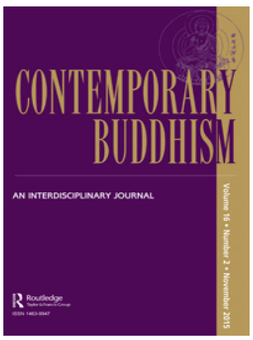

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THE POWER OF ONE SENTIENT BEING: THE COMPUTER SIMULATION OF A BODHISATTVA'S ALTRUISM USING AGENT-BASED MODELLING

Yu-Hsiang Yang, Huimin Bhikshu and **Rua-Huan Tsaih**

The aim of this study is to demonstrate that agent-based simulation is a scientific approach to studying the altruistic behaviours of a Bodhisattva, who is practising Buddhism to achieve Buddhahood. From the Buddhist perspective, the evolutionary model of Hammond and Axelrod (2006a) describes the operation of a community in the world. The study shows that we can simulate a Bodhisattva as a firm-and-pure-altruist (FPA) agent, who always performs both in-group and out-group altruistic behaviours, including the preaching of doctrine and the giving of material objects, and who always remains an FPA agent. Based on the model of Hammond and Axelrod (2006a), ordinary human beings are modelled as four-type agents who evolve according to their genetic potential to reproduce. Our results show that a Bodhisattva can create more pure altruists in the community by sharing doctrine and material objects. The results also show a beneficial situation because the average welfare of all four agents increases if we consider average fitness as a measure of welfare, according to Becker (1976).

1. Introduction

Buddhism began as the world's first altruistic missionary religion. It was founded by Siddhārtha Gautama in the sixth century BCE in northern India. He was titled the Buddha, or the one 'awakened' by having seen reality clearly, and shared his teachings with all those interested in hearing them (Lewis 2005). Buddhist Studies offers a rich field of study to researchers in fields not only related to religion and philosophy but also extending to history, anthropology, sociology, political science, gender studies, and art, among others. Cabezon (1995) has stated that the study of Buddhism has asserted itself as a discipline in its own right. Scientific methods have also been applied in Buddhist Studies (Lama et al. 1991; Wallace 2003; Lama 2006; Harrison 2010; Jinpa 2010). However, computer simulation has become a powerful tool with applications in religion since Bainbridge (1995) first adopted Neural Networks, an artificial intelligence (AI) tool,

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to generate a model of human learning and decision-making in some theories of religion. Among the many computer simulation tools existing today, agent-based simulation systems facilitate the recently proposed discussion of problems in many disciplines (Macy and Willer 2002; Heath, Hill, and Ciarallo 2009). For example, Upal (2005), Iannaccone and Makowsky (2007), and Dow (2008) discuss different religion-related issues using agent-based simulations. These applications offer evidence that complex agent-based systems make it possible for us to study adaptive behaviour and system complexity (Goldstone and Janssen 2005; Grimm et al. 2005). Along the same lines, this study demonstrates agent-based simulation to be a scientific approach to studying the altruistic behaviours of a Bodhisattva, i.e., a person who is practising Buddhism to achieve Buddhahood.

Buddhism itself can be regarded as a contemplative science through which a deepened knowledge of mental phenomena is instrumental in the quest for Buddhahood. Although such a contemplative science prescriptively emphasizes strict mental discipline to counteract the effects of greed, anger, and ignorance, it is also constituted by the description and explanation of a wide range of observed states of consciousness (Ricard and Thuan 2004; Wallace 2007; Jinpa 2010). The Dalai Lama suggests that, while the methods used by science and by spirituality are different, in essence, however, their goals are the same, propelling humanity forward. One benefit of this approach is that a scientific understanding of the pursuit of reality not only makes substantial progress in the quality of the material life of human beings, but also improves global life satisfaction and happiness. In Buddhist terms, this goal of science can be seen to derive from the wisdom of compassion (Lama 2006). Thus, a Buddhist's altruism is embedded in the pursuit of reality. Mahāyāna Buddhism, the so-called Bodhisattva Path, is like a contemplative science that teaches sentient beings to attain self-enlightenment and to enlighten others, benefiting oneself as well as others in the world.

In Mahāyāna Buddhism, a Bodhisattva is one who is determined to achieve Buddhahood and lead all other sentient beings to the same state of mind/being, motivated by an unconditional compassion and a wisdom that understands the truth of non-self, *anātman* (Yamaguchi 1956; Clayton 2001). In addition, the Bodhisattva, a perfect figure that always helps people selflessly, is a paradigm of a firm-and-pure-altruist (FPA) in the world. The *Mahāyāna-sūtrālaṅkāra*, (Levi, XVIII, 19–21) explains the 'firmness' of a Bodhisattva:

> Firmness is first seen here in view of various ways of learning. Then, it is related to duṣkaracaryā (austerity) in which the Bodhisattva is engaged; next it is related to saṃcintya-bhavopapatti by which a Bodhisattva is reborn at will into saṃsāra and does not abandon it (saṃsārātyāga); and finally it is related to asaṃkleśa, i.e. he does not suffer from its contamination. All these activities are called the Bodhisattva's firmness. (Nagao 1981, 70)

While altruism is based on unconditional compassion from the Buddhist perspective, the term 'altruism' in the West was coined by Auguste Comte

(1798–1857), the founder of sociology (Weiner, Simpson, and Proffitt 1993). Altruism here is defined as a moral principle emphasizing the importance of placing the welfare and happiness of others before those of oneself or of sacrificing oneself for the benefit of others. It is the purist form of prosocial behaviour that occurs when someone acts to selflessly help another person. Altruism is also a traditional virtue in many cultures and a core aspect of various religions, such as Buddhism, Christianity, and Islam. However, the existence of altruism represents a key problem for Darwin's theory of evolution. From an evolutionary perspective, survival of the fittest fails to provide a biological explanation for selfless altruism (Dawkins 2006). Early evolutionary scholars sought to discover how and why selflessness could have evolved. Thus, the purely biological explanation has been expanded to incorporate the genetic kinship theory (Hamilton 1964), reciprocal altruism (Trivers 1971), and the group selection of sociobiology (Wilson 1975). Since the beginning of the late 1970s, political scientist Robert Axelrod at the University of Michigan has held three computer tournaments of iterated prisoners' dilemmas to study issues such as cooperation and altruism. He has created a new era of interpretation, applying computer simulation to the study of altruism and cooperation (Hoffmann 2000; Dawkins 2006). However, Dawkins (2006) has argued that what appears as altruism in these explanations is also an egoism of the genes that related individuals share. As a result, the Dalai Lama (2006) has expressed disappointment with the recent biological research results on altruism which defines it as another function of the 'selfish gene'.

