SIMULATING SOCIALLY-SITUATED COGNITION IN EXCHANGE CREATION

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ABSTRACT

In this paper, using an agent-based-model simulation, we model the socially-situated cognition notion that dynamism in cognition results from the moment-to-moment interaction of an entrepreneur's inner environment and outer environment, using exchange formation as the relevant outcome. We present a fundamental model of exchange: individuals create works for sale to others, as the basis for the simulation. We utilize data from an experiment to represent resource uncertainty and relational uncertainty perceptions as an entrepreneur's "inner environment." We utilize assumptions developed from the literature to model the outer environment as represented by the "entry" and "exit" rates for each iteration (tick) in the simulation. We observe that both inner and outer environment interactions can be effectively modeled as predicted by socially-situated cognition entrepreneurship theory; and that – as suggested by Simon (1981) – inner environments form a foundation whereby variations in a dynamic outer environment have more impact on exchange creation than would be expected when looking at variations in the inner environment alone. The implications of this simulation for theory-building in socially-situated cognition entrepreneurship research are explored.

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> *"A man, viewed as a behaving system, is quite simple. The apparent complexity of his behavior over time is largely a reflection of the complexity of the environment in which he finds himself."*
>
> *". . . there are only a few "intrinsic" characteristics of the inner environment of thinking man that limit the adaptation of thought to the shape of the problem environment."*
>
> Herbert Simon (1981: 65, 66)

This intriguing premise: that the complexity of behavior results more from external factors than from internal ones, as individuals interact with environments, is at the core of our investigation in this chapter. In the field of entrepreneurial cognition, the theory of socially-situated cognition (Mitchell, et al., 2011; cf, Smith & Semin, 2004) provides a theoretical rationale for such an examination. This theory suggests a means whereby entrepreneurial action, which has previously been viewed to occur as part of a "complex system" (e.g., Minniti, 2004: 642), might actually be viewed to be the interaction of two systems, only one of which is complex: inner (simple) and outer (complex). Herein we suggest: (1) an internal system – consisting of the actions governed by mental and physical responses to relational and resource uncertainty; and (2) an external system – consisting of the impacts of the socially-situated (and hence dynamic and widely distributed) cognitive environment of exchange creation. In social psychology this socially-situated view (that action-oriented, embodied, socially-situated, and distributed cognitions comprise the essence of a dynamic vs. a static view of thinking humanity [Mitchell, et al, 2011]), is important to the advancement of entrepreneurial cognition research, because it can be useful in untangling the main elements of exchange creation (e.g., the internal and external systems) one from another.

Helpfully, as applied herein, Simon's notion of "inner" and "outer" environments (alluded to in the aforementioned quotes) encompasses a totality of the conceptual space within which situated cognition exists – where the inner environment reflects the cognitive and affective aspects of the entrepreneur-as-individual and the outer environment reflects the conditions in which the individual operates. In this way, Simon's (1981) assertion is an ideal fulcrum point with which to examine what we see as the fundamental assertion of socially-situated cognition entrepreneurship research: that it is the intensive moment-to-moment *interaction* of inner with outer environments that better explains cognitively-derived results (Mitchell, et al., 2011; Smith & Conrey, 2009: 459). Our research question, as it applies the socially-situated cognition view to entrepreneurship research is: To what degree is exchange creation simple vs. complex? We therefore investigate the extent to which, proportionately, inner-environment, and outer environment account for complexity in the exchange creation process.

To explore this question in detail, in this chapter we: (1) introduce into the discussion a parsimonious cognitive structure for entrepreneurial action (Mitchell, et al, 2012) – to represent

Simon's (1981) notion that inner environments are simple; (2) suggest the properties of this system that may be derived from socially-situated cognition; (3) explore and illustrate through a simulation, how the variations in both inner (internal) and outer (external) environments as suggested by socially-situated cognition theory might be expected to affect outcomes, specifically, how variations in perceptions of uncertainty (the inner environment) impact the frequency of new exchanges within various outer environments (ranging from dynamic to static); (4) discuss the theory-building implications of the simulation results for socially-situated cognition-based entrepreneurial cognition research; and somewhat incidentally, (5) examine a bit more fully, the premise that simplicity in the cognitive system leads us to conclude that any complexity that arises over time is ". . . largely a reflection of the complexity of the environment" (Simon, 1981: 65).

In doing so, we hope to make four contributions to the entrepreneurial cognition literature. First, we seek to make more explicit the relative roles, in entrepreneurial action, of entrepreneurs' inner and outer environments. Second, we hope to demonstrate some of the dynamics in entrepreneurial action: through use of a computer simulation to model the effects of interactions *between* inner and outer environments and thereby generate a deeper understanding of the socially-situated entrepreneurial cognition model. Third, we propose the idea that a more fine-grained interpretation of previous work (e.g., Minniti's [2004] helpful assertion that entrepreneurship is a complex system) provides better theory for further research in a variety of streams: e.g., entrepreneurial action (McMullen & Shepherd, 2006), opportunity creation (Alvarez and Barney, 2007, economic development (Minitti, 2004), etc. And fourth, we seek to illustrate the benefit of simulation approaches in the exploration of socially-situated entrepreneurial cognition theory.

A PARSIMONIOUS COGNITIVE STRUCTURE FOR ENTREPRENEURIAL ACTION

We assert that there is inherent value possible in human relationships; and that not all inherent value in human economic relationships just "emerges" – that for a variety of reasons, at least some of the potential or "un-emerged" new value, encounters value-preventing obstacles, and is therefore dormant. Under this assumption, an entrepreneur functions as*: the economic actor who identifies the obstacles to value emergence, acts to reduce them, and thereby brings dormant value into existence* (Mitchell, Morse & Sharma, 2003: 536; Mitchell, 2005: 195). In this section we describe how a simple model of exchange, can yield a basic characterization of an entrepreneur's "inner environment." This characterization can then be used to: (1) identify the fundamental obstacles to exchange emergence faced by entrepreneurs, (2) point to the cognitive structures that entrepreneurs use to generate obstacle-reducing action, and thereby (3) create new value (by bringing new exchanges into existence that would otherwise not have occurred without their intervention). The argument develops as follows.

We have suggested in prior research first, that: the structure of human-relationship-based value creation takes the form of quite standard exchanges involving only three elements: (1) an individual (exchange creator), who creates (2) a work, which is offered for sale to (3) others (Mitchell, 2001; Mitchell et al, 2003); and second, that: depending upon levels of both "relational" and "resource" uncertainty present in the exchange environment, the actual number of completed exchanges will vary (Mitchell, Mitchell, Mitchell & Alvarez, 2012: 91). Viewed in light of these assertions and findings, the basic function of the entrepreneur is to act to alter the elements of the exchange (individual, works, others) in ways that reduce uncertainty obstacles, and result in the creation of new value through the emergence of new exchanges. As further explained later in this paper, we argue that it is in this process of action that complexity arises primarily due to the nature of the environment encountered: i.e., dynamic environment – easier adaptation through action; stable environment – more difficult adaptation through action; static environment – difficult adaptation through action (cf., Mitchell, Shepherd & Sharfman, 2011).

It is therefore of interest to seek a better understanding of the cognitive underpinnings of entrepreneurs' actions that entrepreneurs engage in to reduce uncertainty and thereby enable exchange. As we alluded to previously, Simon (1981: 65) argues that human beings, ". . . viewed as a behaving system, are quite simple. [That] the apparent complexity of behavior over time is largely a reflection of the complexity of the environment." Thus, it is possible to argue that the latent structure (Merton, 1968) of an entrepreneurial action will also be relatively simple: focused around the three suggested elements of exchange; and that complexity will be likely to arise at the interface of inner and outer environments, where the required adaptive action that arises from thinking and problem-solving behavior occurs.

Helpfully, the basic model of exchange suggested above (Mitchell, 2001: 43; Mitchell et al., 2003: 536; Mitchell et al., 2012: 107, 108) specifies three types of cognition that follow from the simple structure of exchange. As explained next, these three basic types of cognitions, which arise in frequent exchange behavior (Williamson, 1985: 31), enable the action that can reduce uncertainty obstacles created by the existence of (respectively) individuals, others, and work. For example, planning cognitions enable entrepreneurs to "put the future at the service of the present" (Bernstein, 1996: 1) and thereby to lower the uncertainty obstacles otherwise imposed by the bounded rationality introduced by the "individual" (Williamson, 1985: 31). Likewise, promise cognitions enable entrepreneurs to increase trust in exchange relationships, and thereby decrease the obstacles posed by the potential for opportunism introduced by "others" (Mitchell, 2001, 2003, 2005; Williamson, 1985: 31). Finally, competition cognitions enable entrepreneurs to produce a work that is competitive within the marketplace, thereby reducing the uncertainty obstacles posed by the specificity that is introduced by a "work" (Mitchell, 2001, 2003, 2005; Williamson, 1985: 31).

We therefore argue that each of these three types of cognitions results in supple and varied combinations of action, and thereby produces much of the complexity we often observe in entrepreneurship. That is, because planning, promise, and competition cognitions are applied within potential exchanges to remove the uncertainty obstacles that stem from the bounded rationality, opportunism, and asset specificity that can be encountered in the almost limitless variety of social situations that arise in a dynamic exchange environment (Mitchell, 2001; cf., Williamson, 1985: 31), a virtually unlimited number of entrepreneurial thoughts and behaviors are expected to result. Hence complexity arises.

