

The Ecology of Cooperation: Considerations for Litter Research

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Summary

This article examines the role of intertemporal choice and relative inequality, with a focus on how socioeconomic conditions and environmental pressures can yield differing cooperative strategies which impact on littering behaviour and anti-littering interventions. We apply a framework emerging from behavioural biology that has great explanatory utility and which permits researchers to consider a frequently overlooked element in littering, which is key variation within populations.

1. Introduction

There is often a disconnect between desired environmental change and the short-term costs required to deliver it. Environmental ambitions are set at many levels (local, national or international) while the behaviours that will lead to change are reliant on individual execution. For example, reducing the amount of single-use plastics one uses will not result in an immediate, observable reduction of plastic waste in the Pacific gyre. Nonetheless, a population of individuals delivering on this behaviour will have an impact over the long run. Environmental outcomes require the concerted action of individuals who are able to forecast change and place value on the future benefits.

Kolodko and Read (2018) discussed this tension, within the context of littering interventions, noting that short-term goals may outcompete any distal future considerations and that this behavioural situation is not to be seen as necessarily irrational at the individual level, especially when understood as a commons dilemma (Hardin, 1968). They went on to discuss a variety of nudge techniques that might be

used to direct behaviour toward litter reduction. In this paper we will extend the argument of Kolodko and Read in order to focus upon the nature and cause of individual differences in cooperative behaviours within commons and other settings. We will approach this task as behavioural biologists, rather than social scientists, and argue that various forms of cooperation rely on the ability to forecast future social benefits. There are clear individual differences in this ability and some of those differences are developmental outcomes, broadly understood as a consequence of ecological exposures throughout lifespan. We will present one framework for capturing these outcomes that has the distinct advantage of predicting variance in a wide variety of behavioural and somatic phenotypic expression. This framework suggests patterning in littering behaviour is a function of what social scientists refer to as socioeconomic status. Our argument is that socioeconomic status is a marker of ecological realities and is therefore a useful and relatively easily assessed proxy for ultimate causes.

For the purposes of this paper we are defining littering, in broad terms, as the placement of an unwanted item in an area not designated for waste disposal or collection. This can be actively or passively achieved (Sibley and Liu, 2003) and can include anything from discarding food packaging and unwanted food, through to illegal dumping of waste (i.e. fly-tipping).

The paper is structured as follows: First, we provide an introduction to behavioural biology and life-history theory to explore the role of fitness-maximisation in explaining behavioural adaptations (Section 2). We then highlight how cooperation can emerge and evolve within related and non-related populations (Section 3). In Section 4 we discuss how inter-temporal choice and relative inequality affect discount rates which is crucial in stabilizing cooperative behaviour. We then discuss a number of potential interventions (Section 5) based on varied ecologies, before offering some concluding remarks (Section 6).

2. Behavioural biology

Behavioural biology is primarily focused on evolutionary accounts of behaviour. Much of the development of evolutionary biology was achieved through developments in behavioural science, with a focus on social behaviours. This is because social behaviours present specific questions for evolutionary theory, and we shall discuss cooperation below. To begin, however, we must outline the core theoretical commitments of behavioural biology (BB).

As an evolutionary discipline BB is focused upon adaptations, where an adaptation is any trait that operates in such a way as to increase the relative frequency of its underlying genes within the population gene pool. The concept of fitness captures the idea that organisms are vehicles that act to further the replication of the genes that built them (Dawkins, 1989). Fitness is not a property of individuals, but is a modelling concept that enables the examination of evolutionary effects. Thus, individual fitness is increased directly by reproduction, such that genes are replicated and represented across generations and fitness is increased indirectly by the reproduction of genetic relatives, or kin. Traits that increase successful direct and indirect reproduction are adaptations. The sum total of fitness maximizing effort is referred to as inclusive fitness. Inclusive fitness theory assumes that organisms act to maximize their average lifetime inclusive fitness, and behaviours that do this are adaptations that have been selected through evolutionary time (West and Gardner, 2013). Testing this baseline hypothesis is the business of BB.

Behavioural adaptations introduce flexibility, or plasticity, enabling organisms to deal with change. This is a key point. Behaviour is a method of calibrating organisms to complex environments in a way that will enable their survival and reproduction (Godfrey-Smith, 1996, 2002). Behaviours calibrate on a moment-to-moment basis, through learning and also through core developmental processes.

