Evolution and Human Behavior 37 (2016) 159–168

Contents lists available at ScienceDirect

Evolution and Human Behavior

journal homepage: www.ehbonline.org

Original Article

Reward currency modulates human risk preferences

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ARTICLE INFO

Article history:
Initial receipt 19 January 2015
Final revision received 13 October 2015

Keywords:
Decision-making
Risk preferences
Money
Apes
Comparative cognition

ABSTRACT

Monetary and biological rewards differ in many ways. Yet studies of human decision-making typically involve money, whereas nonhuman studies involve food. We therefore examined how context shifts human risk preferences to illuminate the evolution of decision-making. First, we assessed peoples' risk preferences across food, prizes, and money in a task where individuals received real rewards and learned about payoffs through experience. We found that people were relatively more risk-seeking for both food and prizes compared to money—indicating that people may treat abstract reward markers differently from concrete rewards. Second, we compared human risk preferences for food with that of our closest phylogenetic relatives, chimpanzees (*Pan troglodytes*) and bonobos (*Pan paniscus*), in order to illuminate the evolutionary origins of human decision-making strategies. In fact, human and chimpanzees were both relatively more risk-seeking compared to bonobos. Finally, we investigated why people respond differently to money versus concrete rewards when making decisions. We found that people were more risk-prone when making decisions about money that was constrained as a store of value, compared to money that could be freely exchanged. This shows that people are sensitive to money's usefulness as a store of value that can be used to acquire other types of rewards. Our results indicate that humans exhibit different preferences when making risky decisions about money versus food, an important consideration for comparative research. Furthermore, different psychological processes may underpin decisions about abstract rewards compared to concrete rewards.

1. Introduction

Monetary rewards fundamentally differ from primary biological rewards like food. While food is of central importance to both humans and other animals, money is an evolutionarily novel currency. Moreover, money has several properties that distinguish it from biological rewards: it serves as an abstract store of value, it can be flexibly converted into other rewards, and it can take on very large values. Indeed, some theoretical views suggest that money functions as a tool allowing people to acquire their actual goals (Lea & Webley, 2006). Although there have been few studies of the psychological underpinnings of money, some evidence indicates that money can have a large impact on people's goals and behavior. For example, rewarding people with money makes them more sensitive to tradeoffs between effort and compensation (Heyman & Ariely, 2004). Even priming people with monetary concepts can result increased self-sufficiency and reduced willingness to help others (Caruso, Vohs, Baxter, & Waytz, 2013; Vohs, Mead, & Goode, 2006). Yet despite the influence of money on human behavior, most studies of human decision-making focus only on this currency. Studies involving money are critical for understanding present-day economic behavior, but it is unclear if these kinds of decision-making tasks also capture the choice processes that humans use to make decisions about biologically-relevant rewards.

Do similar decision-making processes support choices about both money and biologically-central rewards like food? In fact, several pieces of evidence suggest that people may use different strategies when they are trying to accumulate money, compared to when they face decisions about food or other primary rewards that emulate foraging contexts. For example, people tend to discount delayed food or juice rewards more heavily than even small amounts of money (Estle, Green, Myerson, & Holt, 2007; Jimura, Myerson, Hilgard, Braver, & Green, 2009; McClure, Ericson, Laibson, Loewenstein, & Cohen, 2007; McClure, Laibson, Loewenstein, & Cohen, 2004; Odum, Baumann, & Rimington, 2006; Rosati, Stevens, Hare, & Hauser, 2007). Similarly, people are more risk-prone for juice compared to small amounts money when tested in the same setup for both reward types (Hayden & Platt, 2009) (but see Estle et al., 2007). Patterns of lifespan change in decision-making also suggest an important distinction between the choice processes involved in decisions about money versus food: whereas younger adults discount monetary rewards more steeply than older adults, both age groups showed similar temporal choices about juice (Jimura et al., 2011). Finally, neuroimaging data examining the neural substrates supporting value-based decision-making indicate that the brain regions encoding value are distinguishable based on whether the rewards are money versus consumable rewards (see Clithero & Rangel, 2014 for a meta-

