisfied knowledge drive'" (p.77). However, it is difficult to find any systematic work on the subject in the history of philosophy.

Curiosity in Psychology

Curiosity has been handled more extensively in the field of psychology. Main concerns have been categorizing types of curiosity, its motivational nature and its situational determinants.

Categorization

Like many other subjects in psychology William James set the early foundations of psychological work on curiosity. As noted by Loewenstein (1994), in *Principles of Psychology* James "distinguished between two varieties of curiosity: a more common but unnamed type that was characterized by a 'susceptibility for being excited and irritated by the mere novelty of … the environment' and a second category referred to as ‘scientific curiosity’ that was directed toward specific items of information” (p.77). This distinction is central to the discussions of curiosity. The first one is generally called novelty seeking and the second one is called specific epistemic curiosity. The second category is defined by Berlyne in his path-breaking research on curiosity beginning in the early 1950s. His four-way categorization of different types of curiosity has two axes. On the one axis there are perceptual and epistemic types. Perceptual curiosity is about the exploratory activities of animals which are often described as novelty seeking or sensation seeking behavior. Epistemic curiosity, on the other hand, refers to the motive behind the uniquely human type of exploration mediated by language. In Matthias Moch’s (1987) formulation “Berlyne defined [epistemic curiosity] as an exploration of symbolically representable contents aimed at increasing one’s knowledge” (p. 199).

The other axis of Berlyne’s categorization makes a distinction between specific and diversive curiosity. Specific curiosity refers to the desire for a specific piece of information, whereas diversive curiosity refers to a more general type of seeking stimulation. Loewenstein (1994) notes that:

> In the four-way categorization produced by these two dimensions, specific perceptual curiosity is exemplified by a monkey’s efforts to solve a puzzle, diversive perceptual curiosity is exemplified by a rat’s exploration of a maze (in both cases with no contingent rewards or punishments), specific epistemic curiosity is exemplified by scientist’s search for the solution to a problem, and diversive epistemic curiosity is exemplified by a bored teenager’s flipping among television channels (p.77).

Motivational Nature

Another issue that was extensively discussed in psychology literature is the motivational nature of curiosity. This title comprises the questions of whether curiosity is an instinct or a drive, whether it is intrinsic or extrinsic, and whether it is a primary or a secondary motivation. The task of defining the motivational nature of curiosity is difficult because there are different kinds of factors that can lead an organism to action. Fowler (1965) states that the early conceptualizations of behavior variability began with McDougall's instinct concept (p.9). In this conception, exploration was due to curiosity instinct just like food-seeking instinct. Later on instinct fell short of serving as an adequate scientific concept and the drive concept was introduced. Drives were considered as internal, biological disturbances that drove the animal into activities that restored the equilibrium of its internal state, which was subsequently labeled homeostasis (Fowler, 1965). In this conception, for example, when the animal lacks food, internal disturbances occur which stimulate it into restless activity that persists until food is obtained and the drive is sufficiently reduced. Fowler (1965) discusses this conception and notes that the homeostatic or internal drives, "which resulted from conditions of deprivation and intense stimulation, represented only part of these processes; just as important, if not more so, were those processes underlying behaviors such as curiosity, exploration, and play, behaviors that were presumably elicited by mild, external stimuli" (p.20). There is also an explanation based on the concept of boredom. According to boredom theorists stimuli that were homogenous, unchanging, and therefore monotonous induced a boredom drive that could be reduced by sensory variety (Fowler, 1965). Another position in the discussion of whether exploratory behavior is internally or externally evoked is that it is a combination of them. So, both internal states and external stimuli are at work (Berlyne, 1960; Loewenstein, 1994).

Leaving conceptual subtleties aside, a great part of curiosity studies is about the empirical observation that animals, particularly rodents and monkeys, have a motivation to orient toward novel forms of stimuli and exhibit exploratory behavior intrinsically without the presence of any goal object or condition of reinforcement. Fowler (1965) notes that:

> Collectively, the early studies on exploration achieved two ends: first, through the variety of measures and test procedures that they employed, the general and initially vague term exploration was given specific reference to such behaviors as orienting or locomoting toward, investigating, sniffing, and manipulating particular objects or patterns; secondly, the findings of these studies demonstrated that an animal would explore a stimulus object or pattern to the extent that it was novel, unfamiliar, complex, or provided a change in the animal's present or recent pattern of stimulation (p.28).

Moreover, there are common findings that an animal's exploration markedly declines over time of its exposure to novel stimuli. Therefore, the less novel and unfamiliar the stimuli are, the weaker animal's exploratory response is. As a result, although it is known that there may be extrinsic causes of exploratory behavior, there seems to be a consensus that some exploratory behaviors are intrinsically motivated.

The issue of whether curiosity is a primary or secondary motivation has also been extensively discussed. Secondary motivations are ones that derive from primary motivations. For example, Freud viewed curiosity as a derivative of sex drive. Curiosity is manifested as a result of mechanisms such as sublimation or repression. However, even if it is difficult to demonstrate curiosity's status as a primary drive, researchers mostly excluded the idea that curiosity depends on core drives such as hunger, thirst and fear (Loewenstein, 1994). Findings show that in situations where the physiological needs of animals are completely satisfied they still display exploratory behavior. On the other hand, the motivational force of curiosity can be observed in experiments where animals have to pay effort and even endure aversive sensations for the sake of novel stimuli. Mesulam (2002) not only supports this conclusion but also gives evidence from prefrontal cortex studies.

> Monkeys will work difficult in a setting where the only reward is a brief peek through a window, and human subjects who are given a choice between familiar and novel patterns will consistently spend more time viewing the latter (Buttler, 1984; Daffmer et al., 2000) In keeping with these relationships task-related prefrontal activation decreases significantly as the task becomes more familiar (Raichle at al., 1994). These aspects of frontal lobe function may help to explain why prefrontal lesions lead to apathy and also why patients with such lesions are disproportionately impaired when facing novel situations (Godefroy & Rousseaux, 1997; Daffner et al., 2000) (p.18).

An interesting finding is that when the stimulation becomes too novel in the sense of being strange, bizarre, or unexpected, it may elicit fear and reduce or even inhibit exploratory drive at least as long as the fear persists (Fowler, 1965). The relationship between curiosity and anxiety has been pointed out by many researchers. According to Loewenstein (1994) "James believed that curiosity had evolved to motivate organisms to explore their environments, whereas fear had evolved, in part, to temper the risks posed by such exploration" (p.80).

Incongruity theorists raised a similar point in terms of the relationship between incongruity and curiosity. Loewenstein (1994) notes that Piaget "postulated an inverted U-shaped discrepancy-motivation relationship. At low levels of discrepancy, he believed that new information would be assimilated effortlessly and automatically without requiring much attention or motivation. At very high levels of discrepancy, new information would be ignored because the infant would be unable to relate new stimuli to existing cognitive structures" (p.82). Therefore, although optimum levels of incongruity instigate exploratory behavior, higher levels may induce anxiety and withdrawal.

The Selectivity of Curiosity

The problem of selectivity of curiosity is discussed under the title of situational determinants of curiosity. According to incongruity theorists, curiosity is activated in case of violated expectations. According to Berlyne (1966), collative properties of external stimulus patterns such as novelty, surprisingness, complexity, incongruity, and power to induce subjective uncertainty evoke curiosity. “These are properties depending on collation or comparison of elements from past and present stimulus fields or from different portions of the present stimulus field” (p.178). And according to William James scientific curiosity arises from an inconsistency or a gap in knowledge similar to the way the musical brain responds to a discord in what it hears (Loewenstein, 1994). In *The Psychology of Curiosity*, Loewenstein (1994) proposes a new theoretical account of curiosity consistent with this idea. His information-gap theory integrates insights from Gestalt psychology, social psychology and behavioral decision theory with existing perspectives. This new account “views curiosity as a form of cognitively induced deprivation that results from the perception of a gap in one’s knowledge” (p.76). Information-gap theory incorporates the gestalt notion that human beings have a disposition to make sense of information by organizing it into coherent wholes. A theoretical concept that he introduces is curiosity as a reference-point phenomenon. If curiosity is evoked by information-gaps, one’s informational reference point is relevant, since, in Loewenstein’s (1994) words, “dissatisfaction with one's state of knowledge, like dissatisfaction with one's material condition, depends on a contrast between one's objective situation and a subjective reference point" (p.87). Some other important conclusions of his theory is that "the intensity of curiosity directed at a particular item of information should be related positively to its ability to resolve uncertainty (i.e., to close the information gap)" (p.88) and "curiosity should be positively related to one's knowledge in a particular domain" (p.89). This theory, however, does not elaborate on the totality of interacting dynamics underlying whole/gestalt creation (or composition-creation as it is preferred in this thesis), but on one specific dynamic that will be reformulated in this thesis as 'completion dynamic'. Similarly, Loewenstein (1994) refers to Shrank and Abelson who argue that curiosity arises from the desire to complete a script (p.91). However, a comprehensive account of the cognitive dynamics of scientific curiosity also needs to answer questions such as why we create scripts at all and what other dynamics are at work. Another issue that has not been studied is how the different dynamics may interact. For example, a piece of knowledge may complete a composition (gestalt, whole) and another piece of knowledge may complete one as well as eliminate an inconsistency. These two cases would have different curiosity instigating values. Another interesting issue that is relevant to curiosity research is whether the information pertaining to the core of one's meaning system induces more curiosity than information pertaining to the periphery. There are important studies in children's questions literature, yet they do not seem to be incorporated into curiosity studies. The issue of interest is also crucial for the study of curiosity. Loewenstein (1994) states that "a comprehensive theory of curiosity would need to explain why certain people become interested in certain topics and why certain topics (e.g., anything having to do with the self) are almost universally interesting" and adds that “however, the goal of constructing such a theory is extremely ambitious” (p.93). This point is quite agreeable and commonplace, yet although it is difficult to explain this phenomenon, ‘interest dynamic’ can be integrated into a comprehensive perspective in order to analyze its interactions with other cognitive dynamics that influence the direction of curiosity. Such an integrated perspective seems to be lacking in the literature.

CHAPTER 3: SCIENTIFIC CURIOSITY

This chapter delimits concept of scientific curiosity in relation to the categorizations in the literature and gives a definition that will serve as a framework for the cognitive dynamics perspective.