The lack of prior application of computer simulation to the Buddhist perspective on altruism motivates this present study. The main purpose of this study is to connect computer simulation to the study of Buddhism. Because the current religion-related models cited in literature do not focus on the study of Buddhism or altruism, this study adopts the agent-based evolutionary model proposed by Hammond and Axelrod (2006a) to describe the operation of a community in the world. (Hereafter, the H & A model refers to the agent-based evolutionary model of Hammond and Axelrod (2006a). In the H & A model, there are four roles: the selfish (denoted SA), the contingent altruistic (CA), the cosmopolitan (CO), and the pure altruistic (PA). Hammond and Axelrod (2006a) show that the contingent altruistic behaviour that favours in-group cooperation and repels out-group cooperation not only can highly support cooperation but can also dominate the population. From the Buddhism perspective, the H & A model also provides an operational definition of discrimination, which uses a 'tag' or colour to identify a group. Such an operational definition of discrimination provides the operational definition of no-self altruism when one performs both in-group and out-group altruism.

This study further simulates the behaviours of a Bodhisattva as the FPA agent that always performs both in-group and out-group altruistic behaviours with either the preaching of Dharma or the giving of material objects and that remains an FPA agent even after rebirth. Ordinary human beings are modelled as

four-type agents in the H & A model that evolve according to genetic fitness. The community impact of the altruistic behaviours of a Bodhisattva that is an FPA agent can be traced via the computer simulation.

Specifically, the objectives of this study are as follows:

(1) To show how the altruistic behaviours of a Bodhisattva can be simulated through an FPA agent, while *a community without a Bodhisattva* is simulated by the H & A model.
(2) To show the impact of altruistic behaviours of a Bodhisattva on the community by tracing the simulation-derived evidence of how the FPA impacts the community by giving either Dharma or material objects. For instance, which altruistic behaviours of a Bodhisattva would result in more pure altruistic agents: the giving of Dharma or the giving of material objects?
(3) To conduct further in-depth discussion of Buddhist perspectives through computer simulation.

This paper is structured as follows. Section 2 provides the literature review. Section 3 presents the assumptions and the proposed model. Section 4 presents the simulation results. Section 5 presents the discussion.

2. Literature review

2.1. The Bodhisattva's altruism

The term 'Bodhisattva' was originally applied to Śākyamuni Buddha in the previous stages of his lives before his final achievement of Buddhahood. The word means one who is destined for the attainment of Awakening (*bodhi*) with the essence of perfect knowledge (Hamilton 1950; Wagenaar et al. 1993). The way of the Bodhisattva is realized by rousing compassion and benefiting others with means suitable to their capacity to receive, in order to enter into the mind of Awakening (Tay 1976).

The career of a Bodhisattva is a very long and arduous one. Bodhisattvas remain in the world and are always accessible because they vow to save everyone. After taking vows, one trains oneself along the Bodhisattva Path by performing virtues (with giving at the head of the list), mastering meditation, penetrating into the wisdom of emptiness (which is understood as the universal absence of self-nature), and achieving liberation through wisdom. De Silva (1995) explains that so-called 'liberation through wisdom' can be attained through insight into the reality of impermanence, unsatisfactoriness, and impersonality. This insight is also expressed as a so-called 'non-duality' that plays a salient role in the notion of Bodhisattva's 'Equality Wisdom' (Nagao 1981, 67). With this insight, such a Bodhisattva with truly boundless compassion rejects the artificial barriers that divide one person from another or removes the 'glass wall between me and others' (Nagao 1981, 67). Thus, Yao (2006) suggests that there is no differentiation

in a Bodhisattva's compassion, which implies that we ought to view and treat all sentient beings equally.

Benevolence is also instrumentally valuable in the pursuit of liberation and reality (Olson 2005). Bodhisattvas keep practising the six perfections and 'ten thousand deeds' to fulfil the enlightenment of others until the ultimate and complete attainment of enlightenment. Giving is at the head of the list among these deeds. It includes three types: the giving of material objects or wealth, the giving of Dharma or doctrine, and the giving of fearlessness (Yin-shun 1998). Similar to an old English saying, the former two kinds of giving teach a man how to fish in order to feed himself forever rather than just giving a man a fish to feed him for one day. In addition, the last kind of giving, the giving of fearlessness, frees a man from fear and threats, and then rids him of suffering (Feldman and Kuyken 2011). In sum, a Bodhisattva will attain Buddhahood in the future by beginning with practically altruistic acts.

2.2. Agent-based modelling

Agent-Based Modelling (ABM), or the multi-agent system, refers to the computer simulation of agents (representing individual roles) in a dynamic social system. Here, agents refer to different 'representatives' who interact with each other or the environment based on pre-set rules. The so-called 'agent' is able to produce a series of environmental awareness and actions. Rational agents can be expected to achieve optimal performance and are built on a series of perceptions in addition to their internal knowledge.

Beginning in the 1940s, John von Neumann, the founder of computer architecture, worked on the development of a kinematic model of automata afloat in a sea of raw material; however, he failed to capture the essential logic of self-reproduction with this model. After adopting the suggestion of his colleague Stanislaw Ulam, he proved that the collective dynamics resulting from such simple rules might bear a formal resemblance to the biological process of self-reproduction and evolution (Von Neumann and Burks 1966; Keller 2005). Spatial agent-based models were originally implemented in the form of cellular automata. Conway's Game of Life is a good example (Gardner 1970). Cellular automata represent agent interaction patterns and available local information by using a grid or lattice environment (Macal and North 2010).

On the other hand, deriving from the Schelling Segregation Model (Schelling 1971), ABM focuses on the value of beginning with rules of behaviour for individuals and using simulation to discover the implications of these rules for large-scale outcomes. Thomas Schelling (1978), the winner of the 2005 Nobel Memorial Prize in Economic Sciences, called this 'micromotives and macro-behaviour'. ABM has been applied in multiple disciplines, such as economics, physics, biology, and ecology, to explore the phenomenon of Complex Adaptive Systems (CAS), and it has gradually been more widely used in almost every field of study for a deeper understanding of its particular phenomena. For instance, an

economic system in agent-based economics can be composed of heterogeneous agents, and those summation variables are the results of interactions among these heterogeneous agents. Unlike the 'top-down' mode of thinking in traditional macroeconomics, ABM has introduced a 'bottom-up' style of thinking to macroeconomics under a new paradigm, which presents a challenge to most economists (Tesfatsion 2001, 2002). Thus, ABM serves as an ideal tool for us to advance our thinking from the micro to the macro perspective and to observe the links and relationships between these two levels (Macy and Willer 2002).