A key framework for BB is life history theory, originally cast in terms of r/K selection (Pianka, 1970). Both r and K are parameters in ecological equations, where r denotes

the reproductive growth rate of a population and K the carrying capacity. The basic idea was that carrying capacity could check reproductive growth rate, but also that different option spaces existed for organisms within this dynamic. Thus, in species that were heavily r -selected, more effort would be put into reproduction, and one would expect to see rapid development from birth to sexual maturity, high levels of reproduction, and little specialization. In contrast, heavily K -selected populations would consist of organisms that were slow to develop, had relatively low rates of reproduction, and became niche specialists as they dispersed and moved into particular ecologies due to local carrying capacity constraints. These two parameters are not, in fact, equivalent to one another, and life history theory repackaged these ideas in terms of fast versus slow life-history strategies (Stearns, 1977, 1980, 1992) where slow life histories enabled the development of specializations. Species can be ranked in terms of the relative speed of their average life-histories, but within species there is also variance, indicating a variety of strategic options as a function of circumstances.

The notion that life-histories are strategic is important. Developing organisms are regarded as collecting information about their environmental circumstances and using this to establish rational, fitness maximizing strategies. This is an optimality assumption that incorporates the notion of trade-offs. The key trade-offs in life-history theory are those between current versus future reproduction and the quantity versus quality of offspring produced. These trade-offs are a response to current and predicted resources, where resources are broadly construed to include such things as access to calories and nutrients through to social benefits. At some point in development trade-off strategies may become fixed, but it is important to be clear about what this means. Recent life history theory research into age at first pregnancy in humans demonstrated that maternal birthweight, breast-feeding regime, and socioeconomic status were all predictors. Specifically, early first pregnancies were predicted by low birthweight, reduced breast feeding and low socioeconomic status of the mother (Coall *et al.*, 2011; Nettle *et al.*, 2011). Moreover, these young mothers reached sexual maturity and other developmental milestones sooner than their matched controls (Nettle *et al.*, 2013). Socioeconomic status should be seen as capturing real, ecological facts, under this

model (Marmot, 2010). To put it metaphorically, all of these predictors tell the developing mothers, in this case, about the relatively harsh environment they are living in, and investment in earlier pregnancy makes good evolutionary sense when future extrinsic resource is unlikely to improve and ageing effects will put offspring at risk if reproduction is delayed. Thus current reproduction is favoured over future reproduction. Here, natural selection is seen as the rational actor, having selected for plastic developmental response that is sensitive to key parameters. But the actions of the individuals are also rational under these contexts, as there is much evidence to suggest that attendant psychological processes around desire for and planning families match these parameters (Arai, 2009). In this way learning and development are closely coupled and deliver an outcome that is fixed once delivered: in effect, the bet is taken.

3. Cooperative behaviour

Cooperation is a generic term that captures a number of behaviours. Specifically, a cooperative behaviour will provide a benefit to another individual, and will have been selected for as a consequence of that benefit (Davies *et al.*, 2012). Within evolutionary biology this possibility initially presents as a problem – how could selection operate in order to benefit the genes (or fitness) of another individual? Surely all selected behaviour must directly benefit the behaving organism?

It is important to be clear about what this question means. In our discussion of BB and life-history theory we dealt with adaptations for plasticity. The assumption was that those adaptations were underpinned by genes that had been selected over evolutionary time. For new traits to emerge, new genetic variants must be introduced, and most often those are mutations of an existing gene, leading to new forms of that gene. The various forms of a gene are referred to as alleles. In most evolutionary models that try to understand how a new trait might emerge the question becomes one of how a new mutation, or allele, might go to fixation in a population, remembering that the mutation will arise in one individual only. That individual has to receive some relative

reproductive advantage as a result of the new variant in order for that variant to thrive in the population.

Hamilton (Hamilton, 1964) addressed the issues of cooperation first by classifying social behaviour in terms of actors and recipients, costs and benefits (Table 1).

