How the mind sees coalitional and group conflict:
The evolutionary invariances of N-person conflict dynamics¹

David Pietraszewski^a

Max Planck Institute for Human Development

Word Count: 9852

Author Note

^aCenter for Adaptive Rationality, Max Planck Institute for Human Development,
Lentzeallee 94, 14195 Berlin, Germany. E-mail: davidpietraszewski@gmail.com

This work was assisted through participation in *Evolution and Warfare*, a
NIMBioS Investigative Workshop at the National Institute for Mathematical and
Biological Synthesis, sponsored by the National Science Foundation through NSF Award
#DBI-1300426, with additional support from The University of Tennessee, Knoxville.

¹ A précis of this paper appears in: Pietraszewski (2012). The elementary dynamics of intergroup conflict and revenge. *Behavioral and Brain Sciences*, 36, 32-33.

Abstract

1 All conflicts involving three or more or agents can be described using a vocabulary of only
2 four interaction types. Analyzing the cost/benefit calculations of each agent's role within
3 these interactions provides a more precise way to describe the decisions involved in multi-
4 agent conflict. This in turn allows for more precise psychological and selection-dynamic
5 models of groups and coalitions to be proposed and tested. A framework for the
6 psychological representation of coalitional conflict is described. The cost/benefit logic of
7 loyalty, attribution, defensive aggression, coalitional narratives, and social identities falls out
8 from this analysis, as does the mind's operational definition of a "group".
9

1. Introduction

[Gibson] therefore asked the critically important question, How does one obtain constant perceptions in everyday life on the basis of continually changing sensations? This is exactly the right question...His approach led him to consider...“invariants, [which] correspond to permanent features of the environment.” Marr, 1982

Take a quick glance around you before you continue reading. Whether you’ve just seen a desk, a window, or even just a wall, there is one sense in which what you’ve just seen is remarkable: Since the dawn of life, no visual system has ever produced the exact scene you’ve just experienced, and none will ever again. In a truly remarkable feat of engineering that most of us have the luxury of taking for granted, a very finite visual system captures and represents a near infinite variety of scenes—including the one that your visual system just produced.

The visual system accomplishes this feat by picking out invariances (Cosmides & Tooby, 1987; 2015; Tooby & Cosmides, 1990; 1992). No matter what the scene is of—a savannah or a sedan—it will be composed of a finite set of ever-present elements: lines and edges, colors, and directions of movement. Cognitive systems can therefore be designed to look for and represent these ever-present elements at each point in the scene. These representations then serve as a kind of vocabulary, which when combined can produce a near infinite set of combinations, including the particular array of lines, colors, and movements that you just experienced.

This paper is about coalitional conflict (conflicts that involve three or more agents interacting over time; Harcourt & deWall, 1992). In particular, how the mind “sees” coalitional conflict. Although decades of research have examined different aspects of coalitional and group conflict (e.g., Allport, 1954; Brown, 2000; Buss, 2016; Harcourt &

deWall, 1992; Keeley, 1996; Kropotkin, 1914), it is still by and large a mystery as to how the mind could—even in principle—solve the problem of representing coalitional conflict. The problem is that complex and varied dynamics emerge when multiple agents interact over time, and we haven’t known how to break up these complex dynamics into a finite set of smaller, more manageable elements (Byrne & Whiten, 1988; Harcourt & deWall, 1992; Sherratt & Mesterton-Gibbons, 2013).

This paper solves this problem. In the same way a visual scene is composed of lines, colors, and movements, all coalitional conflicts—whether they involve playground status-jockeying or generations-long patterns of revenge killings—are composed of only a very small number of abstract interaction types. These are the invariances of coalitional conflict dynamics. Adaptations built around these invariances can represent all possible multi-agent conflicts, and as will be shown, can do so at any scale, from anything larger than a dyad, to large-scale intergroup conflict.

Viewing coalitional conflict through the lens of these invariances allows us to (1) more precisely describe what, in principle, is happening inside of coalitional psychology when it is representing past, current, and future coalitional interactions, (2) translate the general problem of representing “coalitional conflict” into more specific and concrete representation and decision-making problems, and (3) operationalize folk psychological constructs—such as social identity, loyalty, and even the construct “group” itself—as concrete classes of events, cues, and outcomes.