There is also a growing trend toward the application of ABM in political studies, geographic studies, environmental studies, and other disciplines, for it does not focus on the causal relations between variables, as statistics and econometrics do. Instead, it is mainly concerned with addressing 'how' or 'what-if' questions—observing how the complicated social/political phenomena in question have been formulated through the interaction between the simulated agents (Epstein and Axtell 1996; Bui and Lee 1999; Epstein 1999). In addition, the patterns being discovered through such observations may be used either to test existing theories or explore new ones (Axelrod 2006). Axelrod (2006) also suggests that ABM can be used to describe certain fundamental questions in many fields, thereby promoting inter-disciplinary cooperation. When existing mathematical methods fall short, ABM presents itself as a useful tool to reveal the underlying unity behind various academic fields.

2.3. Contingent altruism model

Hammond and Axelrod (2006a, 2006b) show that the joint mechanism of tags and viscosity vastly increases contingent altruism or ethnocentric behaviour in the environment of evolving populations. Contingent altruism or ethnocentric behaviour is surprisingly dominant in the sensitivity analysis that the parameters and structure of the model changes. To discriminate group differences among agents, they assign each agent three traits as follows (Hammond and Axelrod 2006a, 2006b):

(1) A tag is used to identify group membership according to one of four predefined colours.
(2) Each agent is specified a strategy—either cooperation or defection—when meeting someone of its own colour.
(3) Each agent is specified a strategy—either cooperation or defection—when meeting an agent of a different colour.

Thus, there exist four agent types: SA, CA, CO, and PA. (1) The SA agent repels both in-group and out-group cooperation; (2) the CA agent performs in-group cooperation but repels out-group cooperation; (3) the CO agent performs out-group cooperation but repels in-group cooperation; and (4) the PA agent performs both in-group and out-group cooperation. Therefore, the contingent altruistic strategy is one of four possible strategies.

SA SA SA SA SA
CA CA SA PA CO
PA SA CA CA SA
PA SA CA SA PA
SA CA SA SA SA

FIGURE 1
An example of a space of 5 × 5 sites

The simulation begins with an empty space of 50 × 50 sites. The space is toroidal, meaning that it has wrap-around borders such that every site has exactly four neighbouring sites, as shown in Figure 1.

Each time period includes four stages: immigration, interaction, reproduction, and death, as shown in Figure 2.

(1) An immigrant with random traits enters at a random empty site.
(2) Each agent has a potential to reproduce (PTR) set to 12%. Each pair of neighbours will interact in a one-move prisoner's dilemma, whereby each chooses (independently) whether to help the other. Giving help has a cost—a 1% decrease in the agent's PTR. Receiving help has a benefit—a 3% increase in the agent's PTR. In the simulation, the standard values of these parameters are initially PTR = 12%, c = 1%, b = 3%, according to the H & A model.
(3) Each agent is chosen in random order and given a chance to reproduce with a probability equal to its PTR. Reproduction consists of creating an offspring in an adjacent empty site, if there is one. Reproduction is *asexual* and consists of creating an offspring that receives the strategy of its parent, with a mutation rate of 0.5%.
(4) Each agent has a 10% chance of dying, making room for future offspring.

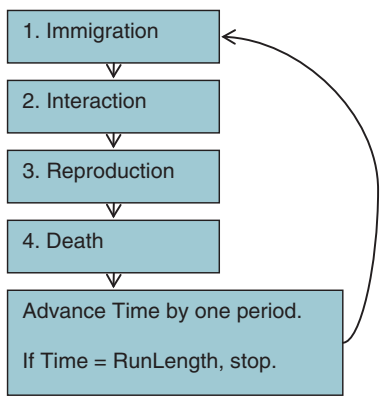

FIGURE 2
Agent-based simulation model (Hammond and Axelrod 2006a, 2006b)

Hammond and Axelrod (2006b) argued that their model can address Putnam's (2000) concept of social capital because it illustrates how contingent altruism creates 'bonding' social capital within groups. Most importantly, however, they suggested further efforts on how to reduce discrimination by creating opportunities to generate 'bridging' social capital between groups. That is also the main point of this study.

3. Experiment design

To trace the evidence of a reasonable explanation of how a Bodhisattva impacts the world, the Bodhisattva is simulated through the FPA agent and the community is represented via the H & A model. That is, the following five agents are adopted in the study: (1) the SA agent proposed in the H & A model, (2) the CA agent proposed in the H & A model, (3) the CO agent proposed in the H & A model, (4) the (ordinary) PA agent proposed in the H & A model, and (5) the FPA agent that acts as an altruistic Dharma disseminator. The latter's agent type is fixed as FPA after each rebirth, while the former four agents evolve according to the genetic PTR.

3.1. Assumptions

To match the Buddhist context, the metaphysical background assumptions that guide this work are elaborated as follows:

(1) A community of the world is represented as the H & A model.

In accordance with the Buddhist perspective, the H & A model will support an operational portrayal of a community that categorizes human beings into four groups. In addition, the H & A model is also prized for its definition of group membership according to colours and tags. Any two individuals in the model who share the same colour belong to the same group and are denoted as *in-group*. Likewise, if the tags of two individuals have different colours, the individuals are denoted as *out-group*. Thus, there is a non-discriminatory intention within pure altruism.

(2) A group of Bodhisattvas, a small proportion to the entire community, is represented by the FPA.

Furthermore, the FPA always performs non-discriminatory pure altruism, or in-group and out-group altruistic behaviours, as he/she has attained *equality wisdom* as a Bodhisattva.

(3) The Bodhisattvas (and thus the FPA) will have no reproduction of offspring but rather will be firmly transmigrated into the world to benefit and enlighten others forever.

While the causes of birth for ordinary sentient beings are indicated by past deeds or karma and defilement, Bodhisattvas are purely reborn by will and the

purpose to benefit others (Nagao 1981). Their 'will' to be reborn gushes forth with the accomplishment of compassionate acts. However, a Bodhisattva accepts a painful life in samsara but embraces no thoughts of fear or disgust, nor is he contaminated by the defilements within the world. From the perspective of the Bodhisattva, samsara means being in a joyful garden. Hence, continuing to transmigrate to benefit others in the world is called the Bodhisattva's firmness (Nagao 1981).