Table 1: Hamilton's classification of social behaviour (adapted from Davies et al. 2012:308)

Effect on actor	Effect on recipient	
	Positive	Negative
Positive	Mutually beneficial	Selfish
Negative	Altruistic	Spiteful

Mutualism makes sense as both parties benefit (though see (West *et al.*, 2011) for clarity on the complexities here). One obvious way in which altruism might emerge is if actors and recipients are related, thus sharing the same genetic variants (or alleles) and enabling direct selection. This idea is referred to as kin selection and enables the stabilization of cooperation across close and more distant relatives just so long as the costs to the individual do not outweigh the benefits, weighted by genetic relatedness. Hamilton captured this in a mathematical expression, referred to as Hamilton's Rule (see (Dickins, 2011)). Under this rule spite will emerge when the recipient is less related to the actor than the average individual in a population. Specifically, it will make sense to harm a non-relative in this way if doing so frees up resource for relatives in the population, thereby benefitting individuals carrying the same spiteful genes.

It is not always the case that cooperating individuals are related. To address this issue game theory was introduced. Game theory focuses upon competitive interactions between individuals and seeks equilibrium solutions to those interactions. These are behavioural strategies that cannot be outcompeted by any other strategy that might be

adopted within the confines of a game. The Prisoner's Dilemma is one of the best-known games used in evolutionary theory. Multiple forms of this game now exist but originally it comprised two prisoners planning an escape. The prison guards become suspicious and interrogate both prisoners individually. There is no direct evidence of an escape plot, so the guards put a deal to each prisoner. Here is how Gardiner expresses the deal (Gardiner, 2001):

Each faces the following proposition. He can either confess or not confess. If both confess then each gets five years. If neither confesses, then each gets one year on a lesser charge. But if one confesses and the other does not, then the confessor goes free, and the non-confessor gets ten years. Neither knows for sure what the other will do; but each knows that the other faces the same choice situation. (p.391)

The original version is a one-shot game where each player has only one strategic move that they can make: to cooperate or to defect. Most people understand the best option for any prisoner in this situation is to defect and confess the plot. If the other prisoner confesses too, any punishment will be relatively light compared to the worse case punishment of an extra ten years, if a prisoner stays quiet whilst the other confesses. Thus on average the best decision is to defect on your prior arrangement with the fellow prisoner. This is an issue of individual rationality. If the prisoners could confer then something else would emerge.

In evolutionary terms the assumption is that the strategy of defection in these circumstances will thwart any mutation that tends to cooperation. If we think of the costs in the dilemma as fitness costs, then the relative benefits of defection will stop cooperation genes going to fixation in a population. Thus BB uses evolutionary game theory to model genetic strategies, which are cashed out in behavioural terms. Equilibrium solutions are referred to as Evolutionarily Stable Strategies (Maynard-Smith, 1982).

The finding that defection is a stable strategy in one-shot Prisoner's Dilemma games is consistent under multiple cost-benefit trade-offs (Axelrod and Hamilton, 1981).

Defection is also a stable strategy in multiple-shot games if the number of interactions is known in advance. Once the last move is reached a player should defect as the last move is effectively a one-shot game, and this means defect will also be best on the penultimate move and so on all the way back to the first iteration.

If the series of encounters goes on with no end in sight, or there is a possibility, however small that the individuals will encounter one another again at a later date, then more complex encounters and strategies can emerge. This was famously tested with a computer contest in which scientists played their strategies against one another, against themselves (in ignorance) and against random defector or co-operator strategies (Axelrod, 1990). There was a high probability of future encounters in this contest. The strategy that won, or was stable, was tit-for-tat. Tit-for-tat co-operates on the first move and thereafter copies its opponent's previous move. Thus tit-for-tat becomes a strategy of co-operation based on reciprocity. It succeeds because it is initially cooperative, but retaliatory, discouraging defection, and; it forgave after one retaliation, restoring cooperation.

Tit-for-tat is a method for facultatively enforcing reciprocity (West et al., 2011).

Reciprocity has been a key solution to cooperation between non-kin – *you scratch my back now and at some future point I will scratch your own* (Trivers, 1971). But this solution is open to free riding, such that individuals could take the benefit but never deliver a future return. This would clearly destabilize cooperation, and the tit-for-tat strategy introduced retaliatory punishment to enforce continued cooperation. In that case the punishment was simply to copy any move, thus defection would be 'rewarded' with defection and over time the average benefits to all players would be driven down. Cooperation thus becomes rational again.