1.2. Background

Evolutionary psychology has already discovered important effects surrounding coalitional or group conflict, including sex differences in intergroup conflict (McDonald,

Navarette, & Van Vugt, 2010), over-confidence (Johnson & Fowler, 2011), the finding that racial categorization is a byproduct for attending to coalitional alliances (Pietraszewski, Cosmides, & Tooby, 2014), and the possibility that intergroup antagonism may be driven in part by pathogen avoidance (Faulkner et al., 2004), among many others. There have also been excellent reviews of functional considerations surrounding group living and conflict (Kurzban & Neuberg, 2005) and descriptions of effects surrounding group conflict (Johnson, 2016). These feature evolutionarily informed considerations of costs and benefits, issues of cheating, coordination, and punishment (Tooby & Cosmides, 2010). These in turn are derived from selection pressure and game theoretic models coming out of human behavioral ecology and evolutionary biology (e.g., Boone, 1992; Sherratt & Mesterton-Gibbons, 2013). Outside of the explicitly evolutionary community, there is also of course also a massive corpus on intergroup conflict and group phenomenon in social psychology (e.g., Allport, 1954; Brown, 1995; 2000; Macrae, Stangor, & Hewstone, 1996). This work documents important real-world and laboratory group phenomena, the motivational and information-processing components behind them, and the situational factors that can exacerbate or alleviate them. These are important pieces of evidence for understanding the design of coalitional adaptations as they interact with social and experimental contexts.

However, despite all of this work, a big problem remains: we don't actually know how coalitional psychology works. As Kaplan & Hill similarly noted of the foraging literature in 1992, "We know virtually nothing about the specific nature of the cognitive processes" (p.197). If we did, we could build something mechanistic (say a software program, simulation agents, or, more fancifully, a robot) that implemented our constructs, and we should see coalitional behaviors and phenomena produced (see Kuipers, 2000). But if you

80 program a robot with sex differences, over-confidence, and race as a byproduct of coalitional
81 psychology (or any of the other constructs and concepts noted in recent reviews, either inside
82 or outside of evolutionary psychology; e.g., Johnson, 2016), you're not going to get the robot
83 doing anything resembling group-like or making coalitional inferences or decisions. So how
84 coalitional or group psychology works mechanistically remains to be discovered.

85 For evolutionary cognitive scientists, this will entail specification at the level of input,
86 process, and output—a computational level in Marr's terms (Marr, 1982) or a cognitive level
87 in Cosmides and Tooby's terms (1987;1994). If we measure our progress as a field in terms
88 of how much of the proximate phenotype has been specified from this point of view—either
89 within or outside of coalitional contexts—we still have a long way to go.

90 Moreover, the situation for coalitional psychology is in some sense worse. In contrast
91 to the models that exist for foraging, for example (which involve decisions based on search
92 and handling time, rates of return, variance in patchiness, and so on; e.g., Kaplan & Hill,
93 1992; Stephens & Krebs, 1986), we do not even have idealized models of what, in principle,
94 is happening when the proximate psychology is representing, predicting, and making
95 decisions about coalitional conflict dynamics. That is, we do not even know what
96 representations these adaptations are using and operating on when they do their job (the
97 closest contributions so far would include knowing that the proximate psychology must
98 assess numerical imbalances in the context of continuation or withdrawal from conflict—an
99 extension of the Asymmetric War of Attrition Model; e.g. Boone, 1992; Johnson & Mackay,
100 2015, and relatedly, must trade off risk and reward in the context of intergroup raids;
101 Glowacki & Wrangham, 2013; Tooby & Cosmides, 1987).

102 This is an unfortunate gap in our knowledge because many other relevant

disciplines—international relations, politics, economics, biological anthropology including human behavioral ecology and comparative studies, evolutionary biology, and so on—have come a long way in advancing our understanding of coalitional conflict, such that our ignorance of the mechanistic underpinnings—the literal cognitive steps in the causal chain of multi-agent conflict and violence—is becoming a limiting factor in our ability to integrate theories from different disciplines and make accurate (or even testable) laboratory or real-world predictions. Our lack of understanding of the proximate psychology is holding us back.

1.3. Toward a mechanistic proximate psychology

So how do we proceed? Although there is no guarantee any particular hypothesis will be correct, the way forward is at least well-marked: (1) describe the invariant tasks that need to be solved for an adaptive problem, (2) provide tentative answers to how in principle these may be solved by proximate mechanisms, and (3) then at that point start to empirically test for these proposed proximate solutions (this is an *Evolutionary Functional Analysis*; Tooby & Cosmides, 1992). Although getting to step 3 is important because without it, we won't know if we are correct, it is important to start out with steps 1 and 2, because without them, we won't even know what we are looking for. This paper attempts to make forward progress with respect to steps 1 and 2 for the adaptive problem of representing coalitional conflict dynamics.

2. Situating coalitional psychology in a broader functional context

To figure out how something works, it is useful to consider what it is for. The following considerations suggest coalitional psychology solves a subset of a larger set of problems of contingently interacting with other humans with respect to the delivery of costs

and benefits.