Thus according to socially-situated cognition theory (Mitchell et al., 2011; Smith & Semin, 2004), when action occurs (i.e., when an exchange is in process) it can be anticipated to be cognitively dynamic, and there likely will be the following thinking conditions present: (1) as action occurs (2) the embodied cognitions that, in part, motivate that action, will be, (3) widely distributed, (4) within a socially-situated context. That is, an individual entrepreneur-social actor might therefore be expected to have some motivation that arises from an embodied source (e.g., physiological needs, safety needs, socio-economic needs, cf. Maslow, 1943) that is impacted by that person's perceptions and knowledge of their social/ economic situation in their potential exchange relationships with others and the work (Fiske & Taylor, 1984; Hayek, 1937), as that situation is in-turn shaped and defined by the larger meaning/ institutional environment

(Minitti, 2004). Hence we argue that in the dynamics of exchange, socially-situated cognition theory will help to explain the source of the complexity that arises as a potential entrepreneur encounters the obstacles to exchange that are manifest at the socially-situated interface between inner and outer environments: as individuals, create works, for others in a varyingly dynamic environment.

Thus we suggest that planning, promise, and competition cognition-based dynamic action is linked to the person/environment interface through responses to uncertainty as represented in Figure 1 (see also, Mitchell, 2001: 43). Action based in planning cognitions serves the inner/ thinking and feeling environment of an entrepreneur by diminishing uncertainty that stems from bounded rationality to enable the infinitely variable problem-solving behavior required as the outer/ social environment is encountered. Likewise, action based in promise and competition cognitions also serves the inner/ thinking and feeling environment of an entrepreneur by diminishing relational uncertainty that stems from potential opportunism and resource uncertainty that stems from specificity requirements respecting the outer environment, once again, to enable entrepreneurs to engage in the infinitely variable problem-solving behavior required as a dynamic outer/ social environment is encountered.

{Insert Figure 1 about here}

On the basis of this simple cognitive structure (to represent the inner environment of entrepreneurs), and the application of socially-situated cognition theory (to explain the variety and complexity that results as inner environment encounters outer environment), we next offer a parsimonious set of representative properties of the system that may be derived from socially-situated exchange-cognition theory, to support a simulation-based analytical model.

THE PROPERTIES OF A REPRESENTATIVE MODEL

> *Without a theory sophisticated enough to permit modeling or simulations, the whole process of entrepreneurial research slows down.*
>
> MacMillan & Katz (1992: 6)

As will be seen, a very small but crucial addition to the properties of current complexity theory will be necessary for entrepreneurship to be characterized and simulated as both a simple (e.g., inner environment) and complex (e.g., outer environment) system. Minitti (2004) cites Arthur (1997) to argue that entrepreneurship as a complex system exhibits “at least five crucial properties” (of a complex system): (1) a large number of heterogeneous agents interact *locally* in a variety of unpredictable forms, (2) no single agent can control, exploit, or plan all opportunities or interactions in the *specified space*, (3) learning and evolving heterogeneous agents cause a continual process of adaptation and *change*, (4) perpetual novelty in the action *landscape* creates new niches in the ecology of the system, and (5) the system is unlikely to be near a *global* optimum and there exist out-of equilibrium dynamics with either zero or many equilibria (2004: 643, emphasis added). We do not disagree that such properties of complexity are to be found in observed entrepreneurial action, especially in terms of outer environments (as emphasized in the quotation). However, we seek to refine this conceptualization using socially-situated entrepreneurial cognition theory to suggest that when seen as dynamic cognition, and contrary to common assumptions, entrepreneurship (while still complex in its outer environment) is nonetheless based on a more-simple inner-environment-based system at its actual core than previously has been thought.

Accordingly, with respect to the five properties previously suggested (Minitti, 2004: 643), and based upon the socially-situated-cognition-based argument in the preceding section—which asserts a simple-structure account of the objectives and cognitions of entrepreneurs—we may therefore relax the two parts of Assumption 1. We do so by our having developed theoretically, as an extension of prior research, an underlying and predictable latent-structure form of socially-situated interaction: the exchange (Figure 1). Specifically, by positioning a consistent and uniform conceptualization of exchange at the center of entrepreneurship (i.e., individuals, creating works for others) we can eliminate relatively intractable variance from "a large number or *heterogeneous* agents interact locally in a variety of *unpredictable* forms" and replace it with relatively tractable variance from "theoretically *homogenous* agents interact locally in *predictable* form." By these two revisions: from heterogeneous to homogenous, and from unpredictable to predictable, we are enabled to take account of, and to simulate, exchange as a fundamentally simple inner system that is *situated* in the more complex outer environment. As we work to demonstrate in the following sections, it is this combination of both "inner" and "outer" that matters, with the outer environment *generating* the complexity; and the situated, inner environment giving that complexity relevance and meaning. The essence of entrepreneurship is thus captured by the phenomenon of exchange formation; while the essence of exchange formation – its relevance and meaning – is encapsulated within the inner system of response to uncertainty. So, whereas entrepreneurship may appear to be complex to an outside observer; we argue that the essence of entrepreneurship is nevertheless in the simple system.

Nowak (2004) argues that "it is possible to explain [parsimoniously] complex psychological and social phenomena with very simple models if these models are dynamic … without sacrificing depth of understanding," and that "computer simulations have proven to be especially useful for investigating emergent properties in simple models" (2004: 183). In the next sections we therefore report our investigation along these lines.

A SIMULATION MODEL

To examine variations in outcomes of entrepreneurship as a system (specifically: variations in the number of new exchanges) due to variation of both inner and outer environments, we developed a simple agent-based model that simulates exchange completion (an individual connects with a work, and/or other) under varying cognitive and affective aspects of the individual (inner environment), and varying environmental conditions in which the individual operates (outer environment). Again, our objective is to create a clearer picture of how a socially-situated cognition view applied within a new-exchange-occurrence framework, within a representative set of inner and outer environment boundaries, can enable theory development through an examination of the contrast suggested by Simon (1981): that outer environments generate more of the complexity in a given situation than do inner environments and that inner environments represent the simple system, which we argue is at the core of entrepreneurship. In doing so, we seek to explain how the intensive moment-to-moment *interaction* of inner with outer environments can explain cognitively-derived results (Smith & Conrey, 2009: 459). That is, we seek to highlight the simplicity with which inner environment can explain differences in the frequency of new exchanges in the face of complexity in outer environments. In doing so, we also seek to demonstrate the utility of simulation methods to entrepreneurial cognition research, especially as it concerns the examination of cognitive dynamism as suggested by socially-situated cognition.

In this section, after briefly describing our research logic, we: (1) discuss simulations in general; (2) explain our simulation selection process; (3) explain our rationale for representative assumptions about the outer environment; (4) explain our rationale for the data selected to represent the inner environment; (5) summarize the theoretical assumptions developed for the 12 representative cases simulated as included in the research model (see Figure 2, which illustrates the socially-situated cognition simulation process research logic and assumptions); (6) describe the results of the simulation: 24,000 runs of 30,000 events per run, for each of the 12 conditions theorized, and (7) based upon a trial and error examination of runs and events (8,000 to 100,000 and 20,000 to 60,000 events [ticks] respectively; with a 24,000 and 30,000 combination selected to be both representative and parsimonious), report the results of a statistical examination of the representative data sets derived from the simulation results, which compares the likely impacts of both inner and outer environments as modeled in the simulation.

Thus, in this simulation research we followed the logic shown in three sections in Figure 2: (1) initial conditions, (2) simulation interactions, and (3) outcomes. As illustrated in Figure 2, and further described in the subsections of this paper following, the initial conditions of the simulation consisted of assumptions about the *outer* environment that were *modeled* in the simulation; but the initial conditions for the *inner* environment were not assumptions, but rather were *experimentally-derived data* that were input to represent the inner environment. The simulation interactions consisted of 12 exchange event repetition types composed of three exit rate levels (outer environment) at four uncertainty perception levels (inner environment). The outcomes are the number of new exchanges completed given the foregoing assumptions, conditions, data, and interactions. The nature of simulation research and the selections of the simulation type and of the assumptions and data for the initial conditions are described next.

{Insert Figure 2 about here}

Simulations

The term “simulation” loosely refers to an imitation of reality in which conditions underlying such a reality can be imposed to constrict or constrain the behavior of agents operating within its domain according to theory. A variety of simulation-based research methodologies exist. Laboratory experiments can involve participative simulation (e.g., Mitchell et al., 2012) wherein researchers reproduce a representative situation, implement system controls, facilitate participant interaction in the simulation, and observe the results. Other types of simulation include field study simulations[1], wherein researchers present realistic scenarios to field participants (e.g., Fredrickson & Mitchell, 1984), participant interview simulations of individual-, firm-, or industry-level decision-making or cognitions (e.g., Reger & Huff, 1993), or context-control simulations where the setting of a phenomenon is somewhat controlled in quasi-experiments or natural experiments (e.g., Venkatraman & Zaheer, 1990). In such cases, simulation participants are asked to make decisions within the framework specified by the researcher while their behavior is cataloged and scrutinized.