Delimiting Scientific Curiosity

According to William James scientific curiosity arises from an inconsistency or a gap in knowledge and he uses the analogy of the musical brain responding to a discord in what it hears (Loewenstein, 1994). Scientific curiosity as James used it falls under the category of specific epistemic curiosity within Berlyne's four-way categorization. As already noted, this category also includes expressions of curiosity that are not normally associated with intellectual activity. *The concept of scientific curiosity in this thesis is therefore delimited as a particular type of specific epistemic curiosity.* There is no intention here to make a discussion about the concept of science. And it is used as a general term that comprises all intellectual endeavors that seek systematic knowledge. Although the way James and other thinkers used the concept of scientific curiosity implies this systematic nature of knowledge seeking, the word 'systematic' is not used here in a strict sense. It does not refer to a disciplined commitment to any scientific or philosophical methodology, but refers to the natural way human mind systematizes information about an object of inquiry. Again it does not specifically refer to a scientist's or philosopher's way of rigorously systematizing knowledge, but points to a general capacity of human mind. For example, when a child picks up a strange toy out of curiosity, she naturally tries to gain information in a systematic way, meaning that she tries to find out how its parts relate to each other, figure out its mechanism, and understand what she can do with this toy and so on. Similarly children's questions about natural phenomena exhibit this systematic property. Below are some of the first questions children ask about water.

> How does water turn into ice? ; Where does the dirty water go? ; Why do I have to take a bath? ; How does the dirty water get cleaned? ; Who lives in the river? ; Do fish drink? ; How do fish stay underwater? ; Why do boats float? ; Where do rivers go? ; Why does the ocean taste salty, but rivers don't? ; Who lives in the ocean? ; Where does rain come from? ; How do my clothes dry? ; Why do I get thirsty? ; Does everything need to drink water? ; How does the water get hot? ; Is there enough water for everyone? (Ball, 1993)

These first questions about water show that children's curiosity about water is not an isolated curiosity about a single aspect of water such as its perceptual qualities, but a curiosity about a vast number of things that are related to it. These relationships include causal, functional, pragmatic, factual and other types of relationships. Children's scientific curiosity about water is, therefore, an intrinsic motivation to make sense which is, in this sense, *systematical*. As has been emphasized, this type of a curiosity is quite different from a child's wondering about whether her friend will, for example, come to the playground. This curiosity is about specific information and mediated by language as manifested in questions, yet it is not a token of scientific curiosity as it is defined in this thesis. In the same vein the questions "how does this work?" or "how does water turn into ice?" and "will she come to the playground?" are expressions of different types of curiosity. And scientific curiosity has thus been delimited as a subcategory of specific epistemic curiosity. However, it can be objected that every expression of specific epistemic curiosity can be interpreted as having this systematic quality even if it is a gossip or a single practical question. After all, it is not easy to distinguish between the scientific spirit for understanding why human beings behave the way they do and the gossiping spirit for understanding why someone did something in terms of their systematic quality. However, the connotations of the word scientific rather than specific epistemic seems to be enough for clarifying what kind of systematic endeavors are implied and therefore justifying the usage of scientific curiosity. As a result, although children and scientists are at different conceptual levels, their explorations about phenomena are motivated by the same scientific curiosity and both display a systematic aspect.

Defining Scientific Curiosity

It has been argued that scientific curiosity is an intrinsic motivation for systematically making sense of phenomena. Yet, in order to elaborate on this definition, the concept of sense-making needs to be scrutinized. Bruner's ideas (1990) about the need for sense making can be helpful in this. He says that:

> […] there are certain classes of meaning to which human beings are innately tuned and for which they actively search. Prior to language, these exist in primitive form as protolinguistic representations of the world whose full realization depends upon the cultural tool of language (p.73).

The critical point in this passage is the idea that there are classes of meaning that human beings are innately tuned and its full realization depends upon the cultural tool of language. This thesis argues that the compositional capacity of human mind, which finds its highest expression in language, is central to the understanding of how we 'make sense', and is therefore relevant to scientific curiosity. Compositional capacity is intended to refer to the open-ended human capacity to create systems of representations (or 'compositions' as it will be called) out of simpler representations.

In her study on the uniqueness of human intelligence, Spelke (2003) examines this compositional capacity and says that “natural languages provide humans with a unique system for combining flexibly the representations that they share with other animals. The resulting combinations are unique to humans and account for unique aspects of human intelligence” (p.292). These representations are unique since they transcend the limits of fixed core representations of nonhuman animals and the capacity depends on a system that allows “representations to be combined across any conceptual domains that humans can represent and to be used for any tasks that we can understand and undertake” (p.291). And, notably, “its representations are neither encapsulated nor isolated, for they are available to any explicit cognitive process” (p.291). To clarify how compositional capacity is relevant to making sense and scientific curiosity, two questions need to be asked: (1) How to characterize the combinatorial processes of composition-creation underlying ‘making sense’? (2) How do cognitive dynamics influence these processes? These questions will be elaborated in the relevant sections. For the moment, it will be continued with Ed Tronic’s experiment which sets an empirical ground for the need for making sense and its systematic aspect.

Tronic (2008) establishes a setting where the mothers hold a still face and refrain from responding to their infants and, in another experiment, their toddlers. The result was a painful experience on the side of infants and toddlers. In Tronic’s (2008) words “as the still-face continues, the infant's state of consciousness is likely to change to something like, ‘I must try to hold myself together’ and the need for making sense of the world is so great that when play is resumed after the still-face some of the toddlers ask questions that attempt to make coherent sense of what happened with the mother (‘Why didn't you talk to me?’) even though it brings back the painfulness of the experience" (p. 6). And Tronic (2008) neatly describes the need for making sense in his study.

> The link between systems theory and pleasure is provided in Jerome Bruner's beguilingly simple assertion that humans are meaning makers. As meaning making open systems, humans utilize energy to create complexly organized, coherent, integrated, and flexible states of consciousness. States of consciousness are psychobiological states that contain the private meanings individuals give to their place in the world. The meanings may be in or; more likely, out of awareness, nonetheless they function to organize and anticipate the future based on the immediate present and updated past. Paradoxically, though systems principles suggest that organisms strive to maximize the coherence of their sense of the world, the shared states that human beings seek to nourish their existence are always unpredictable and messy, and may be contradictory and incoherent. This messiness is inherent to the process of meaning making because of the many kinds of meanings to be integrated, limitations in the capacity of meaning making systems, and the many kinds of meaning making processes. […] Nonetheless, the messiness of meanings is essential; it is the ooze from which new meanings are created (p.5).

One thing to note about Tronic's words is his emphasis on the systematic aspect of meaning making which reveals itself in his usage of systems theory terminology. This systematic aspect of meaning making is inherent in the meaning of making sense and it implies a background of meanings within which a phenomenon needs to be properly located. The following sentence can be considered as an example: "*It just doesn't make sense - why would she do a thing like that?"* The background of meanings underlying this sentence can be analyzed as follows:

1. There is an unexpected phenomenon: an action of a person.
2. There is a background of images about the way this person behaves such as her character, codes of conduct, principles, habits, patterns of behavior and so on.
3. A particular behavior of this person does not fit into the knowledge schemes of the speaker.
4. This incongruity makes this particular action 'senseless'.

In such cases of inability to make sense one often craves for the missing information s/he needs to have in order to make sense of the situation. Here is another depiction of making sense by Harper (2000).

> If we had a film of a clown doing somersaults, and nothing else (i.e., we knew nothing about circuses, about the history of clowns and so on), then the film would not tell us what we need to know to make sense of what the clown was doing…One would need to know something about how they are part and parcel of circuses, and how their somersaulting is viewed [by many observers] as a kind of sentimental self-mockery (pp.244-245).

Sense-making is systematic in this sense and implies a systematic understanding of 'meaning'. Quine's model of knowledge as described by Friedman (2002) can be illuminating for such an understanding.

> Our system of knowledge, in Quine's well-known figure, should be viewed as a vast web of interconnected beliefs on which experience or sensory input impinges only along the periphery. When faced with a 'recalcitrant experience' standing in conflict with our system of beliefs we then have a choice of where to make revisions. These can be made relatively close to the periphery of the system (in which case we make a change in the relatively low-level part of natural science), but they can also – when the conflict is particularly acute and persistent, for example –affect the most abstract and general parts of science, including even the truths of logic and mathematics, lying at the centre of our system of beliefs. To be sure, such high-level beliefs at the centre of our system are relatively entrenched, in that we are relatively reluctant to revise them or give them up (as we once were in the case of Euclidean geometry, for example). Nevertheless, and this is the crucial point, absolutely none of our beliefs is forever 'immune to revision' in light of experience (p.183).

Quine's model is relevant in two aspects. First he depicts knowledge as a system with a core and periphery, second he construes this system as dynamic and subject to revisions. In the same vein, the meaning of a thing for us implies a system of meanings with a core and periphery, which is dynamic and subject to revisions. In the psychology literature, the relationship between the need for sense-making and the way human mind is predisposed to organize/order/structure/systematize meaning is emphasized by incongruity theorists such as Hebb, Piaget and Hunt and Gestalt psychologists as well as Bruner (1990). Loewenstein (1994) notes that:

> […] the incongruity theorists' notion that there is a natural human need for sense making has received broad support from diverse areas of research, although little of it was cited by incongruity theorists. As Gilovich (1991, p.9) wrote, "We are predisposed to see order, pattern, and meaning in the world, and we find randomness, chaos, and meaninglessness unsatisfying. Human nature abhors a lack of predictability and the absence of meaning" (p.83).

Gestalt psychologists have particularly stressed the motivational force of the drive toward gestalt creation as pointed out by Loewenstein (1994).

> Gestalt psychologists have been some of the most persistent advocates of the view that there is a human need for sense making. Indeed, the very notion of a gestalt reflects the fundamental human tendency to make sense of information by organizing it into coherent "wholes." More important, Gestalt psychologists have argued that the drive toward gestalt creation has motivational force (Heider, 1960; see also Suchman, 1971) (p.83).

Piaget has also articulated important ideas about the dynamic aspect of meaning-systems in his theory of development. He defined the concepts of assimilation and accommodation as mental operations that transform existing cognitive structures. Loewenstein (1994) states that:

> According to Kakar (1976, p.192), curiosity for Piaget "plays a part in the search for coherence and organization. It is a motive force in the need to order reality." Second, Piaget viewed curiosity as the product of cognitive disequilibrium evoked by the child's attempt to assimilate new information into existing cognitive structures. Such a need would naturally arise when reality diverged from expectations, pointing to the inadequacy of existing cognitive structures" (p.82).

These ideas imply that prior to information gaps and collative variables there is a more fundamental force that initiates exploration into symbolically representable contents, which means that information gaps and collative variables are only parts of the cognitive dynamics of this force. It is argued in this thesis that this fundamental force is the desire to create a system of meanings regarding a reference point in order to make sense of it. And as the creation of meaning systems is compositional in its nature, curiosity can be redefined as an intrinsic motivation for composition-creation. Four basic points about composition-creation need to be considered regarding this definition of scientific curiosity: (1) Composition-creation is a dynamic process, (2) it entails the capacities to recognize the world systematically and reproduce it symbolically, (3) the meaning systems of human beings has a core and a periphery as depicted in Quine's model of knowledge, and (4) every new piece of information explored by human beings are incorporated by the preexisting meaning systems, meaning that exploration is influenced by the totality its dynamics. These points is formulated as one basic dynamic called *compositional dynamic*, that is *the creation of and activity within a dynamic system of meanings with a core and periphery*. And this definitional dynamic is the framework within which the cognitive dynamics will be analyzed.