Tit-for-tat, as it has been described so far, is a behavioural strategy initially implemented on computers. For reciprocity to work in natural populations individuals need to be able to keep track of others, thereby understanding that there are probabilities attached to future interaction, and they need to be able to model a future pay-off. Population

structure is key to reciprocity, and cooperation between non-kin, but so too are memory and the ability to forecast. Where these capacities are challenged or limited then cooperation will not stabilize (Stephens *et al.*, 2002; Stevens and Hauser, 2004). This idea is potentially captured in the tragedy of the commons in that individual benefits outweigh population benefits at least in part because the population effect is more distal; the implication is that a littering individual is unable to appropriately model the future costs of accumulated litter. The time periods between choice and outcome are therefore of great interest and are captured in the literature on inter-temporal choice. The tragedy of the commons problem is regarded as a multi-player Prisoner's Dilemma game (Gardiner, 2001). Kolodko and Read (2018) give an example of this, noting that at the individual level the benefits of littering can outweigh the costs of responsible disposal, whilst at the population level, the costs of littering can outweigh the benefits. In effect, a decision to litter is a decision to defect on the public good of responsible disposal because of perceived cost-benefit imbalance. Kolodko and Read go on to discuss a series of nudge interventions that might alter these perceptions. We shall return to this in section 5.

4. Inter-temporal choice and inequality

Imagine searching for a pen to write a birthday card. Rifling through the kitchen drawer yields a cheaply produced biro, which will enable the task to be completed, but a longer search in one's study might yield an expensive pen that improves one's hand and thus the quality of the overall card. Search time is a cost that must be balanced against the benefits of a well-crafted card. As the card is an investment in a social relationship the amount of time searching for a pen is revealing of how much value the actor attaches to that relationship. The situation can be packaged as this choice: a poor pen now, or a much better pen after x minutes of searching.

Financial behaviour often provides examples and models of choices across time intervals – or inter-temporal choice. Imagine being given the choice between £10 in two days time or £50 in two months. Clearly the latter is financially more rewarding, but

the wait is much greater. Those who choose the former might be said to be discounting their future more heavily than those choosing the latter option. Indeed, a discount utility function could be mathematically derived from such choice behaviours to descriptively capture at least this instance of choice (Frederick *et al.*, 2002).

Intertemporal choice has previously been explored using the discounted utility model which suggests that discount rates remain constant and stable over time, that is, the discount rate decreases exponentially as time progresses (Streich and Levy, 2007). For example, if you prefer £10 today rather than £20 tomorrow, you will also prefer £100 in one year rather than £200 in one year and a day from now. This model predicts that outcome valuation is predictable over time, however, hyperbolic discounting has been found to be much more accurate in predicting and describing intertemporal choice (Frederick *et al.*, 2002). Hyperbolic models suggest that people discount more heavily in the near present (e.g. today versus tomorrow) but then the discount rate is less rapid as time progresses (e.g. next month versus the month after next).

Discounting has been studied widely in behaviours such as smoking (Reynolds *et al.*, 2004), substance abuse (Petry, 2001) and gambling (Dixon *et al.*, 2003) where there is a preference for short term payoffs (i.e. the immediate benefits of nicotine, the release of endorphins from a glass of wine, or the occasional immediate payout from a slot machine) - this is indicative of impulsivity and seen as symptomatic of a fast-life strategy (Walther *et al.*, 2012; Griskevicius *et al.*, 2013). Smoking, substance abuse and gambling are also asymmetric in their socioeconomic distribution. Lower socioeconomic status populations are more prone to these behaviours (Barnes *et al.*, 1999; Wilkinson and Pickett, 2009). Those living in situations where long-term futures are uncertain are more likely to heavily discount that future in favour of immediate gratification. What this means, is that future orientation is a highly valuable and relevant mechanism to consider when it comes to environmental behaviours of which payoffs often require a delay of gratification.

Differences in discount rates can be predicted by life history theory whereby

preferences for delayed versus immediate rewards are influenced by mortality rates and resource shortage (Griskevicius *et al.*, 2011). Griskevicius found that individuals who grew up relatively poor chose smaller but immediate payoffs and those who had grown up relatively wealthy preferred to wait for the larger future payoff, when primed with mortality cues. Following our preceding argument, if one's environment is unpredictable, the wisest option would be to take what you can today, as tomorrow is uncertain, whereas if you expect to live for many years it may be worth your while investing now for a larger payoff in the future.