While the preceding types of simulation have a rich history in organizational research, computer simulation is gaining considerable acclaim. In a computer simulation, computer software is used “to model…‘real world’ processes, systems, or events” (Davis, Eisenhardt, & Bingham, 2007: 481; Law & Kelton, 1991). Researchers construct a virtual representation of

[1] For a comprehensive overview of field simulations, see Snow and Thomas (1994)

theoretical linkages among constructs and test these relationships repeatedly, altering the conditions of the simulation as they proceed, in order to generate a clearer picture of the simulated process or outcome. It is this type of simulation we have utilized in this research.

Simulation Selection

While many types of computer simulations exist, we focused on those that would assist us to develop a simulation that could properly represent a market environment characterized by multiple actors and participants engaging in the simple exchanges consistent with the theoretical properties that bound the analysis, as previously discussed. Thus, we chose to build an agent-based model.

Agent-based modeling is a special type of computer simulation in which autonomous agents interact interdependently (Macy & Willer, 2002). Agents follow simple rules, yet their actions are adaptive and reflect path-dependence, helping to evolve the simulation outcomes over time, which is represented by "clicks" (or "tries"). Agent-based models are particularly designed to examine the behavior of agents within a larger system also marked by simple rules; and they have been specifically suggested to help scholars extract complex causal relationships in entrepreneurship research (MacMillan & Katz, 1992; McKelvey, 2004). Thus, we suggest that agent-based modeling is an appropriate research technique through which entrepreneurial cognition scholars may model the dynamic cognitive events that characterize the social situation of entrepreneurs attempting to create a work for others, in the face of uncertainty, in an outer environment with varying levels of dynamism.

By simulating exchange creation in an agent-based model, we were able to incorporate four essential components of agent-based modeling: (1) various agents; (2) decision-making heuristics; (3) an interactive topology; and (4) non-agent environmental conditions. Three sets of agents were therefore developed based on a cognitive theory of exchange creation (Mitchell et al., 2012): individuals, others, and works as the basic elements of exchange. In the simulation, prior to an exchange, each element exists/ operates autonomously; yet when initially linked with one other element, this dyad forms the initial stages of a path-dependent complete exchange (i.e., where all three elements must combine for the exchange to be completed). The linkage process was guided by the representations of both outer and inner environments in the simulation.

To model the outer environment, non-agent environmental conditions were developed using extant literature, and represent conditions under which exchange could reasonably be expected to take place. Specifically, the shape of the problem (outer) environment was represented by the rate of agent entry and exit, which are controlled and allowed to vary based on theoretical expectations. Then, following a Bayesian simulation design method, we developed the agent decision-making heuristics (the constraints of the inner environment) using the results of a laboratory experiment conducted by Mitchell and colleagues (2012). Results of the experiment informed our expectations for individual agent actions; in particular, the cognitive receptivity of agents to combination is expected to be a function of relational uncertainty and resource uncertainty. Thus, based upon previous empirical results, we provided initial probability distributions to realistically simulate perceived exchange opportunities from the perspective of the exchange creator, wherein individuals can create works for other persons.

Our model was constructed in NetLogo 4.1.3, a computer program specifically designed for multi-disciplinary agent-based modeling. An example of the visual output of this simulation is shown in Figure 3.

{Insert Figure 3 about here}

A more detailed explanation of the exact derivation of both the outer environment assumptions and inner environment data follow.

Outer Environment Assumptions

As we have noted previously, the (effects of the) outer environment were represented in the simulation by the rate of agent entry and exit. We explain these assumptions for each, in turn.

Entry. In any given marketplace, the number of individual entrepreneurs entering the market varies according to certain conditions, the most important of which are unknown/ unknowable, and are therefore by default assumed to be random. However, it also can be expected that any marketplace will be populated by some set of existing agents attempting to exchange; and it is reasonable to suppose that even a random level of entry will nevertheless be shaped (to some extent at least) by the preexistence of these agents in the market space. So to begin each simulation run, we first established initial conditions under which the simulation would operate. That is, in each run of the simulation an initial number of individuals, others, and works were introduced (15 of each based upon trial and error exploratory runs of various initial numbers of elements present [for each: low 6 to high 60], to discover the relevant range). Then, consistent with the other properties of the simulation (i.e. random entry and exit criteria), the number of individuals, others, and works in the market space changed over time as the simulation progressed.

Theoretically, it is also reasonable to suppose that the resource scarcity and tight niche packing arguments of the population ecologists will be likely to be helpful in explaining, and justifying as reasonable, the rate of entry into the market space: that entry will be slowed by, for example, crowding (or density) within the marketplace (c.f. Carroll & Hannan, 1989). Accordingly, the rate of market entry for each new agent was programmed to represent marketplace crowding as a function of the number of exchanges completed: as exchanges increased, the rate of entry decreased. The equation constructed to simulate the rate of market entry for new exchange-creating individuals entering a variously crowded market space is as follows:

$$Rate\ of\ Individual\ Entry = \alpha_0 + X_i \sim Pois(\lambda_i)$$

$$\lambda_i = \frac{1}{1+n}$$

where n is the number of exchanges present in the marketplace, and α_0 is the initial value[2]. This representation of the rate of individual entry is reasonable to expect since, for example, individuals that have connected with works and others are not as active *and* they consume resources (the works and others that are still in the market space and not available to connection-seeking individuals); and therefore there will not be room for other individuals, others, and works to enter the market space. Accordingly, this representative rate of entry was calculated by

[2] Thus, α_0 represents the number of individual entries allowed by the researchers: each tick in addition to the number of individual entries randomly generated by the Poisson distribution. Hence, this term allowed the researchers to force more individuals to enter the market to the extent required by theory. As noted, the initial value determined to well-represent a relevant range was 15 agentic elements for each of individuals, works, and others in the simulation.

a random number generated using a Poisson distribution: where, as the number of exchanges increased, the mean (λ) decreased, moving the distribution inward and constricting the number generated to a lower number, thus decreasing the rate of market entry, as the theory we have argued would dictate.

Exit. Consistent with theory (e.g., Mitchell, Shepherd & Sharfman, 2011), the market exit rate was used to represent the level of market dynamism present in the variably hostile market space that it is reasonable to assume is experienced in some degree by most entrepreneurs attempting to start up a new stream of exchanges. Helpfully, it has recently been found that in the face of uncertainty, agents in " . . . more dynamic environments make less erratic strategic decisions"; and that " . . . erratic strategic decisions increase with environmental hostility, but do so more when environmental dynamism is low than when it is high" (2011: 694). Thus, in the relatively hostile new-exchange market space, we can expect that individuals who must immediately complete an exchange (and if not must exit) exist in a highly dynamic outer environment. We therefore represented high environmental dynamism in the simulation with a speedy exit rate (after 1 tick); medium dynamism with a moderate exit rate (after 9 ticks); and low dynamism with a very long exit rate (18 ticks).

Thus, a market exit rate was programed for each combination-set of agents (individuals, others, and works) as follows: unlinked agents, individual-other linked agents, individual-work linked agents, and agents that had combined to form a completed exchange (see Table 1 for the exit decision logic). It was necessary to program multiple rates of market exit given that, in practice, individuals and opportunities have different rates of market exit depending on market-space dynamism: the extent to which an exchange develops toward completion as constrained by, for example, the ecology of the outer environment (e.g., the operation of variation, selection, and retention processes). For instance, an individual "still" seeking an "other" (e.g., a customer) *and* working to create a "work" (e.g., a product or service) after a given time (number of ticks), i.e. an exchange creator which is therefore lagging in the path dependent process, must exit sooner than an individual that has already paired with an opportunity (a work) and is therefore farther along in the process than the unlinked individual, because path-dependent selection has not occurred, and therefore retention is dubious.

{Insert Table 1 about here}

Inner Environment Data

As previously noted, following a Bayesian simulation design, we used prior information collected in the experiment reported by Mitchell and colleagues (2012) to inform an individual's inner environment: the propensity to link with others and works based upon their perceived levels of relational and resource uncertainty. To accomplish this, we used the manipulation checks in the experiment (2012) reflecting relational and resource uncertainty, to examine the proportionate occurrence of exchanges between low and high uncertainty quartiles in each case. We used the reported series of analyses of covariance to compute and compare the mean levels of exchange completion for low and high quartiles respectively, with appropriate controls (Table 2). Based on this analysis, we were able to approximate the prior probabilities of participants' being able to establish connections with others and works, to be: 64.3% for relational uncertainty and 72.76% for resource uncertainty. These probabilities were obtained by dividing in each case the mean of the high quartile by the mean of the low quartile (relational uncertainty = 20.596/32.033 = .643; resource uncertainty = 21.401/29.411 = .7276). We therefore used the mean scores as the basis for representing relational and resource uncertainty (the inner environments) within the simulation. We have reason to suppose that these prior probabilities are fairly robust, given that the explained variance (R^2) of the ANCOVA analysis = .54 (for relational uncertainty), and .49 (for resource uncertainty). Using the counts underlying these percentages, we programmed into the simulation an individual's likelihood of forming exchange linkages.