CHAPTER 4: SYMBOLIC CAPACITY

In this chapter the emergence and processes of symbolic capacity from infant declarative pointing to children's questions will be analyzed. Infant pointing is significant in that it gives us developmental clues about the unique way human infants engage in the objects. In play behavior it can be observed how infants bring together objects and representations of objects beginning with simple associations and then evolving into rule-governed representational structures with complicated relationships. Finally, through language and systematic recognition of visible and invisible relationships of objects and events, human mind reaches its highest capacity to systematically reproduce phenomena in symbolic forms. Humans are the only species that make drawings of objects in their natural environments. Through language humans become capable of representing phenomena in linguistic codes and resulting meaning compositions are what we need to make sense. However, as noted by Tronic (2008), the process of meaning making is inherently messy and best understood as a dynamic system. In the following analyses, it will be attempted to reach conclusions about the cognitive dynamics of this process, which can be seen as the general tendencies or priorities of cognition in the process of composition creation triggered by curiosity motivation. And they are basically about the direction of this motivation, i.e. its selectivity property.

Infant Declarative Pointing

Pointing is a gesture that has the function of directing one's attention to something. Infants begin pointing things for other persons at about 11-12 months of age

(Tomasello et al., 2007). Studies on infant pointing have mostly focused on its role in the development of language and its relation to curiosity has not been analyzed. Infants' use of their finger in order to influence others' mental states reveals important clues about the development of language. Yet, it is also important for curiosity studies in that gestural pointing also gives us clues about the infant's own subjective intentional states. Before discussing the implications of these clues, a brief theoretical introduction into the nature of infant pointing is to be made.

Major findings of the infant gestural pointing studies are that: (1) the basic function of pointing gesture is to influence others' intentional states, (2) pointing is an act of shared intentionality and joint attention (which is also called the Triangle - composed of the pointer, the recipient and the object referred to), (3) in order for a pointing act to be functional, pointer and recipients have to share a context (which is called common ground or joint attentional frame) in order to eliminate intentional ambiguity, (4) pointing requires serious 'mindreading' (Tomasello et al., 2007).

An important issue about infant pointing is the reason why the pointer wants the recipient to attend to some referent. This is particularly important for the purposes of this study in that it gives clues about infants' motives for pointing. Following Bates, Tomasello (2007) and his colleagues maintained that pointing emanates from two motives: declarative and imperative (p.18). In imperative pointing infants use pointing with an imperative intention such as requests and orders to obtain a desired object or event. In declarative pointing infant's intention is to share attention or interest about objects and events. Interestingly, apes exhibit imperative pointing but not declarative pointing (Tomasello et al., 2007). And imperative pointing emerges earlier than declarative pointing in the developmental sequence. In the literature on pointing, declarative pointing is further analyzed into two sub-types. One is expressive declaratives used for sharing emotions and attitudes about things and the other is informative declaratives used for helping others by providing them with desirable or needed information. Tomasello et al. (2007) note that:

> In the original Bates et al. (1975) formulation, proto-declarative pointing was analogous to a declarative sentence, such as "The cat is on the mat". Statements of this type have truth-values that indicate how well they fit to the true state of the world, what Searle (1995) calls a mind-to-world direction of fit. However, in many subsequent analyses, the prototype of declarative pointing is when the infant points to, for example, an interesting animal in the distance, expresses emotions, and alternates gaze to the adult. The infant is interested or excited about the new animal, and seemingly wants to share her excitement with the adult by getting him to look at it along with her and share a reaction (hopefully the same) to it. This is not much like a declarative statement with a truth-value, since its motive seems very different. We thus believe that we should distinguish between (i) declaratives as expressives, in which the infant seeks to share an attitude with an adult about a common referent, and (ii) declaratives as informatives, in which the infant seeks to provide the adult with needed or desirable information (which he currently does not have) about some referent. Experimental research has established each of these as an independent motive for infants at around their first birthdays (p.18).

Informative declaratives are observed in situations of social co-operation, where, for example, the adult needs help to find an object. In informative pointing behavior, infants show no signs of excitement for sharing emotions and attitudes about the referent object. Expressive declarative pointing, however, seems to be related to feelings of curiosity and wonder. The argument is that even though the main motive of expressive declaratives is thought to be sharing an attitude or interest with an adult, there must also be a subjective motivation for the infant for directing her attention toward a specific external entity in advance. We share things that we like and also because they are novel, interesting, different from canonical routine things we know about. Therefore, subjective motivation in a way precedes the social motivation to share as implied by Tomasello. If the intended object raised no interest in the infants, they would not point to it in order to share the sensation with others.

Actually, there are empirical results that support this view. An argument that would invalidate this view would be that the sole function of expressive declaratives is to attract the recipient's attention. In a study to test this argument, Tomasello et al. (2007) observed that the adult gives different responses to infant's pointing.

> 1) Emoting positively toward the infant without looking at the event - on the hypothesis that the infant wants adult attention and emotion to the self, a la Moore and colleagues, not attention to the referent (Face condition);
> 2) Looking to the event without looking to the infant - on the hypothesis that the infant simply wants to direct the adult's attention to the event, not share attention and interest (Event condition);
> 3) Doing nothing - on the hypothesis that the infant is pointing for the self only, or is not attempting to communicate at all (Ignore condition);
> 4) Alternating gaze between the infant and the event while emoting positively - on the hypothesis that the infant wants to direct adult attention to the referent, so that they can share attention and interest in the event together (Joint Attention condition) (p.19).

The first three conditions did not produce satisfaction in the infant, but only the joint attention condition did. Therefore, "these results specifically isolate the infants' motive to share their attitude with an adult in the expressive subtype of declarative pointing, their motive that the adult not just attend to a referent but also align with their attitude about it" (p.19).

The important point to focus on here is the subjective motivation of expressive declarative pointing. What is in external objects/events that gives excitement to an infant and turns it into something she wants to share with others? And what is its relationship to curiosity? In order to investigate these problems a closer look needs to be taken into expressive declarative pointing.

Let us consider an infant's pointing to an interesting object such as a colorful vase. The mother looks at this vase and then turns to the infant emoting positively, which in turn creates a satisfaction in the infant. In this case, what is shared is the representation of the vase. The moment the infant directs her attention to this representation, it must be evoking positive feelings and excitement, which is followed by a desire to share this representation with her mother. The first question to be asked is whether the moment the infant attends to this object and the accompanying excitement produced by its representation is an expression of specific perceptual curiosity. In expressive declarative pointing attention is oriented toward a specific object in the environment without any extrinsic purpose and therefore can be seen as an expression of specific perceptual curiosity. Yet, unlike perceptual curiosity that is shared among animals, the initial attention to the object is accompanied by the gesture of pointing. As was mentioned before, a brief peek through the window can be reinforcing for monkeys. This means that a sight can be intrinsically motivating for a monkey just like the sight of a vase can be motivating for a baby. In the case of monkey, however, the excitement is not followed by a pointing gesture and this brings to mind the question of what prevents them from doing so. The answer is not that they do not have capacity to use pointing gesture, since, as we have mentioned, they do have the capacity for imperative pointing. And it is not that apes do not have feelings of sharing, because we know that behaviors such as grooming involve socially shared feelings. And it is not that apes do not care about external entities since they show exploratory behavior even at the price of physical effort or aversive stimuli as shown in some experimental settings. It is probably a qualitative difference in their respective ways of interacting with external stimuli that makes the difference, but, for the moment, this comparison will be left aside and some further analysis of infant pointing will be made.

One thing expressive declaratives tells about curiosity is that very early in development infants develop an interest in the mental representations of external entities for no imperative/extrinsic purpose, which means that it is an intrinsically motivated behavior. The concept of mental representation is stressed because studies show that infants show pointing behavior in the absence of the referent, in which case the referent must be imagined (Tomasello et al., 2007). Therefore, expressive declarative pointing can be seen as a more abstract way of engaging in external entities. The distance between the infant and the object of interest and the way infant uses pointing as a proto-symbol for controlling the representation of the entity may be seen as a transition from perceptual curiosity to epistemic curiosity. This gesture can also be analyzed in relation to labeling. As naming can be construed as a symbolic way of pointing to things, the finger pointing of the infant can be seen as a preliminary form of asking 'what is that?' Moreover, as can be deduced from Spelke's (2003) proposal regarding fixed core representations, infants must have representations of single objects and events before they formulate what they do not know out of what they do know and the pointing gesture indicates the developmental stage where the infant can single out these proto-linguistic representations. Thus, the capacity to engage in abstract representations (proto-) symbolically for an intrinsic purpose may be a possible explanation of why apes do not exhibit expressive declarative pointing.

The last issue to be raised concerning expressive declarative pointing is that it reflects feelings of wonder more than exploratory behavior. If we were to vocalize the meaning of the gesture, it would be something like "see how beautiful/interesting that thing is!" Such a feeling about an object can be compared to a more active form of engagement through manipulation, inspection and other types of hands-on exploratory behaviors and the latter would look more relevant to curiosity. In other words, it can be asked why expressive declarative pointing is significant for curiosity when animals and human infants can already exhibit exploratory behavior that seems to be much more related. To answer this question one needs to consider in which aspects the capacity to appreciate the representation of distant but perceptually available objects may have its own merits. Piaget (1976) writes:

> A baby sucks his thumb sometimes as early as the second month, grasps objects at about four or five months, shakes them, swings them, rubs them, and finally learns to throw them and retrieve them. Such behaviors involve two poles: a pole of accommodation, since there must be adjustment of movements and perceptions to the objects, but also a pole of assimilation of things to the child's own activity, since he has no interest in the things as such, but only insofar as he finds them useful for a behavior learnt earlier or for one he is in process of acquiring (p.166).

The type of exploration depicted in this passage is a form of sensory motor adaptation to the environment and reflects a motivation of a different kind. In the passage Piaget uses the phrase 'no interest in the things as such' and argues that early in the developmental sequence children's exploratory behaviors are only adjustments of sensory and motor skills, which involve no genuine engagement in 'things as such'. It is not, however, theoretically easy to distinguish between different types of engagement. It can be thought that when a monkey kept in a dark room is craving for the sight out of the window, it is craving for exercising its perceptual skills, or its daily sensory variety intake need. And this kind of an exploratory behavior is far from appreciating the sight in a way that resembles a painter's appreciation of it or that of a child's after a certain developmental stage. In other words intrinsic exploratory behaviors of animals seem to be a limited and passive way of engagement, in that objects have meaning only as far as they are instrumental to the sensory motor adjustment needs of the animal. Expressive declarative pointing, however, resembles the uniquely human talent of pointing to stars and saying 'see how beautiful/interesting these stars are!' And the disposition and capacity to connect with objects as such seem to be central to scientific curiosity. To make further inquiry of how this disposition and capacity evolves, play behavior will be analyzed in the next section.