As indicated above discount rate is also crucial to stabilizing cooperation and therefore will impact upon structured populations facing commons dilemmas. Even in minimally structured interactions there should be an effect. For example, Curry and colleagues (Curry *et al.*, 2008) found that people who were more patient, as measured with a standard discount rate task, were more cooperative even within a one-shot public goods game. The implication here is that a cooperative disposition is integrally related to an ability to forecast, value and invest in potentially uncertain distal pay-offs. Indeed, socioeconomic status has also been related directly to levels of altruism, with poorer neighbourhoods demonstrating less altruistic behaviour (Holland *et al.*, 2012; Nettle *et al.*, 2011; Wilson *et al.*, 2009).

The implication here is clear. At least in the developed world, with high levels of relative inequality (Wilkinson and Pickett, 2009), low socioeconomic status, which captures exposure to health risks, shorter life spans and reduced resourcing going forward (Marmot, 2010), is associated with steeper discounting and lower levels of cooperation. Unsurprisingly, littering behaviour and attitudes toward it are also socioeconomically distributed such that lower socioeconomic circumstances predict more littering and less concern about it (Arafat *et al.*, 2007; Eastman *et al.*, 2013; Santos *et al.*, 2005). Pampel (2014) found that cross-culturally, higher income populations in more affluent countries show greater environmental concern than their low-income counterparts. In addition, slow life history strategists, who place more value on later rewards, may be more concerned with their reputation as they are more likely to attract direct and indirect

benefits from future parties within their social groups (Wu *et al*, 2017; Sylwester and Roberts, 2010). These findings lend themselves to the notion that littering behaviour, for example, is not an issue of immediate concern for those living under lower socioeconomic conditions as they are focused on more immediate fitness-maximizing endeavours.

5. Cooperative landscapes and interventions

Cooperation depends upon the structure of the population but also upon the ability of individuals to forecast and remember. Individual differences in these abilities are a consequence, to some large extent, of exposures to risk and resource differentials across the lifespan, such that low socioeconomic conditions within developed countries create neighbourhoods of individuals with steep discount rates and lower levels of cooperation. Low socioeconomic status is also associated with lower levels of pro-environmental beliefs and behaviours, and this is relevant to the commons problem of littering. These effects can be seen to pulse with changes in macroeconomic fortunes, such that periods of recession lead to greater impoverishment of neighbourhood environments (Allen, 2013). Given this, we might understand the overall problem of littering as one that is happening across a diverse and dynamic landscape and one caused by a variance of ecological pressures on populations. These pressures demand very different priorities, and therefore very different cost-benefit trade-offs. This makes it unlikely that generic policies aimed at reducing littering will work uniformly well.

The association between litter, and other environmental degradation, and poor life outcomes and quality has long been noted and discussed. There are two leading causal theories. The first is 'broken window theory,' which suggests that disordered environments signal that defection is an acceptable behavior (i.e. it is the social norm) and therefore individuals adjust their behavior accordingly. Additionally, visible signs of disorder indicate risk and unpredictability which further emphasises the need to prioritize immediate fitness returns. The second argues that these things might best be seen as a symptom of a lack of social cohesion (O'Brien and Kauffman, 2013). O'Brien

and Kauffman found that social relationships, and a greater sense of social efficacy, led to more prosocial behaviours irrespective of physical deterioration at the neighbourhood level. We do not believe this is a coherent contrast.

Not only does forecasting enable individuals to imagine future reciprocity with an individual presenting in the here and now, it enables the modelling of new social relationships. This idea is captured by the concept of social capital, considered broadly as the *'features of social organization such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit'* (Putnam, 1995, p.67). Social capital has the ability to reduce the transactional costs of collective behaviour (Pretty and Ward, 2001) and facilitates interpersonal feedback opportunities by communication of values and behaviours. In this way culture is developed, which can act as a collective memory as well as a collective prescription about how to act. Neighbours can provide advice to others which can act to challenge previous habits and provide a frame of reference whereby the behavioural norm can be assessed and adjusted to better reflect the expected behaviour (Macias and Williams, 2016; Thoyre, 2011). Interestingly, people are more altruistic toward better connected individuals in a social network, indicating a clear understanding of social capital, or future social resource (Curry and Dunbar, 2011).