{Insert Table 2 about here}

Theoretically Representative Cases

In the simulation we conceptualized four prototypical inner-environment entrepreneurial "individuals," distinguished one from the other by their level of resource and relational uncertainty (respectively): high-high; high-low; low-high; and low-low (HH, HL, LH, LL). We ran 24,000 simulations of 30,000 ticks each, for every one of these prototypes in each of three levels of environmental dynamism (3 x 24,000 = 72,000 runs for each prototype). As previously noted, these three levels are a function of assumed exit rates to reflect the shape of the outer (external) environment.

Thus, 12 theoretically representative cases were simulated according to the foregoing assumptions, initial values, and inner environment probability data. Descriptive statistics for each of these 12 cases are presented in Table 3.

{Insert Table 3 about here}

Simulation Results

Figure 3 displays a screenshot of the 2-dimensional agent-based model interface in NetLogo 4.1.3. Action in the simulation involves the components of an exchange moving randomly as time (ticks) moves forward. Individuals are represented by the "person" figure colored white; others are represented by the "person" figure colored blue; and works are represented by the "box" shapes colored red. As the agents (each of the components) move, individuals identified via programmed selection begin to initiate exchanges. When an individual either links with an "other" *or* when an individual creates "work," the connection between individual and other *or* between individual and work is graphically represented by a grey arrow connecting the individual and other or work component. When an individual has both linked with an other and created a work, the connection closes, a completed triangle forms, and the components turn pink (this allows us to better see when an exchange has occurred). In Figure 3, a completed exchange can be observed in the left-central portion of the interface screen shot.

Statistical Examination of Results

To understand the output of the simulations in a statistical sense (for example to examine questions such as the extent to which there are possibly significant relationships among inner environment variables (resource uncertainty and relational uncertainty: Low vs. High) and outer environment variables (time to exit: Short vs. Long), we generated random data using a normal distribution of the means and standard deviations of simulation results (i.e. the agents' behavior: p(exch) and tick exit times). Specifically, we created four distinct random data sets that represent the distinct inner environments (HH, HL, LH, LL) regressed with exit times as the independent variable, and probability of exchange [p(exch)] as the dependent variable, which then allowed us to examine modeled statistics that represent the exchange behavior emergent in the simulation. The descriptive statistics utilized are presented in Table 4.

{Insert Table 4 about here}

As further explained, we also introduced a quadratic term into the regression equation to satisfy two conditions: one of which was observed in the larger simulation – an asymmetric tendency over very long runs (e.g., 24,000 runs at 30,000 ticks each: Table 3); and the other to address the impossibility of a negative probability (i.e. situations where the relationship between time and exchanges crosses the X-axis) that emerged in the regression. Note that the "long" exit time reported in Table 4 was further extended from 18 ticks (Table 3) to 38 ticks (Table 4) to align with the inflection point produced through use of the quadratic term in the analysis, to sharpen the asymptotic relationship observed in the long simulation runs (Table 3).

To avoid the possibility of a Type II error (i.e. based on the number of paths and effect size we would not overestimate), we conducted a power analysis to identify the minimum number of observations required to detect a small effect size. Thus, we generated 668 random observations from a normal distribution using the mean and standard deviations reported for each designated downtime[3] (exit) simulated (i.e. 1, 9, 18, etc., Table 3). The four different levels of resource and relationship uncertainty (HH, HL, LH, LL) were then categorically regressed on to linear and quadratic exit-rate terms, producing a curvilinear regression equation for each level and type of uncertainty. These regression equations are plotted in Figure 4.

{Insert Figure 4 about here}

Based upon regression estimates, we are able to take into account the quantification of our asymptotic observations from the very-long-run simulations through use of a quadratic term to sharpen the relationship for purposes of statistical examination. This then allows us to credibly represent the relationship between time in a market (represented by exit rate) and the probability of exchange as curvilinear with the probability of exchanging decreasing quickly and remaining low for a period of time, followed by an increase in the probability of completing an exchange.

These results suggest that individuals are best served by entering a market, locating the requisite components, and quickly completing an exchange. This is consistent with the logic derived from the literature as previously noted, that following market inception, finite resources and relationships are quickly claimed, leaving little to facilitate exchanges for others over time. However, after a certain period of time, it appears that individuals with the means to remain in the market (or also late entrants) are able to operate given the existing resources and relationships and complete their exchange. Individuals with greater access to "patient" capital are therefore better able to bide their time and complete satisfactory exchanges. One example in

[3] Downtime in a simulation is a variable that is set by the experimenter. It provides an indication of the maximum life of a particular agent in a particular state. We use the downtime feature to simulate exit dynamism.

Thus downtime is a metric used to detect the actual time (ticks) that an agent has been engaged in a particular state. This appears in our simulation as, "Values used for downtime variables," according to the logic as follows:

If actual time (at the conclusion of the tick) is greater than downtime, the agent is compelled to exit. Actual time starts with time = 0, therefore if the downtime = 0 than an agent will have 2 (0 and 1) ticks to "live" in the simulation. The 0 tick is the initial run. At the end of that run, as it is not greater than downtime, the actual time will be incremented by 1 and it will then go through the second tick. At the end of that tick, actual time is now 1 which is greater than downtime(0) and the agent will be compelled to exit.

practice might be the case of family businesses which, with their propensity to hold larger stores of longer-term capital, are often in a better position to capitalize on fluctuating markets that are unattractive to more short-term-oriented firms (Zellweger, 2007).

Finally, we conducted an ANOVA analysis of the means produced in the 4-dataset-case statistical examination. Specifically, we were interested in the extent to which – based upon extensive simulation of the influence of both inner and outer environments on individuals with varying inner-environment perceptions of resource and relationship uncertainty (HH vs. LL) – Simon's (1981) assertion concerning the relative impact of the outer environment vs. the inner environment might hold. As reported in Table 5, in a comparison of the significant relationships found, it appears that both inner and outer environments matter, but that the relative impact of the outer environment is greater (cf, Dean & Meyer, 1996). That is, regardless of outer environment dynamism, the percentage of exchanges completed is between 1.828 and 2.130 times greater when inner-environment uncertainty perception is low (versus high). Likewise, in dynamic outer environments, regardless of inner-environment uncertainty perception, the percentage of exchanges completed is between 4.532 and 5.281 times greater when exit time is short (versus long). In this way, there is likely to be a significantly greater impact of the dynamic outer environment (4.532 and 5.281 times, respectively for LL and HH cases) than of the inner (1.828 and 2.130 time, respectively for short and long cases).[4] These results thus support the notion that, in a new-exchange-occurrence framework, it is the intensive moment-to-moment *interaction* of inner with outer environments that can explain cognitively-derived, *and* socially-situated, results (Smith & Conrey, 2009: 459).

{Insert Table 5 about here}

DISCUSSION

> *What is remarkable looking at epidemiology, criminology, paleontology, or entrepreneurship is the tremendous wealth of techniques and models used in each field. What is present in the first three fields, and sadly missing in entrepreneurship, are bedrock theoretical models and established empirical links between theories . . . [and] experimentation of modeling using key variables in research settings. . .* MacMillan & Katz (1992: 5)

In the foregoing quotation, MacMillan & Katz (1992) call for "bedrock theoretical models" and "modeling" to be introduced into the field of entrepreneurship research. Based upon a socially-situated cognition model of exchange, we have demonstrated in this paper some of the recent progress that has been possible in this regard. In the following paragraphs we address the implications of our theorizing for: action, embodiment, distribution, and social situation, as the essence of a dynamic vs. a static view of thinking humanity – and specifically of thinking entrepreneurs.

[4] According to *this* analysis, the outer environment has two and one half times the effect on exchange completion than the inner environment (e.g., 4.532/1.828 or 5.281/2.130 = 2.48:1). This relationship can be seen to hold for the very large case simulations as well (See means in Table 3).

Entrepreneurial Action

The study of entrepreneurial action has been gaining increased prominence in recent years, specifically as it concerns the behaviors that occur as entrepreneurs work to create, discover, and/ or exploit opportunities (Alvarez and Barney, 2007; McMullen & Shepherd, 2006; Venkataraman, 1997). The problem, of course, is that while certain actions may have pervasive long-term consequences, such action is nevertheless fleeting, and as such is subject to the difficulties of data obscurity bemoaned by MacMillan & Katz (1992). In short, entrepreneurial action has tractability problems.

In the case of the cognitions that underlie the creation of new exchanges, there is an expectation that – as with most event-specific cognition – the fleeting nature of such dynamic cognition will necessitate research procedures that treat these actions as essentially unobservable; and therefore tractable only by virtue of their representation by surrogate indicators (Posner, 1973). Further, researchers in the field of entrepreneurship are presently evaluating the extent to which the cognitions that underlie opportunity creation (for example, as represented in opportunity creation events) may also be quite rare (Alvarez, Young, & Woolley, 2011). In this paper we have developed and demonstrated the idea that entrepreneurial cognition theory is sufficiently robust in theory to support both an experiment, and a follow-on simulation grounded in the real-world results of that experiment, to examine in greater depth the socially-situated nature of specific entrepreneurial actions: the step-by-step creation of new exchanges.

Our study highlights the symbiotic value added to both laboratory/field experiments and computer simulation methods in the examination of entrepreneurial action. From a Bayesian perspective, we expected that using prior information generated on a smaller scale in an experiment, should inform posterior estimates derived in a simulation. Our agent-based modeling approach to simulating entrepreneurial action demonstrates how this could be accomplished. Using the prior probabilities of linkage formation among individuals, others, and works, we were able to develop a simulation that incorporated a more accurate measure of the likelihood, in simulation terms: that agents would link, and in opportunity creation terms: that an exchange would occur.