Play Behavior

According to some, play is pre-exercise of essential instincts (Piaget, 1976). Yet, Harcourt (1991) describes play as an activity having no immediate benefits for the animal, and which may even be costly due to an increased risk of predation during play. A cat's play with a butterfly is intrinsically motivated just like other types of play behavior. Predator animals play by chasing, pawing and biting and social animals exhibit various forms of interaction during social play and they walk, climb and rush around in locomotion play. Human infants also engage in play activity from birth. Some of the first forms of play are banging-hitting, playing with the voice and exploratory behavior such as mouthing and throwing. After about 9 months of age human infants engage in a new form of play called relational play (Lamb, 2002). And similar to expressive declarative pointing, this stage can be seen as a uniquely human way of engagement with objects and their relationships.

Relational play is important for a couple of reasons. As noted by Lamb et al. (2002):

> Objects in the environment do not play an important role in the child's play during the first 2 or 3 months of life. Three-month-olds, for instance, may coo repeatedly or kick their legs while lying awake in their cribs, or they may arch their backs and drop their bodies onto the mattress over and over again. These actions are recognizable as Piaget's *primary circular reactions* – activities apparently repeated for their own sake. Even after infants have developed manipulative skills they appear to be primarily interested in the actions they can perform rather than in the objects being manipulated. Thus, very young babies may look at a toy in their field of vision, but rarely scan systematically or study the objects they are playing with; instead they put them into their mouths immediately. Even when two objects appear next to one another – a cup and a spoon – the older infant often focuses on actions – banging the spoon in the cup – rather than on the objects. Remove the spoon, and the action is likely to continue" (p. 265).

Therefore, relational play qualitatively differs from earlier forms of exploration in that it involves a systematic way of engaging in objects and relationships between them. Here it needs to be considered what ‘systematic’ would mean in such a context. As was mentioned in discussions about the definition of scientific curiosity, a systematic relation to objects implies an ability to discern the system of relationships regarding objects and events, which will henceforth be called systems recognition.

There are three forms of relational play: relational play, functional play, functional-relational play. Lamb et al. (2002) state that “in relational play infant brings together two unrelated objects (e.g., a spoon and a block) with no indication of pretense. Functional play involves playing with an object in the way the object was intended to be played with (e.g., rolling a toy car on its wheels across the floor). Functional-relational play brings together two objects in a meaningful and appropriate way. For example, the child may take a spoon and stir it inside a cup or place blocks inside a container of some sort” (p. 265). The transition between forms of relational play indicates that the tendency to interrelate objects precedes the tendency to imitate observed patterns of relationship in the environment. This view has some implications for compositional dynamic. It has been argued that although the dynamic of ‘script-completion’ has been extensively considered in the literature, there has not been said much about why we create scripts at all. Relational play seems to give a clue. From the moment infants begin to conceive reality in a systematic way (to the extent of their conceptual level), they automatically begin to reproduce the interrelations of objects at first randomly and then within meaningful relational patterns. As the symbolic capacity develops, this intrinsically motivated activity turns into an intrinsic motivation for systematically re-producing or re-presenting reality in symbolic forms. This process resembles uniquely human behavior of making drawings of objects in that meaning compositions are like mental pictures of reality in linguistically coded systems of meaning.

Therefore, prior to a stage where certain gaps in an already constructed meaning system instigate curiosity, the process of creating relational patterns from scratch is triggered. At the beginning of this process, which is hypothesized as being the time when the infant begins to recognize the objects and events in a 'systematic' way, simply everything is a gap, therefore making the idea of information-gaps too general to be useful. Even at this stage, infants begin to combine certain conceivable parts and bits of reality which serve as relational patterns that will develop into complex meaning compositions of further stages. To analyze this process better, the development of play behavior has to be further considered.

At about 2 years of age a new form of play behavior emerges in human infants: symbolic play. Symbolic play requires the representational skill of bringing to mind objects that are physically absent. Objects may represent things that their physical qualities resemble or they may take on representations of things that have no physical resemblance such as a banana representing a telephone or a block representing a car. In pretend play, the child herself may represent something else.

The crucial point about symbolic play is that it marks a stage where the child begins to control her mental representations by using external objects as forms that contain their contents. And symbolic play activity keeps on making compositions out of these representational contents by bringing them together in novel and meaningful ways. Through the development of imaginative and conceptual skills of infants, imaginative play forms begin to occur. Imaginative play is a creative play with the representations of the world. For example, in imaginative symbolic play, the child can attribute the concepts of flying and humanness to the same imaginary construct such as a superman and make the block represent this imaginary representation. In imaginative play the child becomes the author of the worlds that she creates and goes beyond what is present to the senses and observed in the patterns of reality. This faculty broadens the possibilities of composition creation into a virtual infinity. However, as the concern of this thesis is science rather than fiction, the focus is how this capacity is used to make sense of the world rather than make up imaginary worlds.

So, what do hitherto analyses about play behavior tell about curiosity? First of all, through the development of cognitive capacities there is a progression from orienting toward single objects 'as such' as in expressive declarative pointing to constructing systems of representations as manifested in play behavior. Unlike in perceptual curiosity where the animal is engaged in direct sensory motor explorations of the world, in symbolic play behavior the child is engaged in the representations of the world in the absence of actual stimuli. This is particularly interesting in that it reflects the human capacity to systematically reproduce the world in symbolic representations. And it is by language that this systematic reproductive capacity is fully blown. The relationship between play skills and language has been discussed in the literature and, according to Lamb et al. (2002), conclusions support "an emerging consensus that language and play skills reflect one kind of underlying capacity for representation that itself emerges during late infancy" (p.275). In the next section, language faculty will be analyzed in its relevant aspects.

Language Faculty

Scientific curiosity arises from an intrinsic motivation to make sense, which is also defined as an intrinsic motivation to create a mental composition regarding a reference point of making sense. In order to elaborate on such a characterization of scientific curiosity, the linguistic medium that we use to make sense of the world and its emergence needs to be looked at. The emergence of symbolic behavior in the child in the second year of life is manifested first in infant pointing, then single words, symbolic play and then syntactic combinations of words. Around age five or six language becomes a relatively flexible representational system, by which time the child has a syntactically and semantically elaborated symbolic tool for cognition and communication. Below this process will be investigated in detail.

First words appear somewhere between 10 and 17 months of age and there is a vocabulary spurt anywhere between 13 and 25 months (DeHart et al., 2004). As in symbolic play, the capacity to name things entails the capacity to assign representations to forms which, in the case of language, are acoustic images or signs. As a result of the capacity to articulate and understand words that represent things and events, the scope of what can be pointed to others and be pointed to a person increases incomparably to gestural pointing that is dependent upon the presence of objects in the immediate environment. Through syntactic faculty, sentences can be formed and the hierarchical relationships between symbolic representations of objects, states and events can be conveyed in a systematic way. Let us take a sentence such as “Mummy is coming home. In this sentence the representation of mummy, the representation of the act of coming, the representation of time (now) and the representation of home are combined into a sentential structure where the individual representations are related to each other in a coherent and meaningful composition. The compositional capacity of human mind is not restricted to sentences and together with other cognitive capacities human mind can create increasingly complex meaning compositions.

In İnan's (2009a) words, a significant aspect of language is that "through language we can communicate our experiences to others who have not experienced them, and we can learn from others things that we have not experienced" (p.1). And this largely increases the scope of what can be learned and wondered. Moreover, by the imaginative and conceptual capacities inherent in language not only things that have not been experienced can be learned, but also things that can never be directly experienced be referred to. İnan (2009a) analyzes the way the speaker relates to the referent into two types. "One may first have an object in mind that she/he has (directly or indirectly) experienced, and use a term specifically to single out that object. Let us call such terms (relative to the speaker) ostensible terms. Or one may use a term that refers to an object that she/he does not have in mind, either because the speaker has not experienced the object or does not know to which object she/he is referring. Let us call such terms (relative to a speaker) inostensible terms" (p.4). And he (2009b) states that "given the compositional structure of our languages, we could, in principle, construct infinitely many definite descriptions that are inostensible for us, though only a small portion of them will arouse curiosity" (p.18). In other words, he describes the basic mechanism through which the human mind creates semantic compositions of what is unknown based on what s/he knows and therefore creates the possibilities of curiosity. He gives the example of Neptune, which was introduced as a concept prior to its discovery. Neptune was conceptualized as 'the planet that causes perturbations in the orbit of Uranus' as an inostensible term. Here this sentence will be analyzed in order to specify the cognitive mechanisms at work.

First of all, formation of such a sentence requires the existence of a conceptual system and a representational system that can signify concepts and syntactically combine them. The concepts that are represented in this sentence are the concept of planet, the concept of perturbation, the concept of orbit, the concept of cause and the concept of Uranus. The syntax of the phrase conveys the way these concepts are related to each other. And there are background presuppositions implied by this phrase. These are the presuppositions that there must be a cause of the perturbations in the orbit of Uranus, this cause is a planet and this planet is in the solar system. All aspects of the conceptual and informational system involved in the background can, of course, not be listed. Yet, the composition of the concept of 'the planet that causes perturbation in the orbit of Uranus' and all the other meaning systems that this expression is embedded into make possible the related curiosity, pointing to the conclusion that the compositional capacity is the source of curiosities.

To discuss this point further, it can be asked what characterizes our curiosity about, for example, the solar system? The sight of the sun, the moon and stars may be an impetus for exploration, just like the novelty of an object in the environment may be an impetus for a rodent to explore it. However, what seem to characterize our exploration of the celestial objects are not merely their sensual impressions such as color, shape, position and brightness, but their systematic meaning. What has been called systems recognition is an important aspect of human cognition and a basic capacity related to scientific curiosity. Recognizing something as a system is not only recognizing components of a whole but also the recognition of the principles that make the system work. In other words, systems recognition involves a nomological aspect. Accordingly, it is not only the marvelous appearance of reality that attracts our curious attention but also its marvelous system or structure as Einstein put it. And as noted, it is language that makes possible the exploration of the structures underlying reality in that these relationships are invisible and become an object of inquiry as a result of the compositional structure of language. Physical laws related to the solar system can be considered as an example. If human mind could not combine representations of sun, planets, movement and the concept of laws that make systems move into the mental meaning composition regarding the solar system, curiosity about which laws make the solar system work could not be instigated. Bunge (1998) notes that:

> 'Law' (or 'objective law', or 'nomic structure') designates an objective pattern of a class of facts (things, events, processes), i.e. a certain constant relation or mesh of constant relations really obtaining in nature, whether we know it or not. A law, in this sense of nomic structure, is an extraconceptual object, like the flow of a river. But, unlike the flow of a river, its laws cannot be pointed to: they are imperceptible (p. 392).

