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DOMAIN-SPECIFIC INCREASES IN STAGE OF PERFORMANCE IN A COMPLETE THEORY OF THE EVOLUTION OF HUMAN INTELLIGENCE

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The evolution of humans required performing increasingly hierarchically complex tasks within multiple domains. Hierarchical complexity increases task by task. Tasks occur within, and differ by, determinable domains, their stages of performance measurable using the Model of Hierarchical Complexity. How well one performs within single and multiple domains is considered to indicate intelligence. Original task-initiation is more difficult than imitational learning and can create new domains. Levels of support reduce task difficulty, increasing performance. Task-performance may be generalized to other domains. Stages of developing tools and empathy are presented to demonstrate domains' roles in the evolution of human intelligence.

KEYWORDS: Domain, domain-specificity, evolution, hierarchical complexity, generalization, human intelligence, levels of support.

The purpose of this article is to propose an essential component for a complete theory of the evolution of human intelligence. That component is domain-specific increases in the hierarchical complexity of tasks performed. It distinguishes two categories of new tasks. One includes new tasks learned with or without support, which are novel to the individual but not novel to the species. The other includes those that involve change in performance in species-novel tasks. The development of new domains is marked by introducing novel areas of activity in such a way as this. We consider the understanding of these relationships to be vital to a

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postformal theory of the evolution of human intelligence. We also propose a relationship between domain-specificity, hierarchical complexity, and difficulty of generalizing learning in one domain to tasks in other domains.

The concept of domain-specificity and other elements are introduced in what follows. To illustrate the connection between evolution and domain-specific stage change in human behavior, we present a comparison of tasks of increasing stage of hierarchical complexity in two different domains: early tool making and empathy. Such orderings according to the Model of Hierarchical Complexity indicate where and why there exist both similarities and differences in animal–human comparisons of intelligence.

DOMAIN SPECIFICITY

The concept of domains is discussed in the Mascolo article (this issue) and applied both therein and throughout this special issue. The concept of domains represents an abstract analytical notion at the same time it represents a practical evolutionary function. The functional dimension underlies the concept of domain-specificity discussed here. For example, in animals performing at low stages, each evolutionary task is controlled by separate neural systems: reproduction, species recognition, mate selection, foraging, locomotion, and so on. Domain-specificity serves additional functions in animals performing at higher stages. For example, the survival of Homo Sapiens depended on increasing the hierarchical complexity of tasks performed to generate heat for personal warmth in cold climates and to construct shelters for weather protection. These are two discrete domains that are functional to survival. Each involves very different concepts and task-actions. If the domain-specific stages of task performances had not increased in hierarchical complexity, Homo Sapiens might not have survived in certain climates when its body hair disappeared.

The first question to address is how a new domain of human activity comes about. We propose it results naturally from human interactions with the environment that set up contingencies to which humans respond to meet their concrete needs. It also involves hierarchically complex novel ways to do so. For example, fires triggered by lightening strikes left hot coals or embers as they died down. The heat generated from fire is obvious, depending on proximity. We assume early methods of intentionally generating heat from fire involved placing dried plant growth or wood materials close to or on the embers, making the flames continue or reappear. The concept of deliberately burning materials this way possibly developed "by accident," as one made observations. For example, a breeze may have blown dried leaves onto an ember and flames resulted. To place leaves on an ember for this purpose would score at Preoperational stage 6. By the time early humans began to carry hot coals with them in order to start a fire for heat at a different location, the stage of the task increased to Concrete stage 8, where tools are carried consistently (see Table 1). The name we would give to this domain is *preserving fire-starting materials*. It does not involve tasks to create fire or other heat in any novel way, but uses what naturally occurs like a tool in this specific domain. This preserving fire domain's