The results of the simulation suggest that, under different uncertainty perception conditions, individuals who differ in their propensity to create exchanges will nevertheless be constrained or enabled by an outer environment. Theoretically speaking, the results of this simulation suggest the action orientation of entrepreneurial cognition, and the important influence of motivation and time pressure – two of the three primary tenets of action orientation in the socially-situated cognition model: "motivation shapes action," "time pressure shapes cognition," and "mental representations are action-oriented" (Smith and Conrey, 2009: 456-7).

Motivation. Within the simulation, variations in the motivation-action linkage were represented by variations the resource and relational uncertainty profiles that represented four prototypical inner environments (HH, HL, LH, LL, respectively). Socially-situated cognition theory suggests that the motivation component of action orientation depends to a great extent upon uncertainty perceptions (e.g., willingness to commit errors of commission or omission – or vice versa – depending upon self-regulatory focus [e.g., Crowe & Higgins, 1997] – or, need for belonging as it affects sensitivity to rejection [e.g., Pickett, Gardner, & Knowles, 2004]). One theory-building possibility that is suggested by our results is therefore the notion that the black box of "uncertainty" as it is being pursued within entrepreneurial cognition research, would benefit from theories (e.g., self-regulatory focus theory) that further seek to explain the inner environment of entrepreneurs in terms of motivation, as uncertainty might shape action-oriented cognition.

Time pressure. The notion of time pressure may, possibly, be introduced into action-oriented cognition by either inner environmental or outer environmental demands. In our simulation we represented time pressure in terms of time-to-exit variations – an outer environment condition. However, in addition to following prior research that frames time pressure as an outer-environment-based variable (cf. Mitchell & Shepherd, 2010), we found little theory to suggest that time pressure would derive from an uncertainty-based inner environment. In this sense, there is a compelling case that time pressure is a key feature of environmental dynamism, which was a key notion in our conceptualization and representation of the outer (external) environment. As our results demonstrate, time pressure (as we can argue represented by exit rate variations) played a critical role in the explanation of reasons for variations in exchange-creation outcomes. We think that the influence of this time-pressure notion on the conceptualization of action orientation in entrepreneurial cognition offers a compelling reason to suggest time as a crucial construct in the better explanation of exchange creation. The results of our simulation offer substantial theoretical encouragement for the importance of time-focused, action-oriented entrepreneurship research. In this regard, Smith & Conrey (2009: 457) note additionally that, ". . . an emphasis on action as the goal of cognitive activity suggests the importance of the body – the vehicle of all action – as a constraint on cognition." We therefore turn next to the implications of embodiment for socially-situated entrepreneurial cognition research.

Embodied Entrepreneurial Cognition

Embodiment, in the socially-situated cognition sense, is defined to be: "how the body shapes the mind" (Robbins & Aydede, 2009: 3; Mitchell et al., 2011: 774). In the case of entrepreneurial cognition, we have argued that it is uncertainty (e.g., opportunity or threat concerning resources and relationships) that, embodied through the perceptions of individuals (i.e. their inner environment), shapes the disposition of the entrepreneurial mind toward exchange. Thus, our "agent" individual (which we endowed with probabilistic qualities that simulated its representation of the world as grounded in that agent's capacity to sense the "exchange world of interest" in our theory building), was shaped in its actions by these embodied uncertainty-focused attributes. This is of interest in theorizing, because much of the entrepreneurial action literature focuses on uncertainty as the primary basis for entrepreneurial action (McMullen & Shepherd, 2006) – and we suggest that the influence of the embodiment/action fusion is important in understanding entrepreneurial cognition.

While the results of our simulation did not suggest that embodiment (i.e. the inner environment as we have positioned it) was the larger source of variance (when compared to the outer environment), they do suggest that variations in the inner environment as they concern uncertainty perceptions are nevertheless a significant and consistent source of variation in new exchange creation outcomes. The question that emerges from our analysis and this line of reasoning is: To what extent does embodiment (e.g., the inner environment) enable or constrain the initiation of exchange behavior. In our simulation we assumed initial conditions and "entry"; but we did not model the type of refusal behavior that might entirely preempt exchange (cf. Mitchell, 2001). In this sense, embodiment might play a much larger role that we can fully anticipate through viewing new exchange probabilities through the lens of our simulation results.

The foregoing limitation concerning the influence of embodiment on exchange formation outcomes, leads us to discuss (but briefly) the potential research avenues available through recent developments in entrepreneurship-focused neuroscience (treated elsewhere in greater depth in this volume). For example, then, as Baucus, Baucus and Mitchell (2014, this volume) suggest, cognition is the umbrella concept subsuming all the unconscious and conscious processes that transform sights and sounds into neural representations, which then allow the individual to make sense of the world, form goals, and select suitable behaviors within a dynamic outer environment. Because sensory functions of the body are essential, in combination with the brain, to convey, for example, familiarity vs. novelty in a situation or pleasure vs. displeasure with a given stimulus, it is necessary for sensory inputs to be merged with stored information through embodied cognition processes (Buzsáki, 2004: 446). Thus, the functioning of cognition as embodiment suggest, for example, that rather than viewing emotions as *impacting* cognition, they should be viewed to be an essential part of cognition and in fact critical for making appropriate choices (Damasio, 2005).

So when, in response to uncertainty in the outer environment, an individual has a fear reaction (e.g., fight or flight), it is reasonable to expect that – as seen through an embodied cognition lens, and as reported in our results – such an individual will have variability in responses to resource and relational uncertainty, which will be expected, in turn, to impact the likelihood of successful engagement of others and works within the market environment. From a theory-development standpoint, we can therefore (based upon this logic) accord with suggestions by Baucus, et al. (2014) that studies of neural phenomena in entrepreneurship (e.g., entrepreneurial affect [Baron, 2008], entrepreneurial effort [Foo, Uy, & Baron, 2009], etc.) are better grounded ". . . in anatomical and physiological analyses that describe the structure of specific brain areas (i.e., cortical fields and subcortical nuclei) and the functions (i.e., computations) performed by these structures" (Baucus, et al., 2014: XX). Such techniques as diffusion tensor imaging or resting-state magnetic resonance imaging (rs-fMRI) studies can – by mapping the functional systems through which information flows and cognition occurs reduce observational subjectivity (cf. LeDoux, 2012) and offer key insights for more clearly differentiating among the cognitive processes of entrepreneurs.

Distributed Entrepreneurial Cognition

The idea that thinking occurs *beyond* a given individual: that "the boundaries of cognitive systems lie outside the envelope of individual organisms encompassing features of the physical and social environment" (Clark & Chalmers, 1998; Wilson, 2004), suggests that "the mind leaks out into the world, and [that] cognitive activity is distributed across individuals and situations" (Robbins & Aydede, 2009: 7-8). This is the idea behind the notion of distributed cognition. In this view ". . . mind is much more a matter of what we do within environmental and social possibilities and bounds" (van Gelder, 1995: 280). Helpfully, dynamic systems theory tools have been suggested to help to model how various elements of a cognitive system change in relation to one another over time, ". . . because those state changes depend as much on changes in the external environment as on changes in the internal one" (Robbins & Aydede, 2009: 8).

It is within this theoretical context – that of distributed entrepreneurial cognition – that we have constructed the simulation reported in this paper. As earlier reported, both outer and inner environment are implicated in the creation of new exchanges. What might this mean for theory building within the entrepreneurial cognition literature?

First, we suggest that, by effectively modeling the key entrepreneurial process of exchange creation, we have reason to suggest the importance and viability of tracking cognitive causal processes that are both internal to, and which also cross the boundary of the individual organism (2009: 8). From a theory-building standpoint, we have provided the basis for hypotheses that investigate such boundary crossing in the case of living and breathing entrepreneurs.

And, second, we suggest that, in the results of our simulation may be seen how cognition may often be ". . . enabled by information-processing loops that pass through the outside world as well as the mind" (Smith & Conrey: 2009: 461). This demonstration has theoretical relevance to broader research questions that propose entrepreneurship as symbol manipulation (e.g., Cornelissen & Clarke, 2010). Cornelissen and Clarke suggest a ". . . a more integrative understanding that embeds individual entrepreneurs within their social contexts," and better permits them to ". . . imagine the opportunity for novel ventures, refine their ideas, and, after an initial investment, justify their ventures to relevant others to gain much-needed support and legitimacy" (2010: 540). They suggest ". . . linguistics and discourse analysis for analyzing shifts and changes in how entrepreneurs inductively reason about novel ventures." Our research provides a theoretical rationale for hypotheses that argue for such analytical methods, by demonstrating how the looped interaction of individuals with a dynamic outer (external) environment where factors external to the mind – such as the distributed nature of meaning or language in that environment – ultimately influence entrepreneurial outcomes.

Hence we wonder whether entrepreneurs, whose cognitive maps underestimate the role of distributed cognition on eventual outcomes, may encounter exchange creation results that are suboptimal. Research that connects inner and outer environments based upon the notion of distributed entrepreneurial cognition appears to have substantial promise in better understanding such limitations.