As a caution, although systems recognition and its nomological aspect finds its highest expression in scientific and philosophical activity, there is no specific reference to a scientist's way of looking at the world, but a general assumption about human cognition is being made. And this is simply something that can be observed in a child who examines the properties of a strange toy and asks "why is the red light flashing now?" This point will be elaborated in the chapter on children's question and for the moment it will be continued with compositionality.

To continue with the question of what characterizes our curiosity about the solar system, another point that is worth noting is that, we not only direct our attention toward isolated representations regarding a reference point for making sense but, as a result of systems recognition, also to things that are related to it. And compositional structure of language makes possible the expansion of meaning systems toward related meaning systems. This characteristic of scientific curiosity is discussed by İnan (2006).

> For instance suppose I am curious about why dinosaurs became extinct. Even if I value being curious more than I value learning or acquiring knowledge, I could still be motivated to find the answer to my question, as long as I believe that my inquiry into the subject would bring about new questions that would allow me to be curious. Suppose my research leads me to believe that dinosaurs became extinct because of a meteorite shower that took place millions of years ago. Now even if I am no longer curious about why dinosaurs became extinct, now I could be curious about what caused the meteorite shower, whether it will happen again, why the meteorite shower ended some forms of life but not others on earth etc. By satisfying my curiosity, I may end up being curious about more things than before (pp.17-18).

Schmitt and Lahroodi (2008) call this property 'tenacity of curiosity'. And similar to İnan, they evaluate this property in terms of its epistemic value.

> It is a contingent fact that typical states of curiosity have what we will call tenacity. That is, for a typical state of curiosity whether p, one has more than a desire to know whether p; one is also disposed to be curious about issues related to p. Of course, for any state of curiosity whether p, one will tend to desire to know q if one thinks that knowing q is necessary for or likely to facilitate knowing p. If one is curious whether gold dissolves in aqua regia, and one thinks that to find out it will help to know whether silver dissolves in the same acid, then one will desire to know the latter. This follows simply from the fact that curiosity whether p entails desiring to know whether p (together with the fact that desiring anything tends to make one desire what one thinks to be instrumental to it) (p.137).

Tenacity, in this sense, is related to compositional dynamic. As curiosity can be delineated as a desire for creating compositional systems of meanings (rather than isolated representations) regarding a reference point, even a single 'marvelous' clue (appearance of the sun) can trigger a whole reaction of curiosities which in the end of centuries of scientific work turns into a great composition about the solar system. Information-gap perspective, which emphasizes the point where we crave for completing the picture, does not take into account cases where a single piece of information creates a wave of excitement and suddenly immerses one into a new realm of research. In many such cases, only psychological factors such as willingness to step onto unknown territories may be a need for the expression of curiosity, rather than background knowledge or familiarity with the subject. Interestingly, similar conceptual mechanisms are at work when curiosity is instigated from scratch and by information-gaps. To take the example of Neptune, as the curious person takes ‘solar system’ as a reference-point for making sense, she naturally tends to imagine possible scenarios to fill the conceptual gap caused by the perturbations in the orbit of Uranus. In this particular case, the curiosity might increase due to the possibility of finding a new planet, since the number of planets is significant information for completing the picture (or composition) about the solar system. Basically, all theoretical endeavors have such a motive of completing the picture regarding a reference point (e.g. solar system). Many have proven to be wrong and many have been proven like in the case of the discovery of Neptune.

The moment the very first dinosaur fossils were found in the history of science, however, can be given as an example of starting from scratch. Although the first ‘dragon-seekers’ had no background knowledge about these dragon fossils, the amount of curiosity instigated in these people and myriad of questions that have rushed into their minds are not difficult to imagine. This would be a case where one does not need to know much, to know that there is so much curious unknown about a subject. And the conceptual baggage makes possible the anticipation of so much curious ‘unknown’ that this may even be a greater source of curiosity than learning the last planet in the solar system. Here Quine’s system of knowledge and its relationship to compositional dynamic should be emphasized. Inspired by Quine’s model of knowledge, compositional dynamic has been defined in this thesis as the creation of and activity within a dynamic system of meanings with a core and periphery. In order to understand the cognitive dynamics of curiosity instigated by first dragon fossils, this compositional system needs to be taken into consideration. In this case, for example, the curiosity-instigating value of the first fossil findings is related to the whole scientific narrative about the paleontological history or our general knowledge about what kind of beasts can inhabit the earth. When these meaning systems are shattered in the core, this makes a greater sensation and excitement than something like finding a new variation of a well-known species which would only affect the periphery. This dynamic of scientific curiosity is called 'hierarchical dynamic' and will be considered in the following chapters.

As noted earlier, compositional dynamic can help understand the cognitive dynamics of scientific curiosity. For example, a person may be curious about the concept of curiosity. Curiosity is a concept about a psychological phenomenon and our exploration of this concept is carried out in the abstract realm of our system of meanings. What can be obtained in the end is a better structured mental composition about the concept of curiosity. But what triggers such a curiosity? The conditions may vary. Berlyne (1954) asks the question of selectivity of curiosity: "Why does an individual seek or learn one piece of information rather than another?" (p. 181) And he examines the role of conceptual conflict in inducing curiosity. According to Berlyne et al. (1966), conceptual conflict "is most often due to collative properties of external stimulus patterns, for example, novelty, surprisingness, complexity, incongruity, and power to induce subjective uncertainty. These are properties depending on collation or comparison of elements from past and present stimulus fields or from different portions of the present stimulus field" (p. 178). The definition of 'to collate' is to gather information together, examine it carefully, and compare it with other information to find any differences. Therefore, collative dynamic of curiosity works when there is a meaning system to which newly gathered information is compared. However, to repeat the point once more, this explanation does not include all cases of curiosity. Why was there interest in the topic in the beginning? This question is discussed from other angles in the psychological literature on interest. Renninger et al. (1991) note that there are two conceptualizations: individual interest as disposition and individual interest as actualized state (p.7). Dispositional interests are about relatively enduring characteristics or general orientations. Studies have concentrated more on actualized states of interest.

> Such actualized interest is believed to arise out of an interaction between internal and external conditions. According to Hidi and Baird (1986, 1988), two sources are involved: the person, with his or her characteristics, attitudes, and general situation, which contains the special stimuli and conditions for an interested engagement. However, it should be noted that the situation-specific sources that can elicit interest include not only the characteristics of the object of interest (e.g., the content of a text), but other factors as well, such as the instructional design that fosters interest. Likewise, a person's social relationships (e.g., peers, teachers, role models) can influence the emergence of interest (p.8).

Although researchers on interest make some distinctions between curiosity and interest studies, they mostly overlap in their problems and arguments. However, the above quotation adds a dimension to the topic of instigators of curiosity such as the role of a person's social relationships and the content-specific text characteristics.

> Both situational interest and specific curiosity are, in some ways, motivational states that encourage a person to interact with the environment in order to acquire new information. In addition, situational interest and specific curiosity are strongly influenced by environmental factors, some of which are common to both (e.g., novelty). Although the two concepts are clearly similar, Hidi and Anderson suggest a number of points on which the concepts differ, the most important of which are: (a) situational interest can be elicited not only by collative variables, but by content-specific text characteristics, and (b) situational interest may develop into relatively enduring individual interests (Renninger et al., p. 9).

Interest studies point to some new factors in their explanations about the instigators of curiosity. For example, a subject totally unknown to a person such as supernovas can raise interest in a class environment, where in the beginning the person gets bored from the subject of the class and then develop an interest towards the end. What triggers such a curiosity is not incongruous information since the person has no previous mental schemes about what kind of stars can inhabit the universe or any other set of beliefs to collate this new information. So, where will collative variables be located in such cases? It can be said that supernovas are a novelty for this person and novelty is the collative variable. But what does it mean? Does it mean that everything we do not know is a novelty and therefore potentially curiosity inducing? It sounds odd but this possibility needs to be considered. If this idea is true, then children must be extremely curious since everything is a novelty for them, which is generally true. This conclusion implies that the ultimate reference point of curiosity, i.e. reference point for what we want to know, is 'everything'. However, there are cognitive, psychological and sociocultural constraints that limit this potential such as intelligence, memory, time; personal dispositions, preferences, other concerns of life, willingness for strenuous mental activity and determination to endure stress induced by inability to structure thought, to eliminate inconsistency and to fill knowledge gaps; educational opportunities, encouraging educational environment and familial attitudes regarding curiosity. In this thesis, however, the interest is not cognitive, psychological, sociocultural constraints that inhibit curiosity, but how the motivation takes direction (as a result of cognitive dynamics) when triggered. These dynamics have been mentioned in the discussions so far, but before bringing them together in an integrative framework, an inquiry into the question asking behavior of children will be made.

CHAPTER 5: CHILDREN'S QUESTIONS

Children are notorious for asking too many questions. Sometimes whys and hows of children can be overwhelming for adults. Yet, questions have an important function in child's cognitive development and, therefore, have been subject of many studies. Children's spontaneous questions are also important in that they are manifestations of curiosity and an important source that gives information about its dynamics in the developmental sequence. In this chapter, conclusions of these studies will be evaluated in their relevant aspects to the cognitive dynamics of scientific curiosity.

In Berlyne and Frommer's (1966) formulation "questioning is a form of *epistemic behavior,* that is, behavior directed toward, and reinforced by, acquisition of knowledge [and] it is motivated primarily by *epistemic curiosity,* conceived as a condition of high drive or arousal induced by *conceptual conflict"* (p.178). As has been discussed, 'conceptual conflict' refers to collative properties of external stimulus patterns such as novelty, surprisingness, complexity, incongruity, and power to induce subjective uncertainty. Experimentation with children provides some confirmation for the curiosity-inducing effect of collative variables, as manifested by questioning (Berlyne & Frommer, 1966).

> The two experiments provide evidence that certain collative variables, namely, novelty, incongruity, and surprisingness, make children more inclined to ask questions, confirming expectations derived from Berlyne's (1954 a; 1954 b; 1960; 1963; 1965) theory of epistemic curiosity. On the other hand, no significant effect of amount of information or of uncertainty was found. It is quite likely that the degrees of difference in these variables represented by our stimulus items were too subtle for the Ss to be responsive to them (p.187).