Social capital has been linked to more engagement in pro-environmental behaviours as it fosters values of collective over individualistic interests (Thoyre, 2011). Differences in social capital have been found between contrasting socioeconomic populations, with more deprived populations reporting less social capital. Conversely, more affluent populations reported more trust in others and that they believed that their neighbours were more likely to look out for one another (Nettle, 2015). In other words, the more connected one feels to a community, the greater likelihood social cohesion can prevail and lead to cooperative behaviours. Research indicates that people give more in economic games when they are provided with information about the potential recipient, such as seeing them or being told their name and hobbies (Eckel and Grossman, 1996; Bohnet and Frey, 1999a, 1999b; Charness and Gneezy, 2008).

Instead of making the contrast, our claim is that risky, or uncertain futures, make cooperation difficult to stabilize, which in turn reduces the social capital of a population and makes long-term future pay-offs less likely still. In other words, this becomes a vicious circle of downward degradation (as depicted in Figure 1).

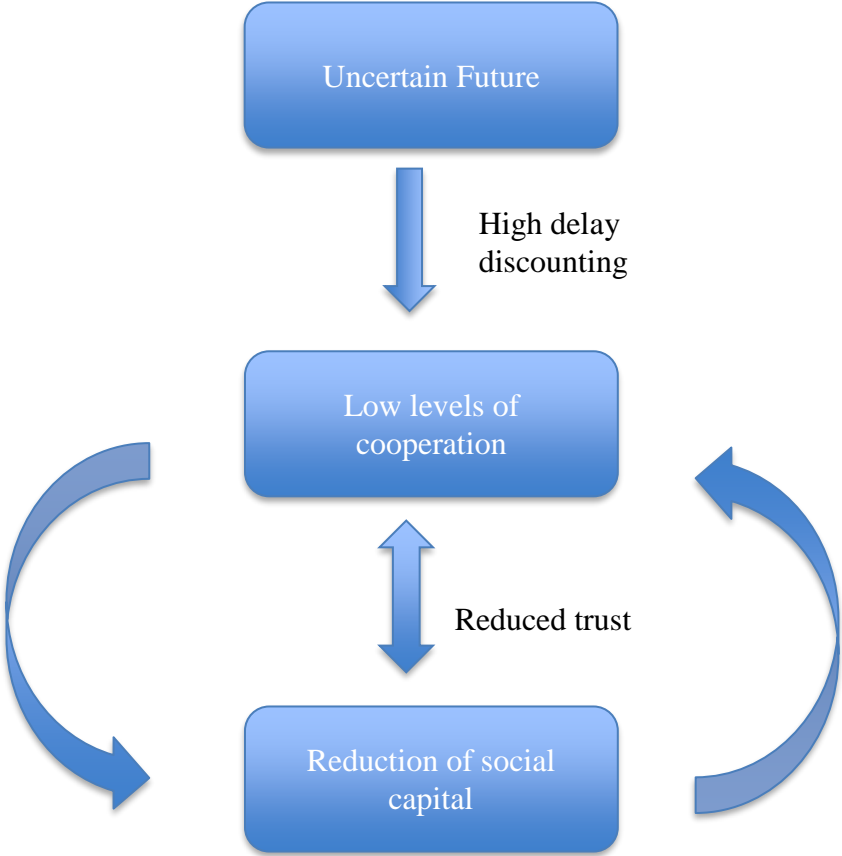


Figure 1: Representation of the challenges in formulating cooperation within low socioeconomic populations.

Acting at this point, with social interventions designed to facilitate reciprocity, has been found to be consistently effective (Kraft-Todd *et al.*, 2015). Kolodko and Read (2018) note that there are social and situational contexts to littering. They claim that social

contexts are best dealt with through efforts to promote cooperation, including communication strategies, shared social values and territorialization (such that individuals are associated with small patches that they have some ownership over). Situational contexts require the development of what they refer to as ‘new paths of least resistance’ to the appropriate behavioural outcome. This can amount to innovations in bin design and placement, or financial incentives and disincentives (or punishment), both of which we consider below.

