Formalization of Cognitive Continuity/Discon., to Settle the Darwin’s-Mistake Debate

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Introduction
Darwin’s (1859) Origin doesn’t discuss the evolution of the human mind. He saved treatment of this topic for the subsequent Descent of Man (1897), in which he advanced two claims:

1. If the cognitive powers of nonhuman animals are discontinuous with those possessed by humans, then the human mind must the product of evolution by mutation and natural selection.
2. The cognitive powers of nonhuman animals, including specifically reasoning powers, are continuous with those enjoyed by humans; continuity is established.

Bringsjord, Holyoak, and Fossevi (2008) have written “Darwin’s Mistake,” in which they purport to refute C2 by establishing discontinuity (they don’t in this paper affirm C1). Many vehemently disagree with PHP (witness the commentaries on PHP’s target BRS paper, and the debate remains intense, and unresolved. Yet, if the hitherto informal concept of continuity can be formalized, and (2) that formalization, applied to the debate, settles it. We provide the formalization (and corresponding simulations), and with it settle the debate (in favor of PHP). Our work falls under AI and computational cognitive modeling of the logistc variety; a fact we here simply report without defense (for explanation and defense e.g. see Bringsjord 2008; Bringsjord 2008).

Logico-mathematical Ingredients
A collection of formal ingredients are necessary to adjudicate the debate over C2. In general, we need the following quartet:

1. Cognitive Calculi A cognitive calculus is viewed as a pair ((C, T) where C is a formal language (based therefore on an alphabet and a formal grammar) able to represent mental states and T is a set of inference schemata extending to at least quantified modal third-order logic. Conveniently, cognitive calculi fall into an infinite order of complexity, i.e., higher order logics are solvable (we write solvable) given a previous calculus (we write vsolvable) and a problem (we write prob).
2. Problem Classes/Problems We need to have on hand a precise definition of the relevant problems p0 that fall into their class of problems prob. Herein, we mention only a pair of problems: p0 is the language-recognition problem of deciding whether a simple string coded as a string u built from the alphabet {a, b} is of the specific form a^n b^2. p1 is the extended seriated cup challenge of obtaining a plan that, when executed, secures a goal configuration of cups, where y is allowed to be an arbitrary first-order formula (e.g. “Every small cup is inside at least three cups larger than itself”). See Fig. 1.

Solvability/Unsolvability Here we simply appropriate those concepts from the theory of uncomputability, according to which problems can be classified e.g. as Turing-solvable/unsolvable.

Production of a New Cog. Calc. from a Prior One
In order to settle the discontinuity debate, one needs a relevant class of theorems whose form should by now be thoroughly unsurprising. Here is a sample member of the class:

Defining Discontinuity
The core idea behind the concept of discontinuity we employ is straightforward: one agent, a1, is discontinuously above a second agent, a2, just in case there are at least two problems p1 and p2 that irremediably (relative to a1) separate them. More formally:

\[ a_1 \text{ is discontinuously above } a_2 \iff \exists \ \gamma', p \in \text{PROB} \quad \land \quad \text{Solves}(a_1, p; \gamma', p, \gamma') \quad \land \text{Solves}(a_2, p; \gamma', p, \gamma') \quad \land \quad \text{Solves}(a_1, p; \gamma', p, \gamma') \quad \land \quad \neg \text{Solves}(a_2, p; \gamma', p, \gamma') \quad \land \quad \gamma' < \gamma < \gamma' \]

Figure 1: Extended (requires full first-order logic; note quantification) Seriated Cup Challenge Expressed in Spectra

Technology Ingredients from Logician AI/CogSci
One particular cognitive calculus that serves our needs nicely in modeling problems in connection with the agents that face them is the descretic cognitive event calculus (DCEC17). DCEC is a multi-sort modal logic that includes operators for what an agent might believe, know, desire, perceive, or say (as well as operators for what the agent has an obligation or intention to do). From the AI-technology side, we use Spectra (Govindarajulu, Naveen Sundar 2017), a new, unprecedentedly expressive state-of-the-art planner which utilizes the automated reasoner ShadowProver (Govindarajulu, Naveen Sundar 2016) as its core to discover a plan from the initial state, the goal, and the possible ways a state may change as actions are performed; see Fig. 1.

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Toward Theorems
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References

Acknowledgments
The research reported herein has been in part made possible by the support of ARO(DAAD19-07-1-0091) for creation and implementation of computational logics and automated-reasoning systems brought to bear on the discontinuity debate. In addition, the development of some of these logics has been made possible by support from ONR.