Berlyne and Frommer (1966) also found indications that sensitivity to gaps in information increases with increasing age and questions are more effectively formulated toward relieving uncertainty (p.188). In another study on children's questions experimenters established a setting where kindergarten children were allowed to play with three familiar and a new toy and encouraged to ask questions to the experimenters. The new toy was a green wooden box with levers. The relationship between lever movements and effects was randomly changed every 1 to 5 minutes in order to induce conceptual conflict. Moch (1987) notes that as predicted by Berlyne's theory, "the informational questions refer largely to that object that was new and unfamiliar to the children" (p.208). This experiment can be analyzed in terms of the concept of systems recognition, which is the recognition of phenomena as a system of principle-based relationships. When systems recognition comes together with 'interest-based orientation' to a certain phenomenon, a desire for making sense of the phenomenon is induced. In this case, as the children can recognize the toy as a system and as this toy falls within their 'interests', they seek to figure out its mechanism. And its unusual patterns of causality induce conceptual curiosity. On the other hand, there is a shifting ratio of explanation vs. fact questions as age increases. Between 3;1 and 4;0 there are 21 explanation (such as: why is the red light flashing now?) and 52 fact questions (such as: where is the switch?); between 4;1 and 5;0 there are 33 explanation and 37 fact questions; and between 5;1 and 6;0 there are 36 explanation vs. 24 fact questions (Moch, 1987). In Chouinard's (2007) comprehensive study on children's questions, the relationship between factual and explanatory questions has been analyzed more extensively. Yet, before coming to her findings about this particular topic, the general perspective of the study needs to be given. She basically asks the question of how the process of asking questions builds up knowledge work. The model Chouinard (2007) offers is as follows.

> The child is engaged with something, and brings an existing conceptual structure to the situation. […] a conceptual structure is defined as some area of knowledge, such as a concept, category or domain, that consists of both particular facts (pieces of information, possibly learned in isolation, possibly

> even by rote memorization), and explanatory/predictive core principles that unite those facts and make predictions about them and the concept/category/domain in question. The child encounters some problem (i.e., incomplete knowledge, or a gap in knowledge; some contradiction in expectation or knowledge already in place; ambiguous information or circumstances), and this leads to a state of disequilibrium. This state motivates the child to ask a question to get information that can resolve the problem at hand. The response that the child receives gives information about which direction the knowledge state should now be pointed toward; the answer itself shows the child how to revise/reorganize the structure, or which new knowledge structure should be used as a replacement. This information is applied to the current knowledge structure, which is revised in light of new information, whether that revision is just to add information that was missing (enrichment, sometimes referred to as the simple accumulation of facts/knowledge) or to reconceptualize the knowledge state in some way (conceptual reorganization, which involves a new organization of the conceptual structure, primarily through its explanatory core principles). The child then proceeds with the new knowledge structure, and sees how this works out (p.4).

Chouinard's model basically overlaps with the dynamic meaning system as has been discussed in this thesis in relation to compositional dynamic and it is also similar in that she tries to understand question evoking dynamics in relation to this model. This Piagetian model with its emphasis on explanatory 'core' principles helps identify the hierarchical dynamic of curiosity that was offered in the previous chapter. Chouinard (2007) makes three different studies for analyzing question-asking behaviors of children. One is an analysis of the CHILDES database based on naturally occurring, longitudinally collected and spontaneous questions and responses of children aged 1;2-5;2 years. Second is a diary study of children's questions. The questions in this study were recorded across a broad range of situations and sixty-eight children between the ages of 1;0 and 5;0 years participated. A feature of the second study is that it also takes into account questions of younger infants via gestures, expressions, and vocalizations such as a 1-year-old infant picking up an unfamiliar kiwi fruit from a packet of groceries and vocalizing 'uh?', which is interpreted as asking 'what is that?'. The third experiment is designed to analyze questions that children ask about a specific domain, which, in this case, is the domain of animals. Some of the common findings of these studies can be summarized as follows.

1) The majority of questions asked by children are information-seeking in all age groups and, therefore, the main function of children's questions is acquiring information.
2) The majority of children's informational questions at all ages are fact questions. However, as the children get older the number of explanatory questions increase and also within a single exchange there is a shift from factual information to explanatory principles at all age groups.
3) Children ask more questions about biological information when engaged with animals than in other settings. This implies that when the opportunity is present, children's curiosity about this domain is revealed (Chouinard, 2007).

Similar findings regarding the transition from facts to explanatory questions were found in previous studies. As noted by Davis (1932), Sully, for example, proposes two categories of questions: (1) thirst for fact (what, how old, where, who, naming), (2) reason and cause (why), beginning at two, but most frequent from three to four years. And Davis (1932) also mentions the study of Stern where he describes two ages of questions, the naming period, reached in the second half of the second year, and the three to four year stage of when and why, directed mainly toward justification of commands and the desire to know.

The emphasis on 'thirst for fact' and 'naming' is important for several reasons. Firstly, it may be interpreted as an indication that the child has a general curiosity about her environment and wants to connect to it by naming the objects and collecting factual data. Notably, early words of children have a tendency to be bound to the specific contexts in which they are learned. Around the time of vocabulary spurt (about 18-months) children begin to use words to refer to categories of objects, events and people. This is interpreted as the development of a conception that ‘everything has a name’ (DeHart et al., 2004). And with this conception there comes the period when the toddler begins to ask incessantly, “What that?” It is worth noting that the conception of question asking as a way of requesting information seems to provide a channel for curiosity through which inflation in naming occurs. Similarly, as the children’s conceptual development proceeds they begin to use questioning for requesting explanatory information more frequently.

However, the relationship between factual vs. explanatory questions is not straightforward. Chouinard’s (2007) study show that in a single exchange where the child asks a sequence of questions built on each other, there is a significant direction of passage from factual to explanatory questions (p. 51). On the other hand, as demonstrated by Berlyne and Frommer’s study (1966) types of requested information can vary according to the category of the stimuli.

> In Category D (surprisingness), the tendency for Plus items to elicit more explanatory than factual questions became significantly more marked with increasing age. In all categories, few children asked explanatory yes-no questions, which require not merely the formation of a hypothesis but the formation of an explanatory hypothesis. Such questions were found to an appreciable extent only among grade 5 children when faced with the Plus items in Category D, that is, the surprising magic tricks. Significantly more explanations than facts were sought in Category D and significantly more facts than explanations when facts were conspicuously lacking, that is, in Category B (amount of information) and Category C (uncertainty) (p.188).

In this study Plus items refer to the stimuli that are high in collative variables. For example, in Category D in which the collative variable of ‘surprisingness’ was tested, Plus items include things such as magical tricks and Minus items include things that resemble the procedure of magical tricks with no surprising outcomes. Berlyne’s point about explanatory yes-no questions is also worth mentioning.

As early as gestural pointing, children display the capacity for mindreading. In the case of pointing they can influence others' intentional states by pointing to objects and events and infants know that recipients can understand their intentions. In the case of naming, the question 'what that' can be interpreted as a request for the information of how a specific object is named by the recipient of the question. In other words, questions of such kind imply the infant's conception that everything has a name in the mind of others. This is related to what Loewenstein calls curiosity as a reference-point phenomenon. The child realizes that others know the name of everything and this realization is also the realization of her lack of knowledge about the names of many things. Similarly, when the child realizes that others know about 'whatness, whyness, howness etc.' of phenomena, she begins to ask questions triggered by her recognition of her ignorance. To formulate a question such as "why is the red light flashing now?" the child has to be aware that things have causes (the concept of whyness) and others might know them. However, not all questions are answered by adults. If children keep on asking questions whether they are answered or not, then there must be a deeper conception that every question has a potential answer regardless of someone knowing it. Interestingly, in some studies (Moch, 1987) that compare fact vs. explanatory questions of children the amount of explanatory questions relatively decrease at around ages 6;1-7;5. The reason may be that children at that age can form hypotheses about the problem at hand, which also can be an explanation of the higher occurrence of explanatory yes-no questions in older children. At these ages, children ask relatively more questions for the confirmation of their hypothesis than specific interrogations (i.e., questions beginning with interrogative adverbs, such as "what," "where," "when," "why"). However, it can also be hypothesized that the ability of children to hypothesize about a domain is related to its complexity as a problem and to the amount of knowledge the child has about the problem. In other words, the children can hypothesize about a toy or a magic trick, but we would not expect them to ask more yes-no questions about issues that are above their conceptual level. In the next section, the conclusions of discussions hitherto will be integrated into an approach labeled as the cognitive dynamics perspective to scientific curiosity.

CHAPTER 6: COGNITIVE DYNAMICS

In this thesis scientific curiosity has been delimited as a particular type of specific epistemic curiosity and defined as an intrinsic motivation for ‘systematically’ making sense of phenomena. This definition has further been analyzed and reformulated according to the compositional dynamic, which is the creation of and activity within a system of meanings with a core and periphery. This principle is proposed to be fundamental to the understanding of cognitive dynamics of scientific curiosity in that ‘composition-creation’ is the way human intelligence makes sense of phenomena systematically. It has been discussed in this thesis that from the earliest stages of the emergence of symbolic capacity, humans engage in the representation of objects and events as such and recognize them systematically. And when systems recognition regarding an ‘interesting’ domain comes together with an intrinsic motivation to systematically make sense of this domain, human mind is directed toward symbolically re-producing the system in a meaningful composition. Meaningful compositions (micro-compositions) that human mind creates are embedded in higher compositions (macro-compositions) the totality of which constitutes the entire meaning system of the individual. Compositional dynamic has therefore been defined not only as ‘the creation of’ but also ‘activity within’ a dynamic system of meanings and it is the fundamental dynamic of curiosity. It has also been hypothesized that the ultimate ‘reference point’ of compositional dynamic is potentially ‘everything’. When scientific curiosity is directed toward a particular reference point, the process of composition creation is triggered and there are cognitive (sub) dynamics that influence its course. These cognitive dynamics are interest dynamic, expansion dynamic, completion dynamic, hierarchical dynamic and perfection dynamic. Interest dynamic is about how interests influence the direction of curiosity. Expansion dynamic is a result of the tenacity property of curiosity (İnan, 2006; Schmitt & Lahroodi, 2008), which is an expansion of curiosity toward related system of meanings. Information gap filling, which was theorized by Loewenstein (1994), has been called completion dynamic. The direction of curiosity from factual information to explanatory core principles has been called hierarchical dynamic. And finally collative variables of Berlyne will be discussed under perfection dynamic and other dynamics that have been mentioned. These dynamics are assumed to explain the general trends of this process. However, the interactions between these dynamics are also important for an integrative understanding of the direction of curiosity.