Socially-Situated Entrepreneurial Cognition

It is becoming well established that dynamic cognition research eschews the "boxology" notion of, for example, input-process-output as it applies to entrepreneurship research (Mitchell et al., 2011). Instead, socially-situated cognition research ". . . rejects this picture of autonomous, context-free inner processes in favor of a view of an organism as involved in intensive moment-to-moment interaction with its environment" (Smith & Conrey, 2009: 458-9). Our simulation was conducted based upon these socially-situated assumptions.

One of the primary observations that we can make, considering the results we have reported in this paper, is that the socially-situated entrepreneurial cognition model is important to the further exploration of the creation of new exchanges as it applies to such mechanisms in entrepreneurship research as opportunity recognition, discovery, and creation (Sarasvathy, Dew, Velamuri, & Venkataraman, 2003). This is because the conceptual structuring of the dynamic view – e.g., where the social situation is a looping interface between inner and outer environments – can be expedited by having the point of departure offered by the effective simulation of both uncertainty (inner environment) and dynamism (outer environment) as they iterate.

Another observation we make, is that it appears – again subject to data, assumptions and a simplifying theoretical rationale – that the impact of the environment in the looping dynamism of exchange-creating cognition is not linear. We suggest based upon our simulation observations, that over very long exchange-time periods, that the relationship between exchange-time and percentage of exchanges completed may be asymptotic; and we illustrate this using likely results of our statistical examination of the descriptive statistics produced in extensive simulations (24,000 runs or 30,000 ticks each, for each of 12 prototypical cases). The hypothesized existence of an asymptotic relationship between outer environment and exchange creation may be an important and useful dimension of the "social situation" as further theory is proposed to explain opportunity formation.

Limitations

While it has been possible to model certain socially-situated entrepreneurial cognitions related to exchange creation – through use of a simulation fed by both empirical (inner environment) and likely-assumption-based (outer environment) data; it has not been possible to accomplish this without encountering limitations imposed by the nature of the research methodology and the theories applied. In the following paragraphs, we identify the primary limitations we have identified and explain the steps we have taken to mitigate their effects in this research. These include assumptions-based limitations, the disadvantages coincident to the use of computer simulations, results-interpretation limitations, and issues related to the selection of the simulation itself.

Assumptions-based limitations. By definition, entrepreneurial cognition – even socially-situated cognition that implicates the external environment – requires actual people/ entrepreneurs for it to occur. Thus, the simulation results that we report (in the sense that we have made entry and exit assumptions with respect to the outer environment) are somewhat more distant from real organisms than they would be had we also had (for example) experimental data available as inputs to the outer-environment conditions, as we did in the case of the inputs representing human inner environments. However, we also note that as weaknesses go, the availability of data from "real people" to represent the inner environment is a substantial improvement over most simulations which are not enriched in this manner. And therefore, we do not view the utilization of non-organism assumptions to represent the outer environment to be a severe limitation, given that economic or other statistics are often used to represent exchange environments in other research (e.g., Dean & Meyer, 1996).

Disadvantages of computer simulations. Primarily, computer simulations suffer from problems of limited external validity. Given that researchers must often distil complex latent constructs into simple and tractable quantitative representations, the applicability and generalizability of the findings generated by simulation research can fail to accurately mirror reality (Davis et al., 2007). As a solution to this problem, Davis and colleagues (2007) suggest that, following the creation of a simulation, scholars should verify findings with empirical data when possible. This helps to extend the external validity of simulated findings to real-world contexts. This is, we believe, an area for fruitful future research.

Interpretation of results. Untangling assumptions from results in simulations is often also a challenge. It is important in such research to demonstrate how, and especially in what manner, the results are not spurious and simply a reflection of inputs, but rather, are useful observations for such purposes as theory building. Of course, we readily admit that – as in all empirical research – the results *are* the reflection of the inputs; but, we assert, only to the extent that they constrain the nature of the interactions (e.g., that the prior probabilities of interactions – based upon experimentally-obtained data – in fact *do* reflect expectations for the impact of resource and relational uncertainty on the likelihood of agents in the model achieving linkage with another exchange element.) Additionally, once the interactions begin to occur as the simulation proceeds, with randomness, with empirics, with initial values, and with entry and exit assumptions as a beginning point; it is not unreasonable to expect that the unknown territory describing "how things will play out" is not strictly "determined," but that it is, rather, somewhat revealing, at least.

Computer simulations have several additional advantages that could be leveraged by entrepreneurship scholars. First and foremost, computer simulations are particularly suited for developing theoretical insights under conditions of high internal validity (Cook & Campbell, 1979; Davis et al., 2007). Given that in a computer simulation the researcher controls every facet of the simulated process or outcome, computer simulations are highly tractable and are thus able to generate insight into both simple and complex interrelated causal relationships (Ganco & Agarwal, 2009). Second, computer simulations can be conducted at a fraction of the cost of other experimental methods. Laboratory and field simulation techniques require considerable resource outlays and extensive research procedures for the effective and appropriate management of human participants. Given the increasingly stringent requirements of institutional review boards at most major research institutions, for example, the time and effort expended to develop and institute an effective laboratory or field simulation can be daunting. Moreover, to collect longitudinal data, researchers are required to conduct multiple iterations of the simulation, introducing problems found in similar research designs using human participants (e.g., maturation, attrition, fatigue, historical bias, etc.). As an alternative, computer simulations are readily manipulated to impose new underlying assumptions or conditions without obscuring the observations and can run countless times with few of the limitations of human-simulations research.

Simulation selection issues. The serviceability of agent-based modeling methods to model outcomes is also open to discussion. This is because of the limitation in simulation methods to produce "final" outcomes (in the sense that statistical tests of probability samples may be asserted with respect to some population of interest). Rather, simulation outcomes are multifinal, or possibly equifinal. Agent-based modeling has been suggested as a serviceable means for investigating and abstracting from multifinal and equifinal outcomes (McKelvey, 2004). Multifinality refers to an event in which different solution possibilities exist from a single niche problem. In an opposite scenario, equifinality refers to a system in which multiple initial circumstances lead to the same outcome (Gresov & Drazin, 1997; Payne, 2006; von Bertalanffy, 1968). Despite the ubiquitous nature of both equifinality and multifinality in entrepreneurial phenomena, organizational scholars have seldom investigated them specifically, often due to the problem of data obscurity (cf. Macmillan & Katz, 1992).

However, understanding the implications of alternative starting conditions and solutions for inherently obscure entrepreneurial phenomena holds considerable value for entrepreneurship scholars and entrepreneurs alike. Our simulation demonstrates how, under certain specified conditions in the model, we were able to evaluate variance across assumptions (12 prototypical cases) and to generate and to thereby assess a variety of outcomes (i.e. the multifinality phenomenon). However, we have also been able to demonstrate how, by varying assumption and initial condition values of a simulation across a great many runs, we have been able to see if and how agents reach similar outcomes given vastly different origins (the equifinality phenomenon).

Conclusion

We began this paper with a description of how cognition is dynamic: action-oriented, embodied, distributed, and socially-situated. We also advanced the notion that complexity arises, as suggested by Simon (1981), from the interaction of inner and outer environments. This introduction led us to consider a question relevant to entrepreneurial cognition research, which we suggested socially-situated cognition theory might assist to better explain: To what degree is exchange creation simple vs. complex?

Conventional wisdom suggests that it is complex – depending upon such a wide variety of factors and elements that the latent structure is virtually impossible to conceptualize in one simple model (Minitti, 2004). Socially-situated entrepreneurial cognition research offers a different account: that the outer environment is *generating* the complexity, and that the situated, inner environment is giving that complexity relevance and meaning. While not reducing the actual number or extent of variables, it nevertheless permits a simple-system viewpoint to be conceptualized: one that explains most of the complexity in terms of categories of latent variables (Merton, 1968): inner environment/ uncertainty perception levels; and outer environment: levels of dynamism. Based upon this theoretical structure, the boundaries of these assertions have been examined through our simulation; and what we have found is that – as Simon says – both inner and outer environments matter a lot, with the inner environment offering simplicity in providing relevance and meaning; and the outer environment introducing complexity. This supports the socially-situated cognition assertion that cognition is dynamic precisely because of the moment-by-moment interactions between inner and outer environments. We therefore conclude that our simulation and theory-building analysis has substantial explanatory power in untangling the observed complexity in at least the exchange-creation process of entrepreneurship.