2.1. *Conflict as contingency*

Humans use violence to deter and incentivize others' behavior and to gain material rewards (Daly & Wilson, 1988; Glowacki & Wrangham, 2013; Kydd & Walter, 2006; Macfarlan, Walker, Flinn, & Chagnon, 2014; Sell, 2011). These “are not esoteric hobbies but essential talents for members of our species, affording obvious advantages to their well-being” (Pinker, 2016; xi).

Using costs in this way requires calculating how others will react to a particular event. This suggests a rich and largely unexplored psychology of *social contingency*: sets of adaptations for anticipating how others will react to the costs you impose on them or on others. This psychology (1) translates actions and outcomes into an abstracted grammar of costs and benefits, (2) anticipates how the action or outcome will have cascading effects on the social world (3) and delivers ‘best bet’ possibilities to decision-making systems.

These particular capacities are instances of a broader set of capacities to reason about social contingencies of the form, *if you do X, I will do Y*. Contingent reciprocity and social contract reasoning (e.g., Axelrod & Hamilton, 1981; Cosmides, Barrett, & Tooby, 2010) are other specific instances of this broad set of capacities (see also Hirschleifer, 1987; McCullough, Pedersen, Tabak, & Carter, 2014). That is, both threats and promises have underling structure in common.

2.2. *The dyadic-triadic gap*

Given that there is nothing particularly coalitional about the delivery of costs and benefits, nor in predicting or guiding one's own or others behavior, why do we need to postulate a separate coalitional psychology for negotiating cost-benefit contingencies? Can't

149 we just use models of dyadic interaction?

150 We cannot, because there is a qualitative shift in dynamics when moving from two to
151 three or more agents interacting over time. As Sherratt & Mesterton-Gibbons (2013, p.34)
152 note: “models of interactions which are apparently multi-player are frequently built up from
153 dyadic interactions...Unfortunately, this approach is inappropriate if the emergent social
154 pattern of interest is a non-linear dominance hierarchy or other coalitional structure, because
155 the behaviors that mediate such social structures are often intrinsically asymmetric and
156 polyadic (i.e. they involve three or more individuals).” In other words, a *coalitional*
157 designator as separate class of events in the world (and thus requiring an additional set of
158 adaptations¹) is required because unique dynamics emerge when multiple agents interact over
159 time that do not reduce to dyadic interaction (Harcourt, 1988). In particular, the possibility of
160 third parties being drawn into, or responding to, otherwise dyadic conflict creates a unique
161 possibility space that needs to be taken into account by the proximate psychology (for
162 foundational papers on triadic interaction, see: Harcourt, 1988; Harcourt & deWall, 1992;
163 Heider, 1958; Grammar, 1992; Patton, 1996; Strayer & Noel, 1986).

164 Evidence for this gap between dyadic and coalitional dynamics can be seen even before
165 we consider the dynamics themselves, and just look at the taxonomic distribution of species
166 capable of engaging in dyadic versus coalitional interactions: the two sets do not overlap,

¹ To head off a potential misunderstanding: The claim is not that any one of these particular systems is entirely and uniquely designed for “coalitional” problems (such that there is an entire bounded “computer” just for “coalitions”); this is a misunderstanding of functional specialization. The point of functional specialization is functional specification: If a task is to be done, a system must be specified that can do it. But there is no claim that all of the sub-functions that make up that system are entirely and uniquely bound to just coalitional contexts (in the same way, although the mechanistic systems for building clocks and chairs have to be different overall, this doesn’t mean they cannot share some tools and processes in common). What is being claimed here is that we have to specify as scientists what would be required to produce coalitional outcomes, because they do not come along for free from the functioning of other systems. What is not being claimed is that the constituent requirements must be unique and exclusive to just coalitions. This is a common misunderstanding of evolutionary psychology.

suggesting they are not the same problem, and the number of species capable of engaging in coalitional interaction is much smaller than the set capable of engaging in dyadic interaction, suggesting there are additional coalitional computations required above and beyond those needed to negotiate dyads (Byrne & Whiten, 1988; Harcourt & deWall, 1992).

2.3. Triadic Invariances

These considerations suggest that coalitional psychology solves a particular subset of problems for contingently interacting with respect to the delivery of costs and benefits: those that involve three or more agents contingently interacting over time (Byrne & Whiten, 1988; Harcourt & deWall, 1992). The problem, then, is to collapse or characterize how cost/benefit flows play out when three or more agents interact. The complexity created by such n-person dynamics has been a long-standing issue. It has hindered efforts to model both the coalitional dynamics themselves (Sherratt & Mesterton-Gibbons, 2013), as well as the underlying proximate psychology that makes these dynamics possible (Byrne & Whiten, 1988; Harcourt & deWall, 1992).