Compositional dynamic

Most of the analysis of the emergence and processes of symbolic capacity has been devoted to understanding this dynamic. Very early on in the developmental sequence, human infants develop the capacity to engage in the objects in the environment. It has been discussed in this thesis is that this engagement is not motivated solely by sensory-motor adaptation to the environment but is an engagement in the objects as such. Then the emergence of symbolic capacity in children is delineated as the emergence of a capacity to recognize objects systematically and reproduce systematic representations of the world in symbolic forms, which finds its highest expression in language. And the compositional capacity of the human mind has been elaborated since it makes possible the creation of (dynamic) systems of meanings out of simpler meaning units. These dynamic systems are depicted as having core and periphery based on Quine’s model of knowledge. At the core there are explanatory principles and core concepts. In the periphery there is factual information and details. If scientific curiosity is an intrinsic motivation for systematically making sense of phenomena, then it is hypothesized in this thesis that the fundamental direction of the motivation of scientific curiosity is the creation of a system of meanings the ultimate reference point of which is 'everything'. As this creation is a process, it is better described as a 'dynamic' system of meanings. As a result of this developmental dynamic the creation of new meaning is influenced by the preexisting state of the meaning system. Therefore, compositional dynamic is not only the creation of but also activity within a system of meanings. Finally, although the ultimate reference point of scientific curiosity is hypothetically 'everything', in reality there are cognitive, psychological and sociocultural constraints that limit the scope of what can be known. Cognitive dynamics are general tendencies of human cognition that influence the selections of scientific curiosity. Therefore, the complete formulation of what has been called 'compositional dynamic' is the creation of and *activity within* a dynamic system of meanings with a core and periphery the ultimate reference point of which is *potentially* everything. Cognitive dynamics of scientific curiosity can be seen as subdynamics of this fundamental dynamic. They are the general priorities of human cognition in the process of constructing its ultimate system of meanings given its constraints.

Cognitive dynamics perspective to scientific curiosity attempts to give an integrative account of the direction of curiosity. And its fundamental compositional dynamic implies that given infinite time and ideal conditions an ideally curious person is intrinsically motivated to make sense of everything. This assumption, of course, does not hold in the real world and various constraints mentioned above limit curiosity. However, this assumption explains a characteristic of curiosity called ‘independence from interest’ by Schmitt and Lahroodi. Schmitt and Lahroodi (2008) have proposed three basic assumptions about curiosity.

> First, curiosity is tenacious: curiosity whether a proposition is true leads to curiosity about related issues, thereby deepening our knowledge. Second, it is to some extent biased in favor of topics in which we already have a practical or epistemic interest. Third, and most important, curiosity is largely independent of our interests: it fixes our attention on objects in which we have no antecedent interest, thereby broadening our knowledge (p. 125).

The first two propositions have been discussed and will be further discussed in the sections on cognitive dynamics. The third proposition, on the other hand, is related to compositional dynamic. It claims that there is a dynamic of curiosity which is independent of practical and epistemic interests. Practical interests are extrinsic or instrumental motivations to know and they have not been included into the definition of scientific curiosity. Epistemic interests, however, correspond to cognitive dynamics and are included into its definition. Schmitt and Lahroodi (2008) define epistemic interest as follows.

> [Epistemic interest] is a desire to contribute to an epistemically estimable distribution of knowledge, where what it is for a distribution to be epistemically estimable is determined by cognitive and not merely by practical considerations (we drop ‘‘epistemically’’ and speak of ‘‘estimable distribution’’ from here on in). We need take no stand in this article on what knowledge is, or on which cognitive considerations — quantity of content, coherence, explanatory power, and the like — define an estimable distribution (p.129).

The fact that things can instigate curiosity regardless of interest or other cognitive priorities support the assumption that at the most fundamental level human curiosity is ‘potentially’ directed toward making sense of everything. And at certain occasions this potentiality reveals itself by bypassing all practical and epistemic interests and being curiously drawn by any ‘thing’. It also reveals itself more often in people who are acknowledged as ‘curious’ characters. What characterizes these people is not only curiosity *about* particular things that they are interested in, but a general curiosity about potentially everything. Although these people may have priorities as to what they inquire, a friend's chat about the intricacies of IT sector and its increasingly complex technologies can give immense pleasure to them regardless of their being familiar with the topic or having any idea about it. It is often that 'curious' personalities request relationships that involve intensive information exchange and they do not miss occasions which can contribute to their knowledge. Children are good examples of such a general curiosity. It is assumed by the cognitive dynamics perspective that the cognitive dynamics that bias curiosity is not as effective in children as it is in adults and this relative unbiasedness is the reason why children ask questions about "everything under the sun" (Bonhivert et al., 1989). A reason for that may be that epistemic interests become salient after a certain amount of general information about the world is acquired. In a way, general curiosity about 'everything' provides children with general contextual knowledge about the world within which particular epistemic interests can be properly located. This idea is congruent with Berlyne and Frommer's (1966) finding that that "sensitivity to gaps in information increases with increasing age and questions are more effectively formulated toward relieving uncertainty" (p.188). As scientific curiosity has been defined as an intrinsic motivation to 'make sense', to use a literary metaphor, in the developmental sequence of composition creation, context precedes the text. And to continue with the metaphor, when the child begins to recognize the world as a system (set of correlated objects, facts, phenomena), his/her curiosity is directed toward creating a general but superficial contextual outline of her desired mental composition about the world. This is one of the points that has been presented as a criticism to information-gap perspective, since this salient aspect of observed child curiosity shows that there is a fundamental dynamic of curiosity which cannot be explained by familiarity with a subject or closing information-gaps. If viewed from the perspective of information gap theory, some of children's questions would look extremely random and unpredictable. And it would be also difficult to accommodate cases where adults are curious independent of their interests.

In the following sections, the specific cognitive dynamics of curiosity will be discussed starting with interest dynamic, which is a prevalent and effective dynamic of scientific curiosity.

Interest Dynamic

Interests are obviously very influential in determining the direction of our curiosities. Some people show strong interest in very specific things such as bugs or pigeons. People who have stronger interest in cars are expected to spend more time and energy in acquiring information about cars than someone who has interest in motorcycles. Similarly, these people would presumably select information about cars if asked to choose between information about cars and motorcycles. It is easier to understand extrinsic interests such as being interested in issues about one's profession, yet it seems to be more difficult to understand why people are intrinsically interested in particular things. The difficulty of the problem may be because of the plentitude of potential situational and dispositional factors such as culture, education, socialization, age and sex. These problems are being discussed in the psychology of interest. The concern of this thesis is, however, not to delineate these factors, but to characterize the influence of interest dynamic on curiosity.

At the most fundamental level, the direction of compositional dynamic is potentially everything. However, our actual curiosities are about particular things. If the most general direction of scientific curiosity is called macro-compositional, particular directions are (relatively) micro-compositional. Interests (extrinsic and intrinsic alike) have specializing effect on curiosity and therefore direct curiosity toward micro-compositions. There are countless natural beings that are potentially curiosity instigating. Yet, a person may have a specific interest in trees. If s/he develops curiosity about her/his interest, s/he will desire to acquire general information in order to make sense of what a tree is. After having acquired general contextual information that is satisfying enough for this particular person, her/his interests would further specialize what s/he wants to learn about trees. For example, one person may be interested in the taxonomy of trees and another person may be interested in their general biological mechanisms. In a way, interests can be construed as strategic preferences made in the face of limitations. If these limitations are about the amount of curiosity, then the elimination of limitations out of curiosity (time, opportunity, source) would not lead to the expansion of curiosity. If it is due to factors external to curiosity, then curiosity would tend to expand toward related issues. This dynamic will be discussed in the next section.

Expansion Dynamic

Even if a person is curious about everything, s/he has to make preferences as to what to learn first. Interest dynamic defines these preferences. Expansion dynamic, on the other hand, refers to the tendency for expanding knowledge to the related domains of knowledge. To use the terminology that has been preferred in this thesis, the intrinsic motivation for systematically making sense of phenomena tends to expand toward related meaning systems leading to the expansion of the meaning composition regarding a reference point. This expansion can be in various directions. A person who is curious about trees can expand her/his curiosity toward birds that are symbiotic with trees (micro-to-micro expansion), forest ecology (micro-to-macro expansion), or barks of the trees (macro-to-micro expansion). The expansion can also be within a composition (intra-compositional expansion). In intra-compositional expansion, the expansion of knowledge is toward completing the knowledge regarding a reference point. Intra-compositional expansion will be discussed under completion dynamic.

Completion Dynamic

Completion dynamic is one of the most studied dynamics of scientific curiosity. Loewenstein's (1994) study that follows William James's ideas and some of its important results have been mentioned before. Actually, the basic proposition of his theory was already mentioned by Berlyne in a passage where he gives the possible answers of different schools of thought to the question of the selectivity of curiosity. Berlyne (1954) states that:

> Although the Gestalt psychologists have not produced a systematic account of curiosity, it is not difficult to guess how such an account would go. They explain much of behavior by the 'principle of closure', the tendency to act in such a way as to close a 'gap', whether in a perceived figure or in some other aspect of the 'behavioural world' (Koffka, 1935; Wertheimer, 1945). It is evident that curiosity consists precisely of a drive to fill in such gaps in the subject's experienced representations. But again, we have no definition precise enough to tell us infallibly what will constitute a 'gap', nor which gaps will have precedence over others (p. 181).

Although Berlyne's remark is critical, Loewenstein (1994) managed to develop this idea into a perspective with some predictable results. Two particularly fundamental implications of the information-gap perspective are that "the intensity of curiosity directed at a particular item of information should be related positively to its ability to resolve uncertainty (i.e., to close the information gap)" and "curiosity should be positively related to one's knowledge in a particular domain" (p.89). Cognitive dynamics perspective incorporates these findings under the name of completion dynamic. And according to this framework completion dynamic is an intra-compositional expansion of knowledge regarding a reference point of making sense. However, as has been discussed, meaning compositions have a core and periphery. Therefore, completion dynamic can be analyzed in two types: (1) completion to the periphery and (2) completion to the core. The former refers to cases where the new information adds to the factual body of knowledge and the latter refers to the cases where the new information adds to the core concepts/principles that unify the facts. The selection among core vs. periphery has been named hierarchical dynamic and will be discussed in the next section.

Hierarchical Dynamic

Evidence from children's questions show that there is a relative increase in questions pertaining to core principles and concepts with age and there is a similar trend toward asking questions about the core concepts/principles within a single exchange when the children ask a sequence of questions built upon each other. As a result of general observation, it can be argued that satiation with factual knowledge may increase the motivation for understanding the core principles that unite these facts. In the history of science, scientists have always wondered about the factual aspects of information about planets in the solar system as well as the principles that keep them moving regularly. And it is not easy to state which kind of information would instigate more curiosity in someone who has no background knowledge about the solar system. However, the attempts to explain the principle about the movements of the solar system are historically so significant that they became the names of scientific revolutions.