Table 1
Evolutionary Comparison of Two Domains

Orders of Hierarchical Complexity	Stages of Tool-Making[a]	Stages of Empathy in Humans[b] (Affect and Actions)
1 Sensory or Motor Actions	Look at stones, touch, or hold a stone. Each of these actions is done singly and not combined with other actions.	Reflex reactions, e.g., lower distress, comfort with comforting stimuli, elicited smiles (Field, 1989). Reflexive imitation: stick out tongue, open mouth (Meltzoff and Moore, 1977). Emotional contagion: Cry when other infants cry (Hoffman, 1978).
2 Circular sensori-motor actions	Look, reach, and grab a stone. Bang a stone by accident on another stone.	Coordinate parent's emotion cues and own behavior. Adjust behavior, e.g., watch for facial expressions of a stranger (Boccia and Campos, 1989). Avoid others' aversive emotions: turn away; suppress ongoing activity, do alternative activity.
3 Sensory-motor	Bang a stone into another stone or other objects, both singly and in combination. Use simple concepts such as bashing a nut with a stone. Classify perceptually.	Couple motor and emotional actions, match intensity of expressions when imitating. Recognize emotional disparity of different people. Console with pat, hug, or concerned look. Compare own emotional response to caretaker's; base own response to stranger upon caretaker's.
4 Nominal	Bash one stone on the other, coordinating the strike to hit near the immediately previous strike. Create successive modifications nonsystematically, different on any dimension. Act on named concepts seen in acts.	Name and associate feelings (e.g., happy, sad) with familiar entities, events, or images. Infant respond with distressed look to adult who looks sad, then offer to adult infant's beloved doll; go to get own mother to comfort crying friend (Hoffman, 1978). React emotionally to distress, anger of family members (Zahn-Waxler, Radke-Yarrow, and King, 1979).
5 Sentential	Hit one stone with the other in a constant direction of movement (each strike at the stone is done in relation to the previous one). Make Mode I tools (Wynn, 1981, 1993) requiring few bangs.	Simple sequences of empathic interactions limited to egocentric helping (e.g., console crying infant). Talk about cause and effect, reflect on cause, actor, action, outcome. Relieve guilt by reparation or evasion (Kuczynski, Kochanska, Radke-Yarrow, and Girnius-Brown, 1987; Zahn-Waxler and Kochanska, 1988). Play-act, feign pretense.

(Continued on next page)

Table 1
Evolutionary Comparison of Two Domains *(Continued)*

Orders of Hierarchical Complexity	Stages of Tool-Making[a]	Stages of Empathy in Humans[b] (Affect and Actions)
6 Pre-operational	Do a sequenced set of things after another sequence to the same tool. Focus on only one aspect, e.g., to bash edges or just produce flakes.	Empathize with story characters. Confuse the real and imaginary; act on mistaken beliefs. Empathy based on cultural message about context (e.g., which kind of animal may be killed). Narrate to integrate situations, context, and cues to infer what an emotion indicates.
7 Primary	Use beginning symmetry or constant spatial amount in early Mode II tools (Wynn, 1981, 1993). Continue the tool-making work until the task is finished.	Match feelings toward the sufferer to sufferer's reality, empathize with another's situation (if it is familiar or perceptible), but not coordinate the actions (feelings are more one's own than matched to other person's feelings aroused in the situation, e.g., "Me too-isms.").
8 Concrete	Make one part of a tool then attach it to another part (e.g., an arrowhead to a stick). Coordinate two separate reversible actions. Carry and store tools consistently.	Describe feelings as inferred directly from others' expressions and linked to specific situation. Understand another's motives and feelings in terms of one's own in a similar situation. State preferences of others and values of things, acts. Coordinate how one feels now and in the same concrete (past) situation and what helped.
9 Abstract	Use standard unit of measure to achieve symmetry. More precisely apply constant spatial amount. Follow peer social norms (Wynn, 1993) for uniform tools. Use variables to consider effects, i.e., points, edges from dull to sharp; varying shapes.	Identify degrees of feelings and suffering along a continuum as states or moods inside the person expressed externally, and understand they can be in conflict (Selman, 1980). Generalize feelings, situations without logically linking generalizations. View feeling as normative: "This is how people feel in a situation like this." Try to help in various nonsystematic ways.