In biology and psychology, the solution to breaking up complexity has hinged on distinguishing between *outcomes* and *design*, and describing how the design works in terms of *invariances* (Barrett, 2006; Cosmides & Tooby, 1987; Hagen, 2016). For example, you likely have a representation of who your mother is. The particular identity stored in your head is an *outcome*. The learning machinery in your head that produced that representation is the *design*. Across bodies, design is invariant and universal, but outcomes are variable and idiosyncratic—since the dawn of sexual reproduction only you and your siblings will have your particular mother, and no one will ever again. To deal with this constant variability, the design needs to be pick out a set of invariant relationships—those things that do not vary

over bodies or over generations—that can diagnose for each individual who their mother likely is (for example, chemical cues during the first few weeks of life; Vaglio, 2009).

Although not usually framed this way (but see (Marr, 1982; Jackendoff, 1992; Cosmides & Tooby, 1994) almost all proximate solutions to adaptive problems involve systems that operate on invariances, at a level of abstraction removed from superficial details. For example, decision rules for social exchange rely on representations of *costs* and *benefits*, foraging decisions on *caloric density*, *search* and *handling time*, *return rates*, and the visual system on *edge orientations*, *colors*, and *directions of movement* (Axelrod & Hamilton, 1981; Cosmides, 1989; Cosmides & Tooby, 1989; Kaplan & Hill, 1992; Stephens & Krebs, 1986). Building adaptations around these classes of abstract invariances, rather than superficial variation, allows natural selection to build phenotypes that respond in an adaptive way to superficially-novel and locally-varying situations, and that can understand ahead of time the dynamics that will play out and what responses will be adaptive, such that no matter what the social exchange is over (a watch or a cassava root), or what the food is (a doughnut or a deer), or what the scene is composed of (a tree or a tiger), a finite set of rules operating on those abstractions can successfully operate over a functionally-infinite number of specific situations (within evolutionarily-recurrent boundary conditions).

To understand how the proximate psychology of coalitional conflict works, the same principle applies: the invariances of coalitional conflict need to be identified, such that a finite set of rules and representations can then operate over these invariances, and thus can be applied to any particular instance of coalitional conflict. This was the problem solved by natural selection when it engineered coalitional psychology, and it is the problem modern-day researchers face when trying to reverse-engineer what coalitional adaptations exist and

how they work.

Although not framed in this way, a set of coalitional conflict invariances was first described in the 1980's in observational and theoretical work on coalitional interactions among primates and young children, as a way of cataloging interaction types that could be tallied, and their frequencies correlated with contextual circumstances and individual differences (Harcourt, 1988; Strayer & Noel, 1986). These invariances are sets of triadic interactions, and are presented in Figure 1.

Figure 1. The four triadic invariances of coalitional conflict (adapted from Strayer & Noel, 1986).

In an *Alliance*, two agents attack or impose costs on a third agent: A attacks B, and C also attacks B. In *Defense*, one agent attacks a second, and a third agent responds by attacking the aggressor: A attacks B, C then attacks A. In *Generalization*, one agent attacks two others: A attacks B and then also C. And in *Displacement*, one agent attacks another, and that attacked agent responds by subsequently attacking a third agent: A attacks B, B then attacks C.

These four different triadic interaction types describe all the possible ways in which a

third party can become drawn into or involved in a previously dyadic conflict. That is, they exhaustively describe the transition from a dyadic to triadic conflict. Therefore—and somewhat remarkably—if we string together sequences of these interaction types, we can describe any multi-agent conflict using only these four interaction types (Pietraszewski, 2012).

These interaction types therefore represent more than just a tallying device for describing behavior: they can be understood as a set of evolutionary invariances that collapse the complexity and variety of coalitional conflict dynamics into a manageable and finite vocabulary, around which cognitive adaptations can be built. Thus, we can refine the adaptive problem to be solved: n-person conflicts are a sequence of triadic interaction reasoning tasks. This means coalitional psychology does not need to get progressively more and more complex as the scale of interaction increases, nor does it need to be hopelessly complex because the particular details of who does what to whom and for what reason are always different. Instead, reasoning about any particular coalitional conflict can be accomplished with cognitive machinery for handling just these four triadic interactions, and then stringing them together over time.

The next section describes the entailments of such a psychology, and gives us an idealized model of what, in principle, is happening when the adaptive problem of negotiating coalitional conflict is being solved.

3. Implications for what is happening inside of coalitional psychology

1. Computationally, decoupling from the details of the immediate event requires open parameters (open entries that can be filled in with different values or indexes) for both

which individual agent is in which role, and also the nature of the cost imposition (see Section 7.3).