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Table 1: Complete Exit Rate Assumptions and Logic

(Note: stated as a maximum value; Downtime is defined as: a metric used to determine when an agent in a particular state will be compelled to exit the exchange space)

Agent	Condition	Calculation of Maximum	Minimum Time	Maximum Time
Individual Others Works	No linkage	Max-Downtime + 1	Max-Downtime + 1	Max-Downtime + 1
Individual Others	Individual Other Link	Others-Linked-Max-Downtime + 1	Max-Downtime + 1	Others-Linked-Max-Downtime + 1
Individual Works	Individual Work Link	Work-Linked-Max-Downtime + 1	Max-Downtime + 1	Work-Linked-Max-Downtime + 1
Individual Others Works	Completed Exchange	Others-Linked-Max-Downtime + 1	1 tick (exchange formed in first round)	Others-Linked-Max-Downtime + 1

Values used for downtime variables:

Variable Name	Assigned Value	Agents Minimum TTL[1]	Agents Maximum TTL[2]
Max-Downtime	0	2 ticks (0, 1)	10 ticks (0 – 9)
Max-Downtime	8	10 ticks (0 – 9)	18 ticks (0 – 9)+(0 – 9) – 1
Max-Downtime	17	19 ticks (0 – 18)	28 ticks (0 – 18)+(0 – 9) – 1
Max-Downtime	26	28 ticks (0 – 27)	37 ticks (0 – 27)+(0 – 9) – 1
Max-Downtime	35	37 ticks (0 – 36)	46 ticks (0 – 36)+(0 – 9) – 1
Max-Downtime	44	46 ticks (0 – 45)	55 ticks (0 – 45)+(0 – 9) – 1
Others-Linked-Max-Downtime	8	Based on Max-Downtime value (see times above)	
Work-Linked-Max-Downtime	8		

1. Agent's Minimum Total Time to Live (TTL) assumes an exchange does not occur within the specified number of ticks.

2. Agent's Maximum Total Time to Live (TTL) is dependent on linkage occurring no later than the Max-Downtime. The first set of numbers is the time available to secure the first linkage. The second set is the time available to complete the exchange (form second linkage with complimentary agent).

Table 2: Results of analysis of covariance for opportunity creation[a]

Table 2a: Results of ANCOVA for top and bottom quartile for relational uncertainty[a]

Covariate	Economic exchange *F*	Group Mean	η^2
Group task motivation (control)	1.62		0.06
Knowledge of other group members (control)	1.71		0.06
Hypothesis 1[b]	25.95 **		0.50
High condition		20.60 (1.50)	
Low condition		32.03 (1.61)	
$R^2 = .54$			

[a] We estimated marginal group means with standard errors in parentheses
[b] For the high condition, $n = 16$ groups; for the low condition, $n = 14$ groups
* $p < .05$; ** $p < .001$

Table 2b: Results of ANCOVA for top and bottom quartile for resource uncertainty[a]

Covariate	Economic exchange *F*	Group Mean	η^2
Group task motivation (control)	2.28		0.08
Knowledge of other group members (control)	6.24 *		0.18
Hypothesis 1[b]	12.82 **		0.31
High condition		21.40 (1.62)	
Low condition		29.41 (1.52)	
$R^2 = .49$			

[a] We estimated marginal group means with standard errors in parentheses
[b] For the high condition, $n = 15$ groups; for the low condition, $n = 17$ groups
* $p < .05$; ** $p < .001$

Source: Adapted from Mitchell et al., 2012

Table 3: Results of Simulation (percentage of exchanges completed)

30,000 Ticks each rep – 24,000 reps: Time-before-exit: Long = 18 ticks; Medium = 9 ticks; Short = 1 tick

Trial	Resource	Relationship	Time to exit	Mean %	S.D.	Max	Min	Median	Mode
1.	High	High	Long	3.81	0.11	4.3	3.39	3.81	3.82
2.	High	High	Medium	5.65	0.13	6.17	5.17	5.64	5.63
3.	High	High	Short	10.16	0.16	10.75	9.58	10.16	10.14
4.	High	Low	Long	5.89	0.13	6.4	5.35	5.89	5.9
5.	High	Low	Medium	8.41	0.15	9.02	7.78	8.41	8.41
6.	High	Low	Short	14.02	0.18	14.76	13.24	14.02	14.02
7.	Low	High	Long	5.21	0.12	5.74	4.75	5.21	5.23
8.	Low	High	Medium	7.53	0.15	8.13	6.94	7.53	7.56
9.	Low	High	Short	12.82	0.17	13.55	12.18	12.82	12.82
10.	Low	Low	Long	8.06	0.15	8.7	7.5	8.06	8.07
11.	Low	Low	Medium	11.27	0.17	12.03	10.48	11.27	11.27
12.	Low	Low	Short	18.34	0.2	19.15	17.58	18.34	18.31

Table 4: Percentage of exchanges completed over time under differing levels of resource and relationship uncertainty

(Based on random observations)

N = 668 (Compare Table 3: N = 24,000, total ticks each = 30,000)

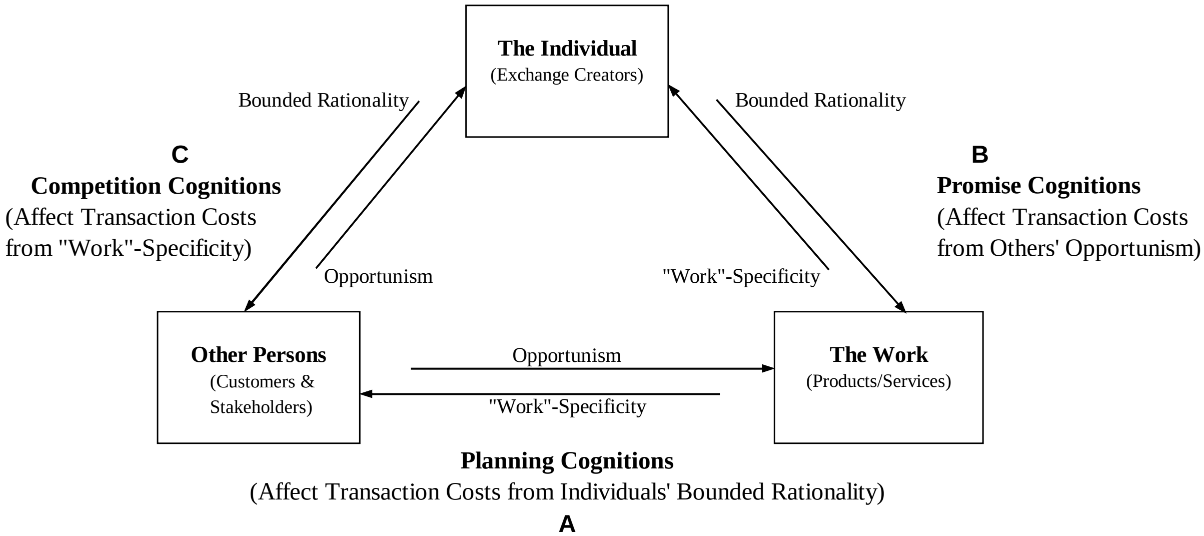
Resource Uncertainty	**Relationship Uncertainty**	**Exit time: After**		
		Short Time: 1 tick	**Medium Time: 12 ticks**	**Long Time: 38 ticks**
High	High	0.096	0.056	0.018
High	Low	0.134	0.082	0.038
Low	High	0.122	0.073	0.026
Low	Low	0.178	0.109	0.039

Table 5 – Means, ratios, and ANOVA differences between:
The percentage of exchanges completed over two times (short = 1 tick; long = 38 ticks),
under differing levels of resource and relationship uncertainty

		Short: 1 tick exit time	**Long: 18 tick exit time**	**Outer Environment**		
Resource Uncertainty	**Relationship Uncertainty**	**Mean % Completed**	**Mean % Completed**	**Ratio**	***N=668***	***F* Value**
Low	**Low**	17.815	3.865	4.532x	334	51,000**
High	**High**	9.585	1.815	5.281x	334	30,000**
Inner Environment	**Ratio**	1.828x	2.130x			
	N=668	334	334			
	***F* Value**	17,000**	56,059**			

** $p < 0.01$

Figure 1: The basic dynamics of exchange



Source: Adapted from Mitchell, 2001: 43)
Based on Gardner (1993); Williamson (1985)