(Continued on next page)

Table 1
Evolutionary Comparison of Two Domains *(Continued)*

Orders of Hierarchical Complexity	Stages of Tool-Making[a]	Stages of Empathy in Humans[b] (Affect and Actions)
10 Formal	Make and use specialized tools for different applications. Make instant decisions about which tool to use in which situation.	Link suffering, moods, expressions, and situational variables; ask how people feel in a given situation. Aware that feelings influence immediate perspectives or perceptions. Imagine self in another's position and situation and sympathize.
11 Systematic	Develop new tools systematically for different situations (problem finding). Adapt to available materials for best tool to function in the situation.	Organize feelings and expressions into systems in each person. See self as impartial, although caring reflector of other's states and perspective. Moderate empathic responses by standing in the hierarchy of the sufferer, i.e., context influences empathetic response.
12 Metasystematic	Compare two systems each with sets of causal relationships for making tools. Find how systematic causal relations interact.	Coordinate congruent disparate emotions, know some systems of emotions conflict with other systems (e.g., personal survival, social justice). Construct and base actions on universal principles of caring, suffering.
13 Paradigmatic	—	See that caring, justice, and survival systems or varieties of conflicting concerns cannot be fully integrated; identify failure to find universal principles for empathy.

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order of hierarchical complexity may end at the Concrete order without further increases.

New domains related to heat production have developed. One example is *forced combustion*, as in furnaces. Bernholt, Parchmann, and Commons (2008) are showing that tasks in the forced combustion domain may require performance at Systematic stage 11. Another example is the domain of *originating heat for home comfort*, a different domain that has considerably developed. The domain-specific tasks may have begun with striking rocks together in a tool-making process, from which a spark ignited nearby materials. Performances in this specific domain have developed into distribution systems for natural hot water radiation (e.g., in Iceland), forced air furnaces using combustion, and solar heating, among others. A Stage 12 metasystem was produced when private residences used solar electric power generating systems and the unused electricity generated at the residence was measured and credited to the residence's account. This extra electricity was routed into the power grid maintained by the electric utility and distributed to the larger customer base (another system). The solar generating system consisted of a number of relationships—angling the panels to face the sun, taking the direct current and changing it into a 60 Hz, 120 volt alternating current system. The power distribution system is extremely complex in itself, with transformers, switches, load balancers, networks, and so on. This indicates the domain of electric power distribution can operate at Metasystematic stage 12.

The development of new domains is marked by introducing novel areas of activity in such ways as this. Such changes are evolutionary by (a) creating new domains of endeavor to which intelligence is applied, (b) the increasing of stage of performance of domain-specific tasks, and (c) the resulting changes in environmental conditions. The latter, in turn, enable or demand additional increases in stage of performance and/or the development of new domains to solve new problems. With the speed of change worldwide since the mid-20th century in particular, such changes have resulted in humans producing many novel domains (Collis 2001, as cited in Mascolo, this issue).

THE SUPPORT DIMENSION OF INCREASINGLY DIFFICULT TASK PERFORMANCE

To understand the demands of performing a task at any stage of hierarchical complexity, it is important to make distinctions in the environmental circumstances that do or do not support an individual's task-performance. Support exists when one uses already-existing methods to perform a task for the first time, either by imitating others or being instructed and learning it (for more discussion of the concept of levels of support, including more levels, see "Cultural Progress is the Result of Developmental Level of Support," this issue). This is called one level of support (Fischer, Hand, and Russell, 1984) expressed as "+1." Two levels of support, "+2," is when one is being instructed and learning it. Zero levels of support, "0," is occurs when performance of a task is developed on one's own, figuring it out for oneself and getting it "right" on one's own. This is another common way individuals learn how to do tasks that are new to them. This was the level studied by Piaget (Inhelder and Piaget, 1958). One negative level of support, "–1," is when one has to discover the problem and possibly new methods without support (Arlin, 1975, 1984). Discovering new methods is inventive, and distinguished from performing a task already performed by others. Each decreasing level of support makes a task's performance more difficult. The evolution of human intelligence involves performing tasks at 0 and –1 levels of support. The following discussion indicates why, and puts more flesh on this introduction of the concept of levels of support.

Wolfsont (2002) assisted students in increasing their performance in specific domains of interest to them. He used the strategy of providing the least amount of support that worked. This resulted in improvement in their performance such that they likely (a) could not make these improvements on their own or could not do so in a timely and effort-efficient manner, (b) perform more independently of further support from others and do so more efficiently without a need for excessive practice or effort, and (c) generalized their performance to other tasks and perhaps to higher stages if needed. In contrast, excessive support, such as instructing the specific solution to the task in a step-by-step fashion, might result in an improved, more complex performance at the risk of very limited generalization and independence in performing in the future. If generalization is to take place, it will more likely require a great deal of practice and effort on the part of the student. Anecdotal data suggest that this is what happens frequently in special education programs for students with learning disabilities. This may be a fruitful area for research.