2. When choosing behaviors, and predicting other's behaviors, there is a calculation of how events will unfold, using the vocabulary of these four interaction types. These calculations are translated into expectations in the vocabulary of these dynamics, such that if any one agent initiated a cost against a second, a representation of what would subsequently happen is modeled.

3. There is a calculation of which role the self is likely to be in, and which role any third party may be in, given specific behaviors and audiences, contexts, etc. Any one agent can be represented in different roles within these interaction types over time.

4. The systems involved can create long concatenated chains of all likely permutations of these interaction types, and accumulate probabilistic information about the most likely sequences of these interaction types (these chains can be thought of as a kind of internal-represented triadic possibility space that is composed of both past, current, and counterfactual strings of interactions). These chains allow multiple competing interests to be integrated and overlain over one another.

5. First-person decisions and third-party expectations are based on the highest probability string of interaction types at any one point in time (including who will be in what role). In other words, there is design to consult the representations of likely sequences of interaction types in order to choose those decisions that are expected to generate the most benefits and least cost for one's extended phenotypic interests.

6. It is unlikely any of this calculation becomes conscious, but the consequence of these calculations (traveling through triadic-possibility space) informs decision-making

processes, producing the conscious experience of concerns, worries, good ideas, things to watch out for, things to hope for, and so on.

7. Information that reveals which individuals will belong to which role is prioritized.

8. Situations that would qualitatively flip interaction-types between agents are highlighted and engage motivation and planning. (For example, events in the world that might cause agent X to defend me, rather than attack me, will be delivered to imagination and planning systems, and I will be motivated to broadcast that the event may occur, or I may actively try to cause it to occur).

9. As events unfold, the most-likely path (and perceptions of desirable paths) are dynamically-updated.

10. Humans, unlike many species, can communicate about who did what to whom displaced in time and space from the immediate event, which means that other agents not physically present can still react and become involved. This means (i) abstractly-communicated information can satisfy the input conditions of these systems (you don't need to see the event first-hand to have some representation of what happened), and (ii) there can be a richer, more detailed, and more delayed set of coalitional dynamics than would otherwise be possible (and this will not be found in species not capable of communicating this information).

In sum, coalitional psychology can be conceptualized as classes of computations in which social contingency adaptations operate over an abstracted vocabulary of triadic interactions and abstracted costs and benefits to make predictions, judge best future behaviors, and keep up-to-date representations of the social world (Patton, 1996;

Pietraszewski, 2012; 2013). Here, these triadic interactions serve as a kind of “vocabulary of conflict”—a format for representing current and past coalitional interactions, and planning future and counter-factual coalitional interactions, and can be thought of as a mental *grammar of transactions* in Jackendoff’s terminology (1992), or a *computational grammar* (Marr, 1982; Cosmides & Tooby, 1994). This is a functional/computational description, not a description of neural or algorithmic implementation.

4. Representation and decision-making problems

Understanding how coalitional psychology works will require understanding why these triadic interaction types occur. In other words, if part of what coalitional psychology does is produce these four interaction types, then part of understanding how coalitional psychology works will require characterizing the functional logic or cost/benefit considerations underlying these decisions—how costs and benefits flow through these triadic dynamics. In principle, a finite number of cost/benefit decision rules will underlie why each particular interaction type will occur.

The Supplementary Online Materials (SOM) of this paper consider the cost/benefit considerations that each role faces within each of the four interaction types. Considering each agent’s perspective within these triadic interactions reframes the question, *What is the proximate psychology of coalitional conflict?*, into sets of more specific and tractable questions, such as: *What are the classes of situations in which an agent finds themselves in role B during an alliance event? What cost/benefit considerations would that agent need to consider? And, What are the on-the-ground cues that would facilitate identifying these situations?* (Pietraszewski, 2012). Both for the purposes of modeling, and also for testing the

design of human cognitive adaptations, proposing and testing mechanistic solutions to the dynamics contained in the SOM will allow us to be more precise about what functions in the proximate phenotype we should be looking for. And if a software engineer or cognitive scientist could build or model mechanistic systems that implement these cost/benefit considerations—even in a simplified artificial environment—we would have for the first time a mechanistic system producing coalitional behaviors and phenomena.

4.1. An Example of traveling through triadic state-space.

The following is an example of how these dynamics play out over time (agents will be assigned numbers rather than letters because the notation of roles A, B, and C used above is based on A initiating a cost towards B, therefore the same agent can be in role A at time 1, role B at time 2, and so on).

Suppose 1 is considering imposing a cost on 2 (cost is denoted by arrow):

1's decision is based on the expected net benefits of the action minus the costs (see Section 8.3). Costs here would be the reaction of 2. (A combined representation of probability and severity). 1's decision comes down to whether the expected costs from 2 will outweigh the expected benefits.