Figure 2: A Socially-situated Cognition Model of Exchange

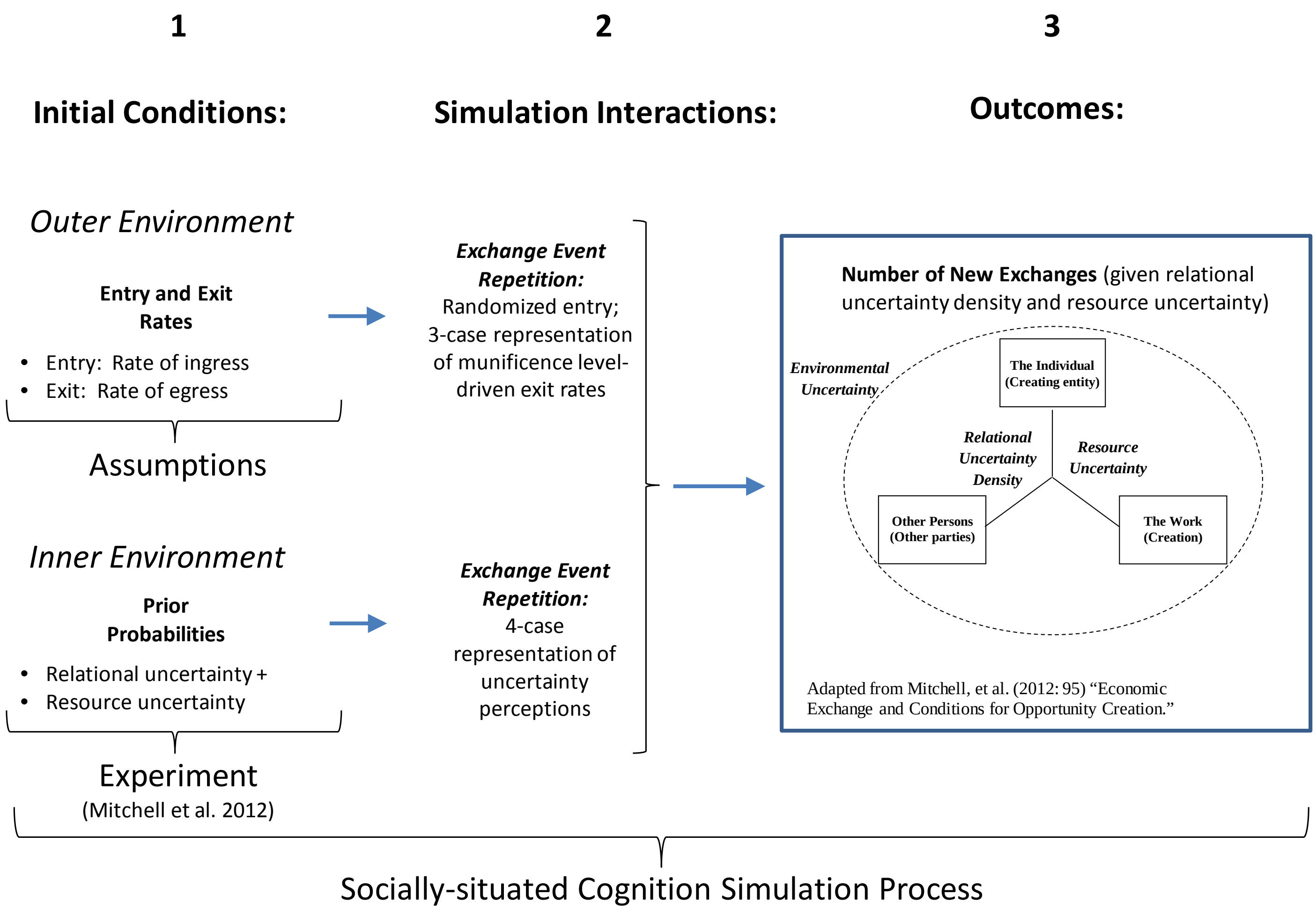


Figure 3: Screenshot of agent-based model in NetLogo 4.1.3

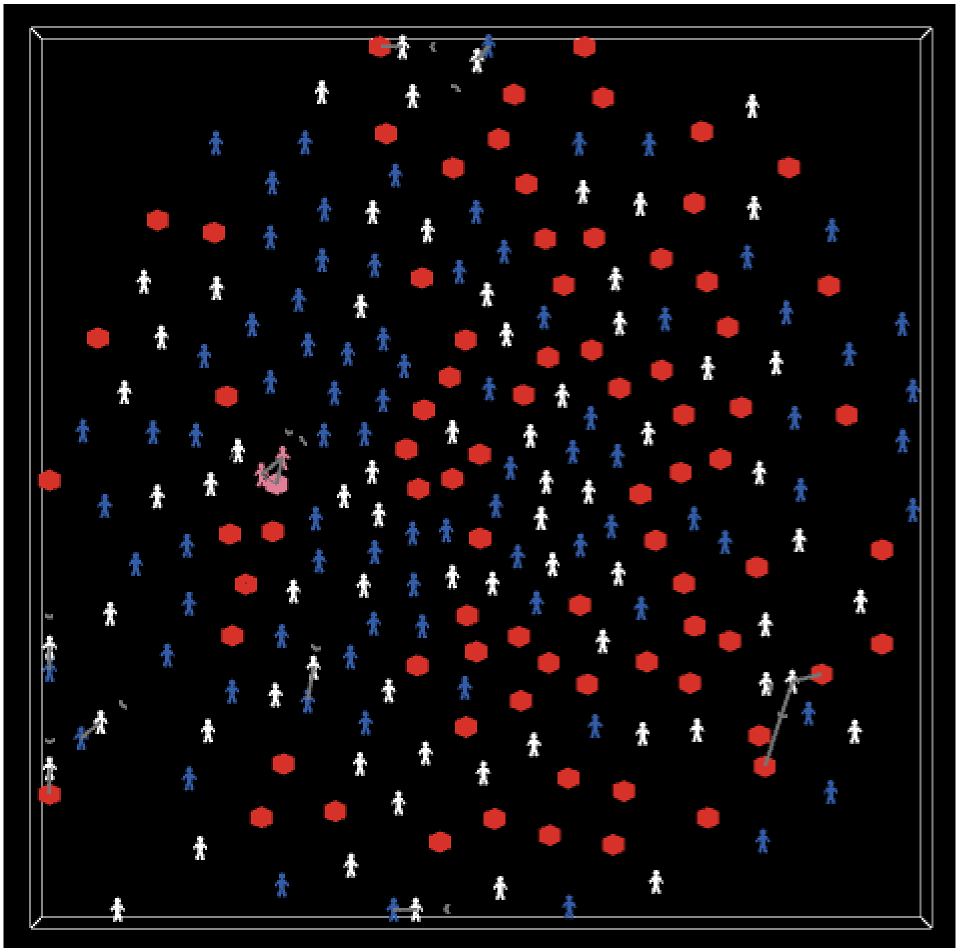
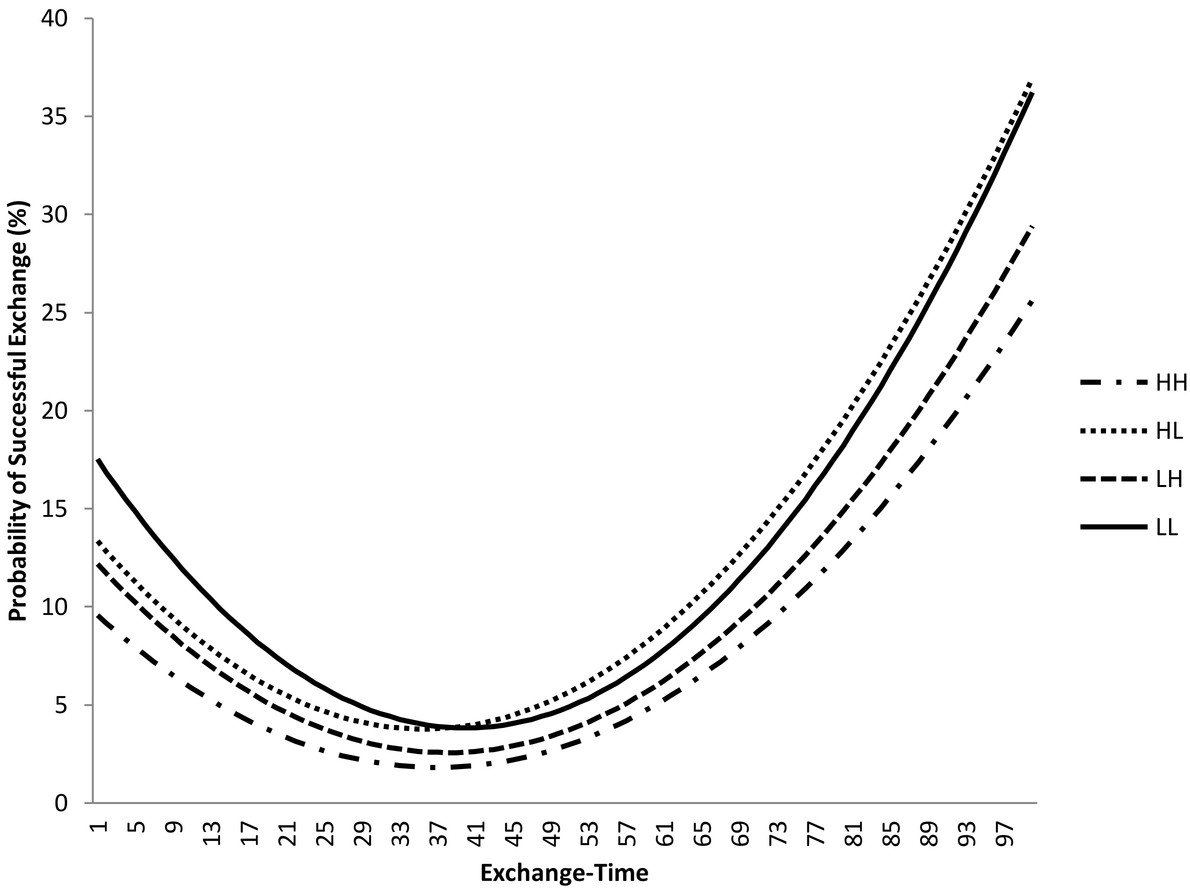


Figure 4: Probability of Successful Exchange under Different Levels of Uncertainty and Time Allowed for Exchange



Note:

- HH = high resource uncertainty, high relationship uncertainty;
- HL = high resource uncertainty, low relationship uncertainty;
- LH = low resource uncertainty, high relationship uncertainty; and
- LL = low resource uncertainty, low relationship uncertainty

Regression Equations:

% of Exchanges Completed (HH) = 10.026 – 0.444(Time) + 0.006(Time^2)

% of Exchanges Completed (HL) = 13.928 – 0.570 (Time) + 0.008(Time^2)

% of Exchanges Completed (LH) = 12.717 – 0.533(Time) + 0.007(Time^2)

% of Exchanges Completed (LL) = 18.229 – 0.719(Time) + 0.009(Time^2)