5.1 Bin design

The design and placement of bins is effectively an attempt at stimulus control (Geller *et al.*, 1979; O’Neill *et al.*, 1980). Early research in littering focused on preventative measures based on behaviour analytic techniques, with the basic idea being to make bins more salient discriminative (or controlling) stimuli that would then become attached to the appropriate behavioural response. In early experiments, such as those of O’Neill *et al.* and Geller *et al.*, information was also posted on or near to bins in order to direct the appropriate behavioural response. The hope was that the response would generalize across bins more generally, and that the litter disposal would become entrained rather than discarding. However, in order to do this effectively experimental procedures that presented related bin stimuli would be required, along with some kind of variable interval of presentation tied to a reward structure in order to avoid extinction of the desired response (Staddon, 2016). This makes it likely that any bin redesign project will have to rely upon schedules of reward and punishment.

5.2 Reward and punishment

Rewards and punishments are used in behaviour change processes more generally. Fines can be effective punishments, if tied tightly to the undesired behavioural response, but can also be damaging in that they can exacerbate the problems facing low socioeconomic status individuals. Fines, as punishments, can therefore be overgeneralized as they impact on many aspects of life. As such they lose their controlling function. Indeed, Gneezy and Rustichini (2000) found that penalties for late child pick-ups from day-care rendered an increase in the undesired behaviour possibly

because the penalty payment essentially bought them the right to do so. Rewards are a commonly used method to improve performance or facilitate behaviour change and can take different forms, such as monetary or social. Again, they must be appropriately tied to the behaviour in focus.

For social scientists rewards are designed to appeal to two primary motivations; intrinsic and extrinsic. Intrinsic motivation relates to the performance of a behaviour as a reward in its own right (e.g. enjoyment of the task), whereas extrinsic motivation is when the behaviour is performed in order to attain a reward or avoid punishment. Research has indicated that extrinsic rewards can have a negative effect on intrinsic motivation because extrinsic rewards can 'crowd out' any existing intrinsic motivation. Self-determination theory (Ryan and Deci, 2000) suggests that there are three essential elements to consider when exploring motivation; autonomy (a need to have a choice and self regulation over behaviour), relatedness (a need to have close relationships with others) and competence (a need to interact effectively with the environment). Indeed, studies have shown that when monetary rewards are offered as incentives, performance often decreases, whereas positive verbal feedback can increase performance (Deci, 1971). The concept of intrinsic motivation might best be linked to the concept of wanting something, as opposed to liking. Want implies some form of need or requirement, whereas liking is some kind of positive response. It is possible to like what one wants; but these responses are under distinct neurological control (Berridge *et al.*, 2009). Deci suggests that money, as a reward may 'buy off' one's intrinsic motivation, whereas verbal reinforcement may be interpreted as less controlling and foster feelings of competency (Deci, 1971 pg. 114). This might be reinterpreted as money being something that is required in a second order manner – it can buy many things – and as such it will operate as a general solution to a general problem. Targetted verbal reward is more directly tied to a behavioural response, by definition, and if verbal reward is something that is liked then this will act as a discriminative stimulus far more effectively. Financial and related reward structures are also problematic because they are costly and the reinforcement schedules required to establish a successful generalized response are not always practical (O'Neill *et al.*,

1980). This suggests the possibility that a low contingency intermittent reward schedule (e.g. rewarding behaviour just on occasion) may render the behaviour resistant to extinction.

5.3 Networks and social capital

Those who cooperate are more likely to benefit from future acts of reciprocity and so making cooperative behaviours observable to others is one way in which cooperation can be sustained. Yoeli *et al.* (2013) applied this theory to a large-scale field experiment where they found that people were significantly more likely to sign up to an energy conservation initiative when they could be identified (as opposed to signing up with a generic ID code or receiving a monetary incentive). These findings indicate that social rewards, such as positive feedback and public recognition may be an effective and less costly alternative to promote pro-environmental behaviours and in addition foster positive feelings.