A third-party capable of cost imposition is now added (3). Now 1's cost benefit considerations are different.

339 Calculation of expected net benefits and costs now require considering if and how 3
 340 will react to 1's behavior.

341 There are two options, either defense (3 will impose a cost on 1) or alliance (3
 342 imposes a cost on 1). The combined severity and probability of 3's behavior determines
 343 expected cost magnitudes for 1. (Three doing nothing in response does not need to be
 344 modeled as a third category, it can simply be a value within either category: if either the
 345 probability or severity of 3's cost imposition is zero, the expected impact of 3 is zero, and 1's
 346 analysis reduces to the dyadic interaction with 2 described above.)

347 Three's response is determined by the considerations of role C in defense and
 348 alliance, as described above. One determinant can be relationship strength—a pair-wise
 349 comparison of relationship strength between all three dyads 1-2, 1-3, and 2-3 (Patton, 1996).
 350 If the relationship between 2-3 is stronger, alliance behavior will occur and 3 will impose a
 351 cost on 2 as well, but if 1-3 is stronger, defense will occur. Thus, if 3 is present, calling up
 352 the relative pair-wise relationships will allow 1 to make better decisions (Perry, Barrett, &
 353 Manson, 2004; Wittig, Crockford, Langergraber, & Zuberbühler, 2014): If 3 is likely to ally
 354 with 1 against 2, 3's presence should lower the threshold for imposing a cost on 2, whereas if

355 3 will retaliate against 1, this should raise the threshold for imposing a cost on 2.

356 The addition of 3 also makes 2's possible reaction different. If 2 knows that 3 will
 357 come to his defense and impose a cost on 1, then 2 will be more likely to retaliate against 1
 358 as soon as 1 imposes the cost. This will create visible changes in 2's behavior, such that even
 359 if 3 does not act, both 1 and also uninvolved third parties can use these differences in
 360 behavior as a probabilistic cues about the relationship between 3 and 2 (e.g., if 2 becomes
 361 more belligerent against 1 when 3 is present, this warrants a probabilistic inference that 3 and
 362 2 will ally). Moreover, if 1 already knows that 2 and 3 are allies, then 2 should be less likely
 363 to expect 1 to impose a cost on 2 when 3 is around, and will use the presence of 3 to pre-empt
 364 cost impositions from 1; an ally is a deterrent.

365 The same scenario can be considered from 3's perspective and a forth agent added.

366 3's decision now needs to take into account the subsequent reaction of 4.

367 3's perspective looks complicated, but is simple framed in terms of retaliation: 3 will
 368 be less likely to attack 1 if he will be attacked by 4 for doing so, and 3 will be more likely to
 369 attack 1 if 4 will join him and also attack 1 (the perspective of 4, and why 4 would choose
 370 one or the other decision is analyzed as role C in Defense, and role C in Alliance). Therefore,
 371 3's choice about how to react will be informed by how 4 will respond.

372 Moreover, if 4 is large or can impose many costs, or if there are many other agents
 373 would also respond in the same way as 4 (e.g., 5, 6, 7,...N), then those responses will be
 374 given even more weight by 3. This calculation would, for example, underlie the calculation
 375 to not attack someone when all of their allies are present, and would also underlie
 376 calculations of relative alliance strength and subsequent decisions to escalate or withdraw
 377 from conflict (Perry et al., 2004; Wittig et al., 2014; Wrangham & Glowacki, 2012).

5. Phenomena that fall out from a triadic analysis of coalitional conflict

As an experimenter, once you start implementing particular strings of interactions over time, as in this example, recognizable phenomena, such as social identity, loyalty, and the construct “group”, begin to emerge. This is helpful, because it means we can now describe and define these phenomena as classes of invariances, and, by more clearly seeing their underlying cost/benefit logic, we can resolve certain long-standing mysteries (such as why there is an asymmetry between offensive and defensive aggression).

5.1. Loyalty

The psychological construct *loyalty* (Brewer, 2001; DeScioli & Kurzban, 2009; 2013) is a consequence of the fact that each agent has their own cost/benefit perspective, and therefore conflicts of interest will arise between an agent’s own current and future interests and their standing relationships and commitments (DeScioli & Kurzban, 2009; Pietraszewski & German, 2013). For instance, if 3 is an ally of 2, or has more of an interest in 2’s welfare,

then the left option—defending 2 against 1—will be the best option. However, if 4 will defend 1 *against* 3, then this changes 3’s cost/benefit analysis, and should lower 3’s willingness to produce Defense against 1 on 2’s behalf, even though from 2’s perspective 3

should come to his aid and defend against 1 (creating a conflict of interest between 3 and 2, even though they are allies). Loyalty describes the degree to which 3 resists that lowering, honoring the pre-existing relationship in the face of personal costs (see DeScioli & Kurzban, 2009; 2013; Pietraszewski & German, 2013).