Wolfsont's optimal support strategy involves collaboratively guiding students through a dialectical learning process in a single session. The process results in improved performances that are easily generalized. Wolfsont uses questions and models physical activities to scaffold and draw out general abilities and then prompts the student to combine these abilities. For example, he assists students to actively coordinate figure with ground for "figure-ground perception," and to actively coordinate perceiving with mentally imaging (a transforming object) for "dynamic mental imagery." Then he prompts the student to combine these "figure-ground perception" and "dynamic mental imagery" abilities—to the level of complexity needed to solve the student's task at hand (e.g., to understand how to find lost computer disks easily and quickly). The student then succeeds independently at the task. Subsequently, the student reflects on the experience to discover and articulate the effective strategy, which can then be used indefinitely. Throughout this process, the facilitator encourages the students to challenge and support themselves. The facilitation also involves helping students to be in an optimal learning/motivational state in order to actively engage in this entire procedure. In all, this might be called a "facilitated personal growth" process. It uses multiple levels of support in a strategically designed metasystem. In the aforementioned example, this ranges from +1 with assisting in the "figure-ground" concepts, to 0 for a general performance or skill to where the student has to solve the task on her own, to –1 where the student has to reflect on the experience and explain the successful strategy that she hit on and could use for long-term application (i.e., generalize from the experience).

GENERALIZING FROM EXPERIENCE

The more that learning is able to be generalized from an increased stage of performance in one domain to increased stage of performance in other domains, the more that individual's intelligence evolves. This is because, for example, more classes may be formed out of concrete variables (Abstract stage 9), more formal relations among abstract concepts may be developed (Formal stage 10), or more relations among formal logics (Systematic stage 11) or more systems of such systematic relations (Metasystematic stage 12) may be coordinated during the task of generalization. For example, Kitchener, King, and DeLuca (2006, p. 83) situate at Metasystematic stage 12 the "ability to make abstract generalizations about inquiry from multiple instances of participating in the inquiry process."

Transferring stage of performance from one task sequence to another, or from one domain to another, is a special case of transfer of training. This kind of activity has been called transfer of training (e.g., Thorndike and Woodworth, 1901), learning transfer (e.g., Ford, Weissbein, Smith, Gully, and Salas, 1998), and generalization in learning (e.g., McKeough, Lupart, and Marini, 1995). We assume the capacity to generalize from experience to be among the tasks involved in domain-specific increases of stage of performance. There is almost no such transfer in animals at Sensory-motor stage 3 or below. These in turn have characterized the evolution of human intelligence and the development of new domains. Whether originating in serendipity or problem-solving tasks, the creation of a new domain involves some transfer or combinations of transfer from familiar domains. All of this involves learning. However, the "*connection* between development and learning in adulthood" has had little focus to date (Merriam and Clark, 2006, p. 83, emphasis in the original; also see Hoare, 2006). Further, and "perhaps most importantly, there is considerable confusion concerning extent of transfer of learning. One fundamental difficulty is that little agreement exists on how to define *task* and *domain* and no standard classification scheme exists for splitting up tasks into domains" (Marini and Genereau, 1995, p. 5, emphasis in the original). We believe this article's discussions shed light on both.

We consider the roles of these concepts in humans' capacity to generalize from experience. The following points would apply to individual and species-wide intelligence. They may clarify some of the limits as well as the utility of generalizing learning from one domain to another. Domain-specific increases in complexity provide more opportunities for generalization. This is because at each stage, there are more prior stages comprised of previous tasks to coordinate, and hence more opportunities. At the same time, there are inherent difficulties with such generalization (Marini and Genereau, 1995; Thorndike and Woodworth, 1901). Different domains have different tasks, contexts, and overall purposes.