Kolodko and Read (2018) in line with the majority of scholars in this field, recommend interventions aimed at small groups. An expressed hope is that successful targeting of small groups will lead to a tipping point for the spread of pro-environmental, anti-littering social values, presumably mediated by social network structures and key nodes between groups, perhaps through some kind of contagion model (Burt, 2000). This hope relies upon notions of social capital and its categorization into bonding, bridging and linking capital (Dahal and Adhikari, 2008). Bonding capital applies to others one shares common traits with, such as family and close friends. This is related to kin selection (Section 2). Social groups formed around these kinds of bonds are very strong and it is of interest that organizations seeking to instil high levels of costly cooperation often invoke fictive kin mechanisms that include uniforms for similarity of appearance and the adoption of kin terms such as brother and sister (Qirko, 2009). Bridging capital refers to the ability to form ties with those who are unlike you and this must rely upon an ability to buffer free-riding costs as well as an ability to model ongoing long-term interactions with non-kin. Where bonding capital can help you by 'getting along' in life, bridging capital can help you by 'getting ahead' by providing a gateway to

accessing more resources (de Souza Briggs, 1997 cited in Putnam, 2000, p.23) but it is intrinsically risky for all the reasons discussed in Section 2. Research suggests that members of lower socioeconomic status have less social capital overall but bonding capital, specifically, can act to buffer against negative health effects (Uphoff *et al.*, 2013). Linking capital refers to ties with organisations or individuals where there is a power hierarchy and this captures links with formal institutions. Institutions make great effort to bind people to trust relations via legal procedures including contracts, and individuals can protect themselves with insurance. This is costly, and therefore excludes many, but in some ways this makes linking capital a less risky prospect than bridging capital. Clearly the number of individuals with different kinds of capital in any one social grouping will impact upon the nature of that local network, but also its connection to and influence over wider social networks. More specifically, social capital is a property of social network structures and can directly impact upon fitness in humans and other primates (Hawkins and Maurer, 2010; Silk *et al.*, 2009).

As we have discussed there are limitations on the formation of social networks due to memory and the ability to forecast. Thus far we have discussed this in terms of the ability to stabilize cooperation, but it is also entirely possible that memory limits the size of possible social networks too and that this has put an evolutionary limit on the size of our networks (Dunbar and Shultz, 2007; Hill and Dunbar, 2003). However, a key issue that has yet to be considered by scholars in this field is how the nature of social networks changes across urban, suburban and rural communities, in line with our discussion of socioeconomic effects above. There is also good reason to ask how the nature of local facilities affects the number of strangers coming into an area and the opportunity to develop and maintain stable cooperative networks (Hristova *et al.*, 2016). According to Hristova *et al.*, some places act to enable bonding and others bridging, with large cities presenting high social entropy (or diversity) such that bridging forms of social brokerage are necessarily higher. Entropy here is a measure of social instability such that there is a high throughput of different and new individuals. This makes repeated future interactions difficult, and following the discussion in Section 2, suggests that cooperation will be hard to establish. This suggests an interaction between social

and situational contexts such that aspects of physical geography yield social affordances, enabling the accumulation (or not) of social capital or particular types. We would predict patterns of littering and also differences in uptake of litter interventions as a consequence of these distributed social capital effects.

6. Overview

Whilst we have been critical in our evaluations of the kinds of intervention summarized by Kolodko and Read (2018) we do not dispute the efficacy of the studies they cite. Effects have clearly been won. What we are suggesting is that those effects deserve further scrutiny using the theoretical tools we have outlined above. Idiosyncracies of local social networks, oddities of reinforcement around reward interventions etc. will all be of value if exposed. The problem with the nudge approach is that it represents a pragmatic borrowing from multiple literatures without any effort to understand how or why interventions work. We believe this is necessarily limiting in two ways. First, it prevents thorough understanding of the problem of littering. Second, we question the longevity of any effects, something that is simply never assayed. Pragmatism is laudable, but time-limited pragmatism perhaps less so.

This second point is most salient. Our framework leads us to believe that littering behaviours are tied to a much broader fabric of social concerns and that the best way to address the issue of littering is to bite the political bullet and to see this as a key issue of inequality and a public health concern. Clearly there are public health consequences to the build up of unwanted items, including food and food packaging as well as other pollutants. But where you see evidence of such future discounting you also find stressed ecologies that have definitive morbidity and mortality consequences for their inhabitants. The much publicized concerns about increases in mental health problems and loneliness are, we believe, linked to the issues of cooperation that we have discussed. Interventions designed to build sustainable social capital in complex spaces like cities, but also in dispersed rural communities, will pay dividends on many fronts including an increased sense of custodianship of our natural environment.

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