Loyalty involves not only incurring costs, but also forgoing benefits. For example, 3 could join up with the numerically superior set of 1 and 4 against 2, and loyalty would describe forgoing that option.

Computationally, loyalty representations modify the weight that an agent will place on commitments based on standing relationships versus immediate personal interests and/or the exploration of new relationships. Situations in which there will be high costs incurred for honoring a pre-existing relationship and/or high benefits for abandoning pre-existing relationship will elicit vigilance for others' loyalty, and reassessments of the expected utility of continuing to be loyal in oneself. These conflict-of-interest situations will be flagged as each agent's proximate psychology explores triadic state space (with state and context-dependent individual differences in vigilance thresholds; e.g., Boyer & Liénard, 2006).

5.2. Disinterested assessments and third-party moral evaluation

If 3 observes 1 attacking 2, consequences follow for 3, even if 3 has no differential relationship with either 1 or 2. For example, 1 might have also done the same to 3, but it just so happened that 2 was the recipient. This would happen for instance if 1 were hungry and was willing to take food from anyone, and just happened to take from 2. Likewise, if 1 did

not know 2 would be the victim, but was still willing to impose a cost, then this demonstrates a willingness to impose a cost on anyone (which diagnoses a willingness to also victimize 3; Krasnow, Cosmides, Pedersen, & Tooby, 2012). That is, when a third-party imposes an anonymous cost on someone else, this demonstrates their willingness to also impose a cost on you.

In these cases, 3 will represent that 1 would have been willing (and thus will be again) to impose a cost on 3 as well (minimally, under the same circumstances, and for the same reason). In other words, the event that did happen (1's attack on 2) can be used to probabilistically predict an event that could have happened, and that might happen in the future (1 attacking 3). Therefore, 1 attacking 2 warrants a negative reaction from 3, and 3 will take lean towards attacking 1.

If however, 1 attacked 2 because previously 2 attacked 1, and 1 was just defending himself, then this has very different implications for 3. In particular, if 3 has not also attacked 1, then the fact that 1 is attacking 2 has no diagnosticity for how 1 will treat 3, so there is no expected cost from 1. Therefore, there is no reason for 3 to react to 1's attack, or to negatively evaluate it.

The folk constructs of justifiable retaliation and the moral evaluation of third party behavior (Delton & Krasnow, 2015; DeScioli & Kurzban, 2009; 2013; Hamlin & Wynn, 2011; Hamlin, Wynn, & Bloom, 2007) are outcomes of designs built around this cost/benefit logic: An *unprovoked* attack on a third-party diagnoses to an agent that there is some probability they will also be attacked (be in role C in Generalization). In contrast, defending oneself does not.

436 5.3. *Uniting around a common enemy*

437 If 1 is attacking 2 in self-defense (i.e., retaliating against 2's initial attack), and if 2
 438 would have been equally likely to attack *either* 1 or 3 initially, then 1's retaliation is not just
 439 neutral from 3's perspective, but is a benefit. This is the logic of creating a common enemy
 440 to justify aggression and recruit others to your side (e.g. Petersen, 2013). If 1 can convince 3
 441 that he is attacking 2 in self-defense (and even better, that 2 will also attack 3), then 3 (and
 442 others like him) will not hinder and will only help 1 impose the cost on 2. This benefits 1
 443 (and to some degree 3) by diffusing the retaliatory costs coming from 2, and reducing the
 444 outlay of costs each attacker has to impose (the costs are split between 1 and 3; see Johnson
 445 & MacKay, 2015; Wrangham & Glowacki, 2012).

446 5.4. *Asymmetry between offense and defense*

447 Both of the above considerations (Sections 6.2 & 6.3) explain the cost/benefit logic for
 448 why defense against an enemy is easier to coordinate and evokes a stronger commitment than
 449 does exploiting others or being on the offensive (for evidence of this phenomenon, see
 450 Böhm, Rush, & Gürek, in press; Rusch, 2013; 2014a;b).

451 5.5. *Coalitional narratives*

452 This asymmetry between aggression and defense in turn explains why narratives of
 453 social history are important (Paez & Liu, 2001). Claims about who has imposed costs on who
 454 in the past have very real consequences: on who will take whose side, and what behaviors
 455 will be chosen. Leadership, coalitional rhetoric, and historical narratives are all attempts to

negotiate and manipulate this information, including which agents belong to which roles (e.g., Coutant, Worchel, & Hanza, 2001; Price & Van Vugt, 2014; von Ruden, Gurven, Kaplan, & Stieglitz, 2014). This can done abstractly (“people X are our enemy”) or with descriptions of events that satisfy the inputs of these dynamics.