(4) Within the interaction, the neighbours of the Bodhisattvas (and thus the FPA) will always benefit from the Bodhisattvas giving either Dharma or material objects.

Nemeth and Takacs (2007) suggest that teaching can be modelled as a transfer of knowledge, improving the survival chances of the recipient while lowering the reproductive efficiency of the provider. Preaching, or teaching, is understood as a Bodhisattva's giving of Dharma or doctrine, which is more valuable and meritorious than the giving of material objects. A Bodhisattva has all kinds of means and expedients for the instruction and discipline of sentient beings (Dayal 1999); these include the Bodhisattva's physical actions, such as self-sacrifice, renunciation of the body, and internal giving.[1] Such acts are not only symbols of the Buddha's Dharma but also the crucial element that seems to have become the Buddha's Dharma. Ohnuma (1998) argues that the Buddha's giving of Dharma may be seen as the 'tenor' or the idea being expressed, while the Bodhisattva's giving of his body, the inner giving of material objects, may be seen as the 'vehicle' or the image through which the concept is expressed.

The above five assumptions are set for the evolutionary simulation of the Bodhisattva's practice of Buddhism to demonstrate the effect of the Bodhisattva's giving and the associated relationship between a Bodhisattva and a representative community. Because CAs invade the populations of PAs and egoists and then dominate the population (Hammond and Axelrod 2006a, 2006b), this study will focus more on the fundamental dynamics whereby in-group favouritism can be converted into non-discriminatory pure altruism. However, the study has no intention to portray any specific social behaviours and the evolution framework we use is an approach for studying the behaviours of a Bodhisattva.

3.2. Experiment design

In this study, there are four models: (1) the H & A model, which is identical to the H & A model proposed by Hammond and Axelrod (2006a); (2) the FPA-GM model, which includes the FPA agent giving just material objects (GM), such as a PA; (3) the FPA-GD model, which includes the FPA agent giving just Dharma (GD); and (4) the FPA-GMD model, which has the FPA agent giving both material objects and Dharma (GMD).

In the FPA-GM model, we assume the FPA performs the material giving and brings more benefits than PA because the FPA has wisdom superior to that

of sentient beings. That is, the neighbours of the FPA will receive a benefit of b = 0.06, whereas the neighbours of PA will receive a benefit of b = 0.03.

In the FPA-GD model in which the FPA performs solely by teaching the Dharma of altruism to others and enlightens his/her neighbours to perform altruistic behaviours, we assume that the neighbours of the FPA will learn the altruistic behaviour from the FPA, as the FPA owns the wisdom and skills from infinite experience in practising the six perfections, four all-embracing virtues, and boundless deeds. The FPA, like the Bodhisattva Perceiver of the World's Sounds (Avalokiteśvara), has the capability to take on different forms (e.g., colours) to enlighten other sentient beings through preaching the Dharma of altruism. The Dharma will transform the CO or CA neighbour into a PA agent and the SA neighbour into a CA agent. That is, the Dharma can enlighten the SA agent by first changing his/her in-group trait because he/she will learn to expand the circle of self awareness into that of greater self-awareness, i.e., regarding one's related group or family as the greater self. Similarly, the Dharma will enlighten the CA and CO agents to be a PA by changing either in-group or out-group selfish traits into altruistic traits.

In the FPA-GMD model, the FPA preaches altruism to others while giving material aid. Recent developmental research shows that the cultural learning of altruism makes little or no difference to learners' giving if the paradigm that they are inclined to learn from only gives verbal statements of *exhortations or preaching*. Once the paradigm himself makes valuable donations, such preaching in combination with his actions will powerfully disseminate charitable preferences or altruistic behaviour to others (Henrich 2009). In the FPA-GMD model, the neighbours of the FPA will also receive a benefit of b = 0.06, whereas the neighbours of PA will receive a benefit of b = 0.03; meanwhile, the Dharma will transform the CO or CA neighbour into the PA agent and the SA neighbour into the CA agent.

Behaviours of SA, CA, CO, and (ordinary) PA agents of the four models within four stages (immigration, interaction, reproduction, and death), as shown in Figure 2, will follow the experimental designs in the H & A model. Behaviours of the FPA agent within these four stages are as follows:

(1) Immigration: An FPA with no colour enters a random empty site near a random agent. The Bodhisattva will journey throughout the land, saving living beings as well as taking on a variety of different forms, according to Lotus Sutra (Watson 1993). Thus, the FPA will immigrate (be reborn) to the neighbouring place of any one agent.
(2) Interaction: In the case of giving material aid, the neighbours of the FPA will also receive the benefit b = 0.06, while the neighbours of PA will receive a benefit of b = 0.03. In the case of giving Dharma, the Dharma will transform the CO or CA neighbour into the PA agent and the SA neighbour into the CA agent.
(3) Reproduction: The FPA will not reproduce any offspring.
(4) Death: The death rate of FPAs follows the design of the H & A model. That is, the FPA has a 10% chance of dying.

The simulations of these models begin with an empty space of 50 × 50 sites. The simulation environment is the NetLogo environment, as described by Wilensky (1999, 2003).

4. Results

The simulation results shown in Table 1 (rows a, b, c, and d) suggest that the FPA could make more of an impact on the population of the four groups in the FPA-GD and FPA-GMD models, compared to the H & A model. The (standard) parameters are as follows: 3% benefit of giving help, 1% cost of giving help, four tag colours, 0.5% mutation rate per trait, one immigrant per time period, 50 × 50 lattice size, and 2000 periods per run. Data are averaged over the last 100 periods. The range shown is plus or minus the standard error based on 100 runs. The ratios of PA agents reach 14.78%, 20.35%, and 22.61% in the FPA-GM, FPA-GD, and FPA-GMD models, respectively, compared to 15.57% of the H & A model, which lacks the giving of the FPA. This result shows that the giving of Dharma can raise the PA population under the (standard) parameters of the FPA-GD and FPA-MGD models.