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http://dx.doi.org/10.1016/j.evolhumbehav.2015.10.003
1090-5138/

analysis of imaging studies examining different reward currencies). Overall, this evidence suggests that people make value-based decisions differently when faced with decisions about food versus money. One possibility is that this stems from a magnitude effect: decisions about higher-value rewards are sometimes treated differently from lower-value rewards (Green, Myerson, & McFadden, 1997; Holt & Laury, 2002), so money and consumables might fall into those respective categories. Alternatively, there may be something fundamentally different about money versus food rewards, even if their values are relatively well-matched. Either way, this evidence suggests that reward type can alter the strategies that people use when making decisions.

These results pose a challenge to understanding the evolutionary origins of human decision-making: nonhuman studies of decision-making typically involve choices about food rewards, hindering comparisons between humans and other species. Yet comparative studies of the traits of different species are one of the most powerful tools in evolutionary biology for illuminating the historical process of natural selection. The comparative method can help pinpoint when specific traits emerged in phylogeny, as well as illuminate the emergence of these traits in relation to variation in species' socioecological characteristics (Clutton-Brock & Harvey, 1979; Harvey & Purvis, 1991; Mayr, 1982). Such comparisons have been critical for understanding the evolution of behavioral and morphological characters, and more recently have been fruitfully applied to the problem of cognitive evolution as well (Amici, Aureli, & Call, 2008; MacLean et al., 2012; Sherry, 2006). Indeed, comparisons of human cognition with that of other species, especially our closest relatives the great apes, have been a critical source of evidence for evaluating hypotheses about human uniqueness (Hare, 2011; Hill, Barton, & Hurtado, 2009; Kaplan, Hill, Lancaster, & Hurtado, 2000; Penn, Holyoak, & Povinelli, 2008; Suddendorf & Corballis, 2007; Tomasello, Carpenter, Call, Behne, & Moll, 2005), including understanding the origins of human economic decision-making (Santos & Rosati, 2015). However, given that humans can respond differently to decisions about different currencies, human and animal tasks that appear similar may actually recruit different psychological processes (Blanchard, Wolfe, Vlaev, Winston, & Hayden, 2014).

To understand the evolution of human-like decision-making, it is therefore critical to equate the problems faced by humans and other animals. In fact, studies of decision-making in humans and nonhumans differ in several other relevant ways in addition to the differences in reward currencies used across species. For example, human decision-making tasks often involve one-shot choices about (hypothetical) monetary amounts presented in a linguistic format (e.g., "Would you prefer a 50% chance of winning $20?"). In contrast, nonhuman studies typically involve a series of iterated choices about consumable rewards, where animals learn about reward payoffs through direct experience. There is some evidence that all of these contextual factors can influence human preferences. For example, people exhibit steeper temporal discounting when making iterated compared to one-shot decisions (Schweighofer et al., 2006). People also show different risk preferences when choosing from description versus experience (Barron & Erev, 2003; Hertwig, 2012; Hertwig & Erev, 2009), by overweighting rare outcomes when making risky decisions from description but relatively underweighting these outcomes when making decisions from experience (Hertwig, Barron, Weber, & Erev, 2004). Finally, the potential disparity between real and hypothetical responses is also a major concern in both psychological and economic research (Green & Myerson, 2004; Hertwig & Ortmann, 2001; List & Gallet, 2001). Some evidence indicates that people can exhibit greater risk-aversion when monetary rewards are real then when they are hypothetical (Holt & Laury, 2002, 2005), whereas other studies have found similar choices for real and hypothetical monetary rewards (Johnson & Bickely, 2002; Lagorio & Madden, 2005; Madden, Begotka, Raiff, & Kastern, 2003; Wiseman & Levin, 1996). Overall, these findings suggest that contexts can affect human decision-making patterns, and many of the ways in which typical human studies differ from typical nonhuman studies make direct comparisons challenging.