5.6. Attribution

Because 3’s response to 1 depends on why 1 is imposing a cost on 2 (Sections 6.3 & 6.4), there is selection on 3 to attend to and/or collect additional information to find out why 1 is acting. This is the process of *attribution* (Heider, 1958). In this case, attributing 1’s actions.

In the context of coalitional conflict, attribution is the collection or assumption of missing information that will determine what an agent will do in triadic state space. For instance, if 1 attacks 2, 3 will pursue new information or use pre-existing information to decide how to respond (see above). This process is recursive: Not only does 3’s response depend on his attribution of why 1 attacked 2, but once 3 does responds, then 1 and 2 will make attributions about why 3 responded in the way he did (as will third-parties). Moreover, because reactions are often based on delayed and opaque information, there can be misunderstandings (for example 3 might defend 1 against 2, thinking that 2’s attack was unprovoked, when in fact 2 was defending himself against 1; third-parties might then attribute 3’s actions to an alliance between 3 and 1, when in fact none existed). It is likely there is design in proximate systems to use beneficial misunderstandings instrumentally, to

avoid costly misunderstandings (e.g., Fisher & Kelman, 2001), and to use biased error-management thresholds for making attributions (which would vary by situation and be calibrated by past interaction histories; Haselton, Nettle, & Murray, 2015)

6. The mind's operational definition of "alliance" or "group"

Triadic interactions are not yet recognizably groups. Is there a way to get from these triadic interactions to groups?

From this perspective, the folk constructs "group", "alliance", and "coalition" are classes of relationships which cause agents to be in particular roles within these interaction types. In other words, "group" is a summary representation (like a mental state; see Barrett, 2015; Wertz & German, 2007; 2013). What it means to be members of a group, as far as the design of the proximate psychology is concerned, is to be in roles A & C in Alliance, B & C in Defense and Generalization, and A & C in Displacement. This would be true of the psychologies driving the decisions of the first-person actors within the group context, as well as the psychologies of third-parties who are forming expectations, making predictions, and updating their representations of the groups and their members (Pietraszewski, 2013). That is, these roles would be part of the cue structure on the input end (i.e., observing these roles allows one to deduce a conflict is unfolding, and also who is allied with whom). And these roles would also be embodied in the motivational and representational changes on the output end (i.e., being allied or in a group with someone makes it more likely one will execute the behaviors that correspond to these roles).

There is a temptation to be teleological and say that it is *because they are group members that they behave in this way*, but of course the causation is the other way around: It

is because A & C in Alliance, B & C in Defense and Generalization, and A & C in Displacement hang together in the world over evolutionary time (based on on-the-ground cost/benefit considerations) that proximate phenotypic psychologies have a representational entry for this class of relationships that produce these effects (what we call “group” members, or friends, allies, and so on). In other words, on-the-ground cost/benefit calculations are carried out over evolutionary time, and the relationships between agents that correlate over time with being in the above set of decision-roles select for representational summaries, some of which can be communicated. The mental entry for “group” is one such entry; it is a proximate summary of these invariant classes.

6.1. Substitutability, scaling up, and social identities

Under a range of contexts and interaction types, multiple agents will be *substitutable* with one another with respect to these triadic interactions. For example, 1 calculates how 3 may respond to a cost imposition towards 2:

But it may be that other agents will also react in the same way as 3. The system can therefore place a representation of that entire set of agents in the agent slot for 3 (Lopez, McDermott, & Petersen, 2011; Moffett, 2013; Tooby, Cosmides, & Price, 2006). This “scaling up” can occur for all three slots: 1’s are calculating if the 3’s will attack them if they attack the 2’s.

This agent-to-sets-of-agents substitution is permissible to the degree that the sets of agents are functionally interchangeable with one another with respect to these inferences and expectations (Barrett, 2001).

Not all such scaled-up sets are groups, however. For example, a set of disinterested third parties may all see an aggressor, 1, attack 2, and want to defend 2 against 1 (see Section 5.2):

Therefore, that set of agents will all be substitutable, and can be placed in the agent 3 slot.

However, this instance of “scaling up” is highly restricted: the interests of the agents within this set may only overlap for this role for this triadic interaction type, and none others. And thus will only be substitutable for this particular role.

Groups, in contrast, are a special, non-restricted case of substitutability and scaling up. If individual agents are in a group (as defined as relationships that cause each of them to be in A & C in Alliance, B & C in Defense and Generalization, and A & C in Displacement), then that set of agents can be placed in any agent slot