We suspect this involves three types of "transfer" of performance to tasks that have some similarity. First, there would be "simple" generalization within the same domain and stage of hierarchical complexity. For example, at Nominal stage 4 of tool-making (see Table 1), one may generalize from one stone to another if they act the same way in use (e.g., find through actions that different softer stones may be used in the same way). This is a form of horizontal complexity. Second, there are known increases in stage within domains, e.g., progress from Nominal stage 4 to Sentential stage 5, creating Mode I tools (Table 1). The task performer, either independently or with support, solves a more complex type of problem. This likely has more potential to significantly increase the utility and/or efficiency of the work done in that domain—by individuals and potentially the species. The latter is an evolutionary and "revolutionary" change: an increase in stage of hierarchical complexity. Finally, we hypothesize that there can be a second type of horizontal complexity in the form of generalization from one domain to a second one. This could represent or support increases in complexity in the second domain. However they are instantiated, such increases in stage of performance in multiple domains are related to conceptions of general intelligence.

How people generalize from one domain to another is an under-examined area that would benefit from research using the Model of Hierarchical Complexity's precision to define and measure tasks and domain-specific increases in performance. This is the Model's contribution to a general theory of the evolution of human intelligence, to which we now turn in earnest.

THE EVOLUTION OF HUMAN INTELLIGENCE

The Model of Hierarchical Complexity indicates that the roles of symbol and language in forming abstract variables are instrumental in the evolutionary leap from the ape family and early hominids to Homo Sapiens. The measurable leap is that between tasks performed at Concrete stage 8 and those performed at Abstract stage 9. This seems to account for the development of human intelligence that exceeds animal intelligence.

To understand this leap requires a closer look at the hierarchical complexity of tasks at the Concrete and Abstract stages, because there is a task barrier against animals performing actions at the Abstract stage 9 (Commons and Miller, 2004). At the Concrete stage 8, task-actions involve coordinating a small number of specific, concrete "things." Such things include other animals or people, places, and events. Each of these must be actually seen or otherwise concretely known about. At the Abstract stage, the tasks involve coordinating large to indefinitely sized sets of things, places, and events. Classes of such concrete variables are formulated by abstracting from large numbers of concrete variables. Thus, there are no concrete instances to view for many of these indefinitely large sets, and therefore these sets are represented by abstract variables.

For example, a group of animals that lives together is made up of specific individuals, from the perspective of each animal. Each animal may be aware that there are some other occurrences of individual animals that behave in connection with more individuals if they have seen them, for example, if they are in competition for food or territory. But the animals see only individuals that behave in connection with more individuals. They may have a concept for "group" because they can see the group(s). But they cannot form the abstract concept of "the family." To do so requires first knowing there are many such groups, seen and unseen. At minimum, it also requires coordinating the group concept with additional concepts. These include knowing that individuals remain part of the family group even if they do not physically live with the other members, as well as recognizing and coordinating mating, births of children, and different ages of members. Such Concrete stage 8 variables as these are required to conceive and classify groups that may be called family groups. This is an Abstract stage 9 task.

Thus, at the Abstract order of hierarchical complexity, for the first time, the value of variables can refer to hypothetical things that do not exist concretely enough to point to or see. Instead, conceptual abstractions are involved. Once one starts using such abstract variables, one needs to develop abstract symbols, such as words, to label those variables. Only humans, thus far, have shown the capacity for creating and using such arbitrary symbols.

THE EVOLUTION OF HUMAN INTELLIGENCE IN TWO DOMAINS

The universality of the Model of Hierarchical Complexity has been employed in ordering problem-solving tasks in a number of domains (see “Introduction to the Model of Hierarchical Complexity,” this issue). This should be particularly useful in attempts to reconstruct the past without the archeological records that could more thoroughly inform us. Two vastly different domains are presented here to emphasize the place of domains in evolution: tool-making and empathy. The domain of empathy is given further discussion to underscore the role of giving nuanced attention to how domains and their development may be conceived.

Examples of Two Domains

Table 1 offers an evolutionary comparison of tool-making and empathy. The sequences in the tool-making column specify the developmental stage from the earliest tool-related behaviors seen in animals including apes and early hominids. The empathy sequences are based on research with humans. As indicated in “Toward a Cross-Species Measure of General Intelligence,” in this issue, chimpanzees solve social (e.g., empathy) and tool-making problems up to and including the Concrete stage 8. Both of these domains have proven important to human survival and evolution, for example, tool-making to provide food and shelter, and empathy to enable enduring mating relationship, parent–child caretaking, and cooperative social interactions.