Hierarchical dynamic is apparently one of the strongest and most pervasive dynamics of curiosity. For example, it would not be expected from a normal person to wonder about how many leaves a tree has (unless there is a peculiar reason for that), but if the person is interested in the leaves of a particular tree, it can perfectly be an interest in the type of the leaves, its structure, so on. Similarly, when a cosmologist takes Andromeda galaxy as a reference point for making sense, s/he would not be expected to be curious about the number of craters of the planets in this galaxy. It would be more likely that this scientist would be curious about whether there are earth-like planets or something of a similar kind if the curiosity is specifically about planets in this galaxy. In most general terms hierarchical dynamic can be explained in terms of concepts/principles vs. factual information. However, factual information can also be classified as core factual information vs. peripheral factual information. Peripheral factual information can be very 'useless' details regarding a reference point. A person who is curious about ant ecosystem may wonder about the average population of ants in a particular location, yet it would not be expected that the same person desires to know the exact number. Actually, it would not, of course, be out of line to know the exact number in this case, yet the effort regarding such a task would seem too much for what it is worth. On the other hand, in many cases peripheral factual information would have no meaning at all. For example, one can be curious about an author, but information about what his/her mother liked to eat would be useless. However, sometimes information about minute factual details – such as what kind of books his/her mother read to her when s/he was a child – can be as significant and stimulating as a core principle. The contextual significance that a piece of otherwise insignificant information takes can be well understood in terms of compositional dynamic in that scientific curiosity *acts within* a system of meanings that influences the curiosity instigating value of the new input. As in the example of first dragon seekers, information about a single detail can act as the missing link in a grand theory. If there is no such intelligible reason for gaining significance, an anomaly regarding hierarchical dynamic may be an autistic symptom. In some types of autism patients memorize every minute detail about something very specific in a way no normal person would do. As a result hierarchical dynamic can be considered as a general selective tendency toward relatively core principles/concepts/facts unless peripheral information is contextually significant. In the next section, perfection dynamic, which is a selection toward information that brings about better structure to meaning systems, will be discussed.

Perfection Dynamic

Perfection dynamic is the cognitive tendency to eliminate inconsistencies in its meaning structure. However, perfection dynamic is not limited to the selection for coherence, although this point is more emphasized in the literature. A person may have a set of facts regarding a reference point and these facts may have inconsistencies. It is expected that a piece of information that eliminate these inconsistencies would be selected if there was a choice among this information and some other information about the same reference point without such an effect. Yet, there are many ways for a meaning system (or a composition) to be imperfect. For example, there may be a perfectly coherent set of facts regarding a reference point, but these may all be wrong. In these cases, the incongruity of the new data with the existing meaning system would instigate curiosity as argued by incongruity theorists (Loewenstein, 1994) and Berlyne (1966). In the psychology literature, the criterion of perfection regarding a meaning composition is often expressed as the ability to assimilate new information into existing cognitive structures (Loewenstein, 1994). One's knowledge about the solar system is more perfect if it can assimilate new information. The discovery of Neptune can be given as an example. The existing knowledge system tends to incorporate the new information about the perturbations in the orbit of Uranus, and therefore to eliminate the inconsistency imposed by the incongruent information. In such a case, perfection dynamic is related to completion dynamic. After all, completion can sometimes be a criterion of perfection. However, perfection dynamic is not the same as completion dynamic. For example, if there are two pieces of information that complete distinct gaps in a composition and one of them has inconsistency eliminating effect whereas the other has not, they would have different influences on the selection process.

CONCLUSION

The cognitive dynamics perspective has so far defined the general cognitive tendencies that influence the selectivity of scientific curiosity. One of the aims of this perspective is to investigate the interactions between dynamics, which is a subject that seems to be lacking in the literature. The basic compositional dynamic has been defined as a definitional framework within which these interactions can be situated. In this chapter these interactions will be discussed beginning with the relationship between novelty and compositional dynamic. In the final section, there will be proposals for future research based on the cognitive dynamics perspective.

Interactions among Cognitive Dynamics

A basic aspect of scientific curiosity is its direction toward novelty. As a result of compositional dynamic, scientific curiosity is potentially directed toward making sense of everything. However, there are countless opportunities of acquiring information about something novel that are deliberately missed. The reason is that there are certain limitations to curiosity which also limit compositional dynamic. Yet, when there is a choice between something familiar and novel, there is a selection toward the novel, therefore confirming the existence of this dynamic. In each selection, however, there are interacting cognitive dynamics involved in the process. When a curious person spontaneously wants to explore something as a result of a general undirected feeling, compositional dynamic is activated. The first dynamic that influences this process would be interest dynamic. Let us imagine that this person preferred to read about subject A and after reading three books s/he still has not lost her/his curiosity about the subject. The person has to make a preference about whether to expand her/his knowledge to related areas (such as subject B which is related to subject A) or to keep reading about subject A in order to complete or perfect her/his knowledge. S/he may prefer to read one more book about subject A, yet if s/he was asked whether s/he would like to read two more books about subject A, or one about A and one about B, the same person might prefer the second offer. Therefore, similar to interest dynamic, there are many situational and dispositional factors that determine the relative influence of differing cognitive dynamics on person's preferences. Some people who are 'perfectionist' and highly focused in their interests would be more likely to complete and perfect their knowledge regarding a specific subject. Others may suffice with general information about some domain and not care much about whether what they know is coherent and well structured. However, even for such a person, if there is a selection among two pieces of information one of which is critical for the coherence of the meaning system regarding a domain and one of which is a piece of ordinary information, the selection would be influenced by perfection dynamic. Similarly, the influence of hierarchical dynamic would be different in different people. Some people are by disposition core-oriented theorists and some are fact-collectors. Yet, although there are dispositional differences, the influence of hierarchical dynamic is pervasive. Even if a person is fact-collector, there is a standard of what s/he would call a significant fact.

An issue worth noting about the interaction among cognitive dynamics is peculiar types of conflict among them. Let us imagine a child who believes that the world is flat. Her/his composition about the shape of the world would be incomplete if s/he keeps thinking why the people at the edges do not fall down. A friend can tell her/him that these people do not fall down because there is a wall at the end of the edges. This would complete her/his composition about the shape of the world but be as imperfect as it is. S/he may be happy with his complete composition about the shape of the world, until one day s/he begins to wonder whether she would fall down if s/he dug enough. If an adult who does not know what else s/he believes about the shape of the world says that this is not possible, this would instigate a curiosity in the child, and s/he would presumably ask 'why?' This why may be a result of her/his reluctance to give up her/his composition and she may keep on selecting information that can help her/him find a way to justify her/his reasoning rather than attending to other interpretations about the shape of the earth. Therefore, someone who thinks that his knowledge about a certain domain is complete may eliminate the influence of perfection dynamic regarding that domain.

Future Research

A conspicuous property of the cognitive dynamics perspective to scientific curiosity is that it attempts to give an internal mentalistic account of the selectivity property of curiosity. It is assumed that human mind has some cognitive tendencies that influence the selectivity of scientific curiosity. It has also been assumed that given infinite time and ideal conditions an ideally curious person is intrinsically motivated to make sense of everything as a result of the basic compositional dynamic. These two assumptions imply that cognitive dynamics are about the preferences human mind makes in the face of constraints and limitations. It has also been stated that cognitive dynamics perspective only attempts to delineate the general tendencies of the selection process. The difficulty of giving a deterministic account of what humans are curious about is obvious. However, similar to economics, it is possible to establish a theoretical language about preferences regarding scientific curiosity. As a part of such an endeavor, this thesis has attempted to integrate the general cognitive tendencies that influence scientific curiosity into the cognitive dynamics perspective. This framework needs further investigation and support from empirical research on curiosity. Below are some proposals for a future research agenda.

1) There are studies on children's questions, which investigate the changes in the percentage of explanatory vs. factual questions by age (Chouinard, 2007). There is information about how sensitivity for information gaps increase by age (Berlyne, 1966). Research can be made on the influence of each cognitive dynamic on children. For example, younger children seem to be characteristically less influenced by completion dynamic. What are the relative influences of other dynamics on children's scientific curiosity?
2) Experimental settings about the selectivity of curiosity can be enriched by assigning the cognitive dynamics introduced in this thesis – expansion dynamic and hierarchical dynamic – as variables to be tested both individually and in their interactions. There can also be settings where the relative influence of different dynamics is measured and compared. These studies can be made both with children and adults.
3) Novel experimental settings other than questions can be designed that can measure the influence of cognitive dynamics on preferences both in children and adults. Below is a proposal for an experimental setting.
    a. Short reading materials (cards) regarding a specific phenomenon such as dinosaurs are prepared.
    b. General contextual information about the phenomenon is given.

c. Readings are classified. Some of them are about completing the subject, some of them about eliminating an inconsistency, some of them are about related issues.

d. Further classifications are made such as dividing readings that have the function of completing the subject into two subclasses in order to measure the influence of hierarchical dynamic: (1) completion regarding the principles that explain the phenomenon at hand and (2) completion regarding significant facts about the phenomenon.

e. The results can be evaluated in terms of both (1) differences in choices among individuals and (2) the changes in the preferences of each individual. Regarding the second evaluation the subject can be told that certain cards are about particular aspects of the subject and others are about related subjects. It can be measured how particular preferences shift in relation to the satiation level of the subject. For example, s/he may be asked to choose among two groups, where in one group there are 5 cards about the subject and in another group there are 3 cards about the subject (dinosaurs) and 2 about related issues (how they went extinct). What would happen if the numbers change (4 to 1; 2 to 3; 1 to 4) and how can the differences in preference be interpreted?

f. To further observe the interaction of interest dynamic and expansion dynamic in children, there can also be cards that are only distantly related to the issue at hand such as cards about comets which are the probable cause of the extinction of dinosaurs.

g. It is expected that the experimental setting offered here would give results similar to experiments on children's questions. For example, it would be expected that children's preferences would display a tendency from cards about factual information (e.g. certain dinosaurs have sharp teeth) toward explanatory principles regarding the subject (e.g. why do dinosaurs have sharp teeth?). And it needs to be explained, if there are contradictory results.
h. A similar experiment can be made with younger children using cards with pictures or by verbally communicating the classified narratives about the subject. Imaginary beings can be introduced in order to eliminate preexisting interest in the subject such as the creatures of 'kurioks' and their world. This imaginary world can be designed in a way that it can give insights into the children's desire to make sense of the systematic relationships of this world. The design can include incongruent patterns. For example, in this world children give birth to their parents, they cry when they are having fun and there is a tree which makes children do somersaults when they pass nearby.

4) Pervasiveness of hierarchical dynamic would be a significant area of research. This research can define anomalies of hierarchical dynamic such as autistic levels of seeking peripheral information. Similar research can be done to see whether other cognitive dynamics can be used for diagnosing other anomalies of cognition. For example, an anomaly in

expansion dynamic may lead to obsessive information on a particular topic and an unusual lack of interest in related topics. Research can be done to see whether there are such cases.

5) Finally the cognitive dynamics of scientific curiosity can be individually evaluated in terms of their epistemic value so that they may give insights as to the educational policy.

Final Remarks

Research on scientific curiosity is significant for the field of cognitive science in that it is an area where research on intrinsic motivation and cognition come together. Therefore, an account of scientific curiosity motivation has to incorporate studies on human cognition. Moreover many of the issues related to the subject require the cooperation of fields ranging from perception to epistemology and therefore making its study intellectually even more stimulating. The significance of the area is not only due to its interdisciplinary aspect, but also due to its importance for our understanding of what makes humans unique. All these points considered, the lack of due interest in the area becomes even more surprising. It is hoped that interest in this subject will increase and the meaning of scientific curiosity will be better understood.

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