The simulation results shown in Table 1 (rows a and b) suggest the populations of four groups in the FPA-GM model to be less different from the ones in the H & A model. This shows that by giving merely material objects, the FPA does not make a significant impact on the population, even though the benefit of the FPA is two times larger than that of the PA. In addition, the ratio of PAs in the FPA-GM model is less than that in the H & A model. In the FPA-GD model, the CA population decreases while the PA population increases (Table 1, rows a and c), indicating that some CAs have been influenced by the persuasion of the FPA. The FPA-GMD model features a high level of pure altruism with respect to the mechanism of combining the giving of material objects and Dharma by the FPA (Table 1, rows a and d). Table 1 also shows that the ratios of CAs in the FPA-GM, FPA-GD, and FPA-GMD models are less than those of the H & A model, whereas the ratios of SAs are increased.

Table 2 shows the average potential to reproduce (APTR) of the four groups in the four models. The results demonstrate that the preaching or teaching of FPA influenced more pure altruists to help others and, consequently, elevated the

TABLE 1
Comparison among the four models

	PA%	CA%	CO%	SA%
(a) H&A	15.57 ± 3.52	78.72 ± 4.22	1.23 ± 0.68	4.48 ± 2.41
(b) FPA-GM	14.78 ± 4.32	74.96 ± 4.80	2.26 ± 0.81	8.00 ± 1.78
(c) FPA-GD	20.35 ± 4.28	69.59 ± 4.88	2.53 ± 0.83	7.53 ± 1.46
(d) FPA-GMD	22.61 ± 4.64	67.67 ± 4.80	2.61 ± 0.80	7.11 ± 1.43

Notes: PA%: the proportion of pure altruists among the four groups, CA%: contingent altruist percentage, CO%: cosmopolitan agent percentage, and SA%: selfish agent percentage.

TABLE 2
Average PTR across the four models

	PA-APTR	CA-APTR	CO-APTR	SA-APTR
(a) H&A	15.94 ± 0.23	16.56 ± 0.12	12.43 ± 0.42	13.57 ± 0.25
(b) FPA-GM	15.85 ± 0.25	16.47 ± 0.10	13.38 ± 0.52	14.22 ± 0.26
(c) FPA-GD	15.92 ± 0.21	16.51 ± 0.12	13.68 ± 0.38	14.29 ± 0.24
(d) FPA-GMD	16.10 ± 0.17	16.54 ± 0.11	13.70 ± 0.48	14.37 ± 0.27

Notes: APTR: average PTR.

APTR levels of all four groups (Table 2, rows a, c, and d). In addition, the results of the FPA-GM model are similar to those of the H & A model, indicating that the FPA's giving material objects has less effect on the benefit of PA (Table 2, rows a and b). Most importantly, however, the APTR level of the PA in the FPA-GMD model is higher than that in the FPA-GD model (Table 2, rows c and d). This might explain why the population rate of PAs in the FPA-GMD model is higher than that in the FPA-GD model (Table 1, rows c and d). However, the side effect of having more PAs providing a higher likelihood of free riding is that the ratio of SAs also increases (Table 1, rows b, c, and d).

The pure altruistic strategy in the FPA-GMD model is sensitive to widely varying ranges of parameters and variations in the model. When any of the following demographic parameters are either halved or doubled, at least 15.95% of the population becomes PAs: costs, mutation rates, group numbers, lattice width, and duration of the run (see the results of the sensitivity analysis in Table 3). The simulation results also show that the CA is just as dominant in a variant of the FPA-GMD model (more than 48% of agents compared to 75%, if no FPA enters into the community), even though no bias toward others that are similar is built into the model. However, most importantly, the population of PAs becomes more than that in the H & A model when the FPA gives both Dharma and material objects.

TABLE 3
Population rate over a range of parameters in the FPA-GMD model

	PA%	CA%
(a) standard	21.35 ± 4.00***	68.86 ± 4.35***
(b) costs:0.005	27.19 ± 4.21***	65.58 ± 4.20***
(c) costs:0.02	15.95 ± 3.52***	60.85 ± 5.95***
(d) mutation rate:0.0025	18.59 ± 4.29***	74.66 ± 4.78***
(e) mutation rate:0.01	25.54 ± 4.08***	59.15 ± 4.71***
(f) colors:2	28.33 ± 5.66***	59.52 ± 5.86***
(g) colors:8	19.42 ± 3.57***	71.36 ± 4.10***
(h) lattice size:25 × 25	34.99 ± 8.18***	48.61 ± 9.20***
(i) lattice size:100 × 100	16.21 ± 1.98***	75.60 ± 2.33***
(j) runs: 1000	24.97 ± 5.03	64.96 ± 5.14
(k) runs: 4000	21.21 ± 3.89	69.03 ± 4.15

Note: *$p < 0.1$, **$p < 0.01$, ***$p < 0.001$.

Most of the variants shown in Table 3 affect the basic result (the predominance of CA), except for runs. It is interesting to note how each parameter change affects the results. The higher the cost (b, a, c), the less pure the altruism because the environment is austere. The more 'randomness' via mutation (d, a, e), the more pure the altruism because tags become less accurate indicators of relatedness, which makes discrimination less effective. The more colours (f, a, g), the less pure and the more contingent the altruism because tags become more discriminatory. The more space (h, a, i), the less pure the altruism because the FPA will have a greater effect on a small community. Thus, most of the parameters do impact the results in the FPA-GMD model. However, the preaching effects of FPA seem to be mostly sensitive to the parameter of lattice size or population size (Table 3, rows h, i, and a).

Figure 3 shows the dynamics of evolution over population size in the H & A and FPA-GMD models. It demonstrates that the number of PAs is inversely correlated to population size while the number of CAs is positively correlated to population size for the FPA-GMD model, indicating that the larger the population is, the less the FPA's influence on pure altruism. In particular, when the population size is 150 × 150, the population rate of PAs is reduced to 15.82%, similar to the 15.57% in the H & A model (Table 1, row a). It can also be observed that the preaching effect of FPA will decrease as the population increases because the effect is supplanted by the evolutionary genetic effects. Somehow, with a population of 400 (20 × 20), the FPAs represent 0.25% of the population, and the number of PAs is more than that of CAs, which indicates that the preaching of FPAs makes a difference on such a small community. Moreover, the difference in the PA ratio between the H & A and FPA-GMD models can be referred to as the effect of FPAs offering teachings and material objects. However, this effect will gradually diminish as the population grows. In brief, the FPA has more influence in a small community than in a big community.

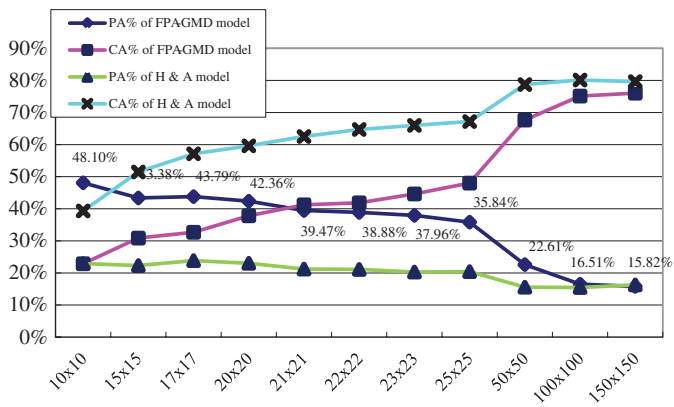

FIGURE 3
Evolution over population size

Examining the dynamics of the model reveals how the FPA enlightens more individuals in pure altruism via the giving of Dharma and material objects. In the early periods of a simulation run, the scattered immigrants created regions of similar agents (Figure 4a). Colonies of those willing to cooperate with a different colour (i.e., the PAs) will tend to grow faster than those willing to cooperate with only their own colour (i.e., the CAs), but over time, PAs face the problem of free riding by CAs, who accept the benefits from PAs. The CA who free rides suppresses the PA and therefore tends to dominate in an entire region (Figure 4b).

Figure 5 is an example that explains the process of FPA persuasion. The most important aspect of regional dynamics is that the CA and PA regions will tend to expand in the FPA-GMD model, as FPAs will change the characteristics of SA, CA, and CO agents (i.e., SAs will convert to CAs, COs will convert to PAs, and CAs will convert to PAs). For instance, in Figure 5a, the square is an empty space in which the two selfish agents (empty triangles) have more opportunities to reproduce

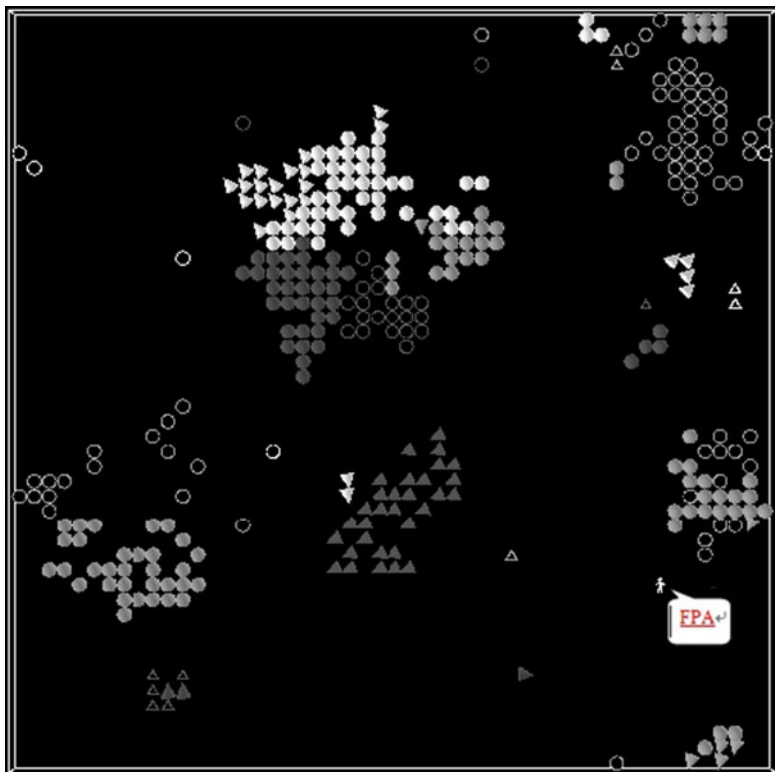

FIGURE 4a
The typical run of the FPA-GMG model after 100 periods. The five tag types are represented as shades of filled-in circles (PA), empty circles (CA), filled-in triangles (CO), empty triangles (SA), and person type (FPA)

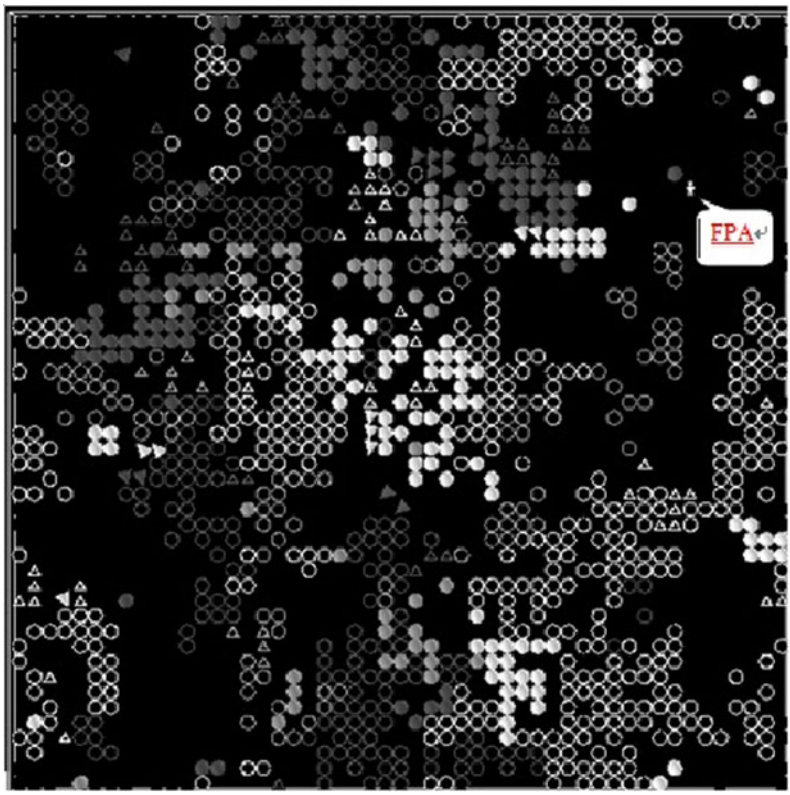

FIGURE 4b
The typical run of the FPA-GMG model after 2000 periods.Although such results demonstrate a limitation of the Bodhisattva tendency to persuade people to adopt a pure altruistic strategy by increasing the population size, he/she does make a difference in the smaller community

than do the CAs (empty circle). After the FPA persuades his/her neighbours with the Dharma of altruism in Figure 5b, the SA agent (the upper empty triangle in Figure 5a) becomes a CA agent (empty circle in Figure 5b), and the CA (empty circle in Figure 5a) becomes a PA (filled-in circle in Figure 5b). The result is that the empty square region will be replaced by a PA, CA, or SA agent (Figure 5b). However, the likelihood of it being a PA or CA is larger than that of it being an SA because the PTR of the PAs and CAs, by the FPA's giving of material objects, is larger than that of the SA.

5. Discussion

The results show that the Bodhisattva can create more pure altruists in the community through the giving of Dharma and material objects, although this

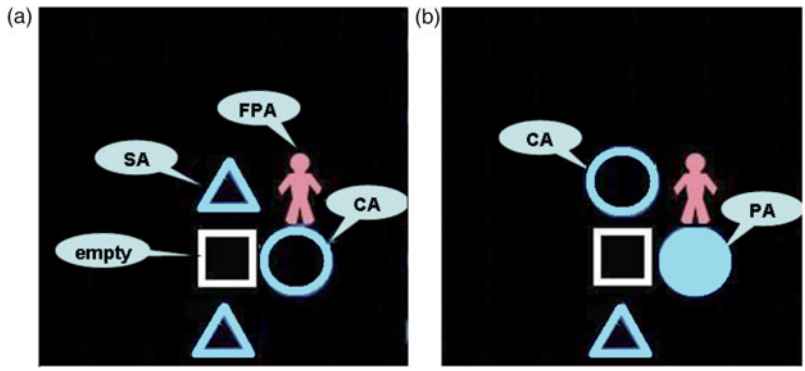

FIGURE 5

An example of how the FPA (person shape) changes the reproduction of the agent. Figure 5a is the situation before the FPA's giving of Dharma, while Figure 5b is the situation after the FPA's persuasion by the giving of Dharma. The empty site is represented by an empty rectangle, the CA by an empty circle, the SA by an empty triangle, and the PA by a filled-in circle

effect is limited to population size. As the old English proverb instructs, *Give a man a fish, and you have fed him for today. Teach a man to fish, and you have fed him for a lifetime*. This finding helps to explain how pure altruists might have evolved under the influence of a Bodhisattva and why such teaching might easily lead to a greater population of pure altruists. The simulation results shown in Table 1 also indicate that CA agents dominate the population in the four models because they receive benefits both from the same-coloured CAs (in-group cooperation) and the different-coloured COs (out-group cooperation), in addition to the free riding of PA benefits. Thus, the CA population outperforms the others.

Just as Hammond and Axelrod (2006b) demonstrate the way in which contingent altruism creates 'bonding' social capital within groups (Putnam 2000; Wuthnow 2002), our result may indicate that a Bodhisattva's giving can cultivate more PA agents to 'bridge' social capital between groups. This also generates net benefits, whereby the average welfare of all groups rises if we consider average PTR as a measure of welfare, according to Becker (1976). Due to his/her great compassion, such a Bodhisattva has the will to enlighten and benefit others by the four all-embracing virtues, i.e., giving (material objects, Dharma, and fearlessness), affectionate speech, conduct that is beneficial to others, and cooperation. Noticeably, the results nearly match the suggestion of Henrich (2009) that the preaching of altruism should be accompanied by the giving of material objects (Figure 5).

However, even the FPA's preaching of Dharma alone improved the level of pure altruism. The results also reveal the limitation of a Bodhisattva to persuade people to adopt a pure altruistic strategy when the population size is large. Most specifically, the population size does not matter, but rather, the FPA proportion in

the population matters: the more Bodhisattvas that enter the community, the more pure altruism that will dominate the population. According to the *Lotus Sutra*, the only significant reason for the Buddha to appear in this world, the real meaning of the Buddha Dharma and the real purpose of Buddha's teachings, is to allow sentient beings to realize the Buddha's knowledge and views and the Buddha's great *bodhi* (awakening). Thus, Mahāyāna Buddhism, the Great Vehicle doctrine, encourages human beings to attain his *bodhi* mind, practise the Bodhisattva deeds, and attain Buddhahood (Yin-shun 1998). The more Bodhisattvas there are in the community, the more pure altruism there will be, and thus, the greater welfare in that society.

Regarding CA, PA, and FPA agents, further discussion is required on the practice of Buddhism from a Buddhist worldview. The altruistic dimension of Buddhism in this paper is explored in relation to the concept of altruism as defined in the *Mahāparinirvāṇa Sūtra*. The definitive passage in this text is as follows:

> Bhagavat, there are three kinds of *maitrī* [loving kindness]: 1) that which has beings as object (*sattvālambana*); 2) that which has things as object (*dharmālambana*); 3) that which has no object (*anālambana*). It is the same for *karuṇā* [compassion], *muditā* [sympathetic delight] and *upekṣā* [equanimity]. . . . The *maitrī* that has beings as object is concerned with the five skandhas and wishes to bring them happiness: we say that it has beings as object. The one that has things as object is concerned with the things that are necessary to beings and brings them to beings: we say that it has things as object. The one that has no object concerns the Tathāgata: we say that it has no object. In general, *maitrī* concerns poor beings (*daridrasattva*), but the Tathāgata, the great Teacher, is always free of poverty and enjoys absolute happiness (*paramasukha*). Thus, although it concerns beings, *maitrī* does not concern the Buddha. It is the same for the *maitrī* that concerns objects. O Bhagavat, the *maitrī* that has all beings as object concerns, for example, a father, mother, wife, son, relative; consequently we say that it has beings as object. The *maitrī* that has things as object does not see the father, mother, wife, son, relative; it sees all the things that result from causes and conditions (*pratītyotpanna*): we say that it has things as object. The *maitrī* that has no object is based upon neither the characteristic of a thing (*dharmanimitta*) nor the characteristic of a being (*sattvanimitta*): we say that it has no object. It is the same for the minds of *karuṇā*, *muditā* and *upekṣā*. (Lamotte 1970, 1027. Terms in square brackets provided by the present authors.)

The CA in Buddhism practises altruism based upon beings, while a CA in biology practises altruism based upon the relatives sharing the same genes. The PA in Buddhism practices altruism that relates to things (*dharmas*), while the PA in biology practises pure altruism. However, the FPA that the present authors postulate practises an 'objectless' altruism.

Firstly, following the *Mahāparinirvāṇa Sūtra*, the CA can be interpreted as one who 'has all beings as object'. Altruism of this kind can be matched to the

kinship or CA agent. Beyond the altruism of the CA, the PA follows the rule of benefiting others, regardless of existing kinship, even though he/she will be replaced by his/her offspring, according to the probability of PTR. From the Buddhist perspective, he/she might be regarded as a Bodhisattva in the stage(s) prior to entering the 'grounds' (*bhūmis*) because he/she discriminates no difference between self and others, and performs in-group and out-group altruist behaviours. In contrast to these two ordinary types of compassion, the FPA belongs to an *objectless type* whose compassion is based neither on *dharma* nor *beings*, according to the *Mahāparinirvāṇa Sūtra*. With the wisdom of non-duality, he/she does not dwell in nirvana but rather saves sentient beings in samsara due to his will or the vows raised by his great compassion. The FPA represents a non-retrogressive Bodhisattva who has reached a truly boundless or non-dual wisdom and performs in-group and out-group altruistic behaviours at each rebirth. Thus, our new model, the FPA-GMD model, suggests the way in which a Bodhisattva changes the traits of human beings in order to elevate the welfare of all four groups, if, following Becker (1976), we regard PTR as a measure of well-being.

The theory of kinship altruism in biology is similar to the altruism based on the statement in the *sūtra*:

> The *maitrī* that has beings as object is concerned with the five skandhas[2] and wishes to bring them happiness: we say that it has beings as object. ... the *maitrī* that has all beings as object concerns, for example, a father, mother, wife, son, relative. (Lamotte 1970, 1027)

Both sides begin with benefit as the goal, but the difference is how 'profit' is interpreted. In biology, the so-called 'profit' is material interest for the sake of survival, just as kinship altruism is based on the existence of gene duplication and species propagation. The *Mahāparinirvāṇa Sūtra* tells us that altruism in Buddhism is modified by three circumstantial factors or objects for loving-kindness. Altruism in which love or compassion is related to all beings bears upon parents, wife, children and relatives. It is limited to the Bodhisattva's human affinities, which is similar to the kin altruism in biology. However, altruism based upon compassion relating to things (*dharma*) and objectless compassion are the unique characteristics of Buddhism. Compassion relating to all living beings is to offer things to make living beings physically and mentally peaceful and happy. Compassion relating to things (*dharma*) refers to providing all the things required by all living beings beyond physical and mental satisfaction. All the materials and tools beings require to be pain free and happy are within its scope. Compassion relating to *dharmas* is not limited by affinities with other beings. Therefore, its altruism can be expressed by the PA of Hammond and Axelrod (2006a) which gives help not limited by affinities with beings. The core concept of compassion relating to things as object 'does not see the father, mother, wife, son, relative; it sees all the things that result from causes and conditions' (Lamotte 1970, 1027).

The objectless compassion originated by the wisdom of emptiness, is one without any cause and condition. In general, the object of compassion is poor beings, whereas the object of 'objectless' compassion is the Tathāgata. However, the Tathāgata is the enlightened one and is permanently free from poverty and suffering, and has attained the ultimate happiness. So, how is it possible to help the Tathagata from any suffering? We cannot relieve the Tathāgata of any suffering, which means, no compassion can be expressed. Therefore, when we see a living being as an unenlightened Tathāgata, we see no difference between the giver, the recipient, and the offering of compassion towards them. The *Diamond Sutra* (*Vajracchedikā*) explains the difference between compassion relating to things (*dharma*) and objectless compassion:

> Therefore the Buddha says, 'the heart of a Bodhisattva should not dwell in forms when he gives.' Subhåti, a Bodhisattva, to benefit all beings, should give thus. All marks are spoken of by the Tathàgata as no marks, and all living beings are spoken of as no living beings. Subhåti, the Tathàgata is one who speaks the truth, who speaks the actual, who speaks what is so, who does not speak what is false, who does not speak what is not so. (Shih 1974, 171)

> Subhåti, a Bodhisattva whose heart dwells in dharmas when he gives is like a man who enters darkness, who cannot see a thing. A Bodhisattva whose heart does not dwell in dharmas when he gives is like a man with eyes in the bright sunlight who can see all kinds of forms. (Shih 1974, 176)

Therefore, the PA of H & A model follows the PTR rule, and represents the Bodhisattvas who have not ascended to the ten grounds (*bhūmi*), while FPA does not follow the PTR rule and sustains rebirth (transmigration) back into the Sahā world to benefit living beings, and can be regarded as the firm or irreversible Bodhisattva.

In conclusion, compassion in Buddhism features several different levels in practice. The top level highlights the objectless altruism of ultimate reality. The *Mahāparinirvāṇa Sūtra* teaches us how to practise the giving of Dharma or material objects (or 'so-called' giving in this text) as follows:

> 'When the Bodhisattva-mahasattva practices giving, his kind heart sees all beings equally, like unto his own only son. Additionally when giving, his compassionate heart bestirs itself, as when a father and mother look at their own son who is ill. When giving, his heart feels joy, as when the father and mother see their child's illness cured. When giving is performed, his mind is away from [not attached to] what is given, as when a father and mother see their son already grown up and living by himself.' This Bodhisattva-mahasattva always vows when he benevolently gives foods: 'I now give this and share it with all beings and intend that by the causal relations of this act all beings should attain the food of Great Wisdom and with effort transfer the merit thereof to unsurpassed Mahayana.' (Yamamoto 2007, 209)

Therefore, the biggest difference between biology and Buddhism with respect to altruism is that Buddhism emphasizes the qualitative improvement in the welfare of all beings, while biology only focuses on the quantitative increase in population. Moreover, Buddhist altruism also contains the soteriological pursuit of understanding reality.

We have demonstrated that the giving of Dharma accompanied by the giving of material objects by a Bodhisattva might be an effective mechanism to improve the level of pure altruism and benefits of human beings in a smaller community. However, other parameters, such as cost, mutation rate, and colour, might be worthy of exploration in future work. The welfare of a human being refers to the average potential to reproduce (PTR) of an agent, according to Becker (1976). However, how a Bodhisattva improves the other qualitative measurements of a human being by examining other Buddhist literature or psychological models is another challenge for the future.

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NOTES

1. Giving of material objects is divided into 'external giving', which is giving of external objects, and 'internal giving', which is giving of the body.
2. The so-called five 'aggregates' (*skandha*) are collections of ultimate constituents that the Buddha analysed to be what we perceive to be self and the phenomenal world. A person is understood to exist on the basis of the organization of these five aggregates. A personal ultimate essence, is understood not to exist through the deconstruction of these aggregates. These five are subdivided into two types:

(1) *rūpa* (sensory materiality) and (2) *nāma* (subjective processes), which, when aggregated, are together called *nāma-rūpa* (Lusthaus 2002).

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