Discussion of the Empathy Domain

The notion of empathy implicitly embeds the notion of *perspective-taking*. When perspective-taking is discussed in relation to another person or persons, it involves role taking, for example, walking in another’s shoes regarding an actual situation or a hypothetical situation. Role-taking may or may not involve emotions. Social perspective-taking has been analyzed by others (e.g., Commons and Rodriguez, 1990; Selman, 1980). Our discussion here, however, is on the development of empathy, which we treat as having a narrower scope because it involves an emotional dimension. We also distinguish it from the evolutionarily relevant domain of spatial perspectives. Such tasks would help a person to travel to and from unfamiliar places (e.g., be able to coordinate how, and that, it looks different on the way back but way-finding is possible nonetheless), or to find prey at the same time one avoids predators (e.g., hiding behind bushes). Such tasks are limited to imagining oneself in different situations and times, as well as coordinating objects from different perspectives and the information available in those situations. In discussing empathy, the component that makes it a classifiable domain is the coordination of the emotions involved. Hierarchical complexity may offer an additional lens for considering Goleman's (1995) emotional intelligence, of which empathy is a part.

The development of empathy involves an increasing coordination of one's own feelings and perceptions in relation to another's actual or inferred feeling and emotions. In a simple form, this involves how one feels at time_1before an event, how one feels about the event once it happens or its possibility is introduced (time_2), processing information about what task seems called for in light of another's feelings in the event's circumstance, and responding with an action of some kind (time_3). This means coordinating one's emotional (re-)actions and perspective-taking on another's emotional (re-)actions. It involves how different people (or the same person at different times demonstrating different needs, moods, etc.) respond emotionally in different situations and how to infer this. This is coordinating emotional skills/complexity and perspective-taking skills/complexity to construct "emotional perspective-taking" or "empathy." At the higher stages of empathy, more perspective-taking complexity is involved at the same time as is more emotional complexity.

The evolutionary survival value of higher stages of empathy seems to come into play when: (a) other people respond very differently from ourselves, (b) do not communicate in the same language or clearly to us, (c) are emoting in situations that are unfamiliar to us, (d) express emotions in incongruent ways so we get "mixed messages," or that we perceive as threatening to us (so that we are defensive rather than empathic), (e) and where it is very important to read their emotions accurately in order to care for them, for example. The demands of coordinating emotions vary. For example, it is difficult to be sympathetic when angry, hence vengeance rather than compassion may be prevalent. With low stages of empathy, people are considered defective, either criminal or mentally ill. They engage in behavior that gets them into trouble because it appears to others that the person does not care about others. Also, groups of hominids that had greater empathy had great social cohesiveness. They had higher rates of survival during hard times including war because they would take care of each other and protect each other. This included taking care of the young of people who did not survive.

To coordinate information about emotions, one needs to de-center from one's own immediate emotional reactions and environment, and imagine what it would be like to be the other and be in their situations. At the Metasystematic stage 12 of empathy, one may find it to be sobering and forgiveness-inducing to realize one could be in anyone else's skin and situation. By contrast, there would be less need for empathy skills—or much emotion, for that matter—if we (a) were all literal in our communication, (b) expressed our needs directly and clearly to others so that they did not need to infer them from our behaviors, (c) if we were all clones of one another, and (d) if we lived in rigid, highly ritualized societies where other people were easily expendable. In reality, though, one person's empathetic actions in relation to another has beneficial evolutionary impacts much in demand in today's world. We would argue that postformal stages of empathy are becoming more valuable, if not essential, as we evolve into a highly interdependent world of diverse cultures that interact to greater degrees than heretofore, for better or worse, and employ powerful tools in the process.

CONCLUSION

Our thesis is that domain-specific increases in stage of performance account for the evolution of human intelligence, and that this explanation is an essential part of a complete theory of evolution. We have confined our scope to human intelligence without including biological, sociocultural, and geophysical dimensions. This scope enabled us to focus on the concept of domain-specificity and how new domains emerge by the performance of novel tasks. That focus, in turn, provided context to introduce several related notions: levels of support, difficulty in performing new tasks at increasing stages of hierarchical complexity, and generalization. Accomplishing new tasks contributes to the development of individuals with the species at times and the development of society as a whole. By presenting the stages of development in two separate domains that can be shown to be related, we documented the role of domain-specific increases in stage of hierarchical complexity in human evolution. A complete theory of development and evolution requires the inclusion of such domain-specific stage changes.

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