In the current studies, we examine how reward currency influences people's preferences risk, or probabilistic variation in payoffs. Decision-making under risk is a critical theoretical issue in psychology and economics as well as biology (Kacelnik & Bateson, 1996, 1997; Platt & Huettel, 2008; Tversky & Kahneman, 1981), so risky choice is a domain that is well-suited for evolutionary approaches to decision-making. Some theories have proposed that risk-aversion is a widely conserved foraging strategy, as a variety of nonhuman species ranging from insects, birds, and mammals are broadly risk-averse for gains when making decisions about food (Kacelnik & Bateson, 1996, 1997). Given that humans also tend to be risk-averse when making decisions about monetary gains (Kahneman & Tversky, 1979, 2000; Tversky & Kahneman, 1981), this suggests that humans and many nonhumans may exhibit risk aversion due to shared common descent. However, several primate species – including rhesus macaques (*Macaca mulatta*), capuchins (*Cebus apella*), and chimpanzees (*Pan troglodytes*) – show more risk-seeking patterns of choice than other species in similar contexts (De Petrillo, Ventricelli, Ponsi, & Addessi, 2015; Heilbronner & Hayden, 2013; Heilbronner, Rosati, Stevens, Hare, & Hauser, 2008). Importantly, chimpanzees are specifically more risk-seeking when contrasted with bonobos (*Pan paniscus*) on matched comparisons across several different tasks (Haun, Nawroth, & Call, 2011; Heilbronner et al., 2008; Rosati & Hare, 2012, 2013). Although chimpanzees and bonobos are humans' two closest living relatives – diverging from each other less than 1 mya (Prüfer et al., 2012) – most theoretical claims about behavioral and cognitive evolution in humans tend to use chimpanzees alone as a model for the last common ancestor of humans with apes (Wrangham & Pilbeam, 2001). However, recent work involving comparison of both species suggests that the last common ancestor may in fact have had a mosaic of chimpanzee-like and bonobo-like traits across different behavioral domains (Hare & Yamamoto, 2015). The critical test of whether human risk preferences are evolutionarily derived or evolutionary conserved is to therefore to examine humans and our closest phylogenetic relatives in a matched decision-making context.

Our study therefore had two main goals. First, we examined how currency influences human choice preferences. While previous research has shown that humans differentiate money (secondary reinforcers) and consumable rewards like food (primary reinforcers) when making decisions (including when making decisions under risk; Hayden & Platt, 2009), it is currently unclear why people respond differently to these currencies. One possibility is that consumables like food are treated as a 'special' or distinct category of reward (Rosati et al., 2007). However, humans may also respond differently to abstract markers of value, like money, compared to other more concrete rewards—regardless of whether they are consumable. To test this, in Study 1 we compared human risk preferences in the same setup for food, prizes, and money. As prizes are not a primary reward (in contrast to food) but are also not an abstract marker of value (in contrast to money), this comparison can disentangle why humans might treat these currencies as different. Importantly, we used small amounts of food, small amounts of money ($1 or less), and prizes with matched economic values to the money. Many magnitude effects in human decision-making stem from comparisons involve very large differences ranging from 20 to 1000 times as large (e.g., $100 versus $100,000; Green et al., 1997; Holt & Laury, 2002, 2005; Kirby & Marakovic, 1996), whereas comparative studies of animal decision-making comprising these smaller variations in value have not revealed consistent magnitude effects (Green, Myerson, Holt, Slevin, & Estle, 2004; Stevens, Rosati, Ross, & Hauser, 2005) (but see Ludvig, Madan, Pisklak, & Spetch, 2014). This methodological approach therefore minimizes the likelihood that our comparison was capturing magnitude effects alone. In Study 2, we then examined how money's unique characteristics may influence people's preferences. In particular, we examined whether risk preferences for money depend on that money's usefulness as a store of value that can be exchanged for other rewards. Finally, all participants completed a hypothetical risk questionnaire involving choices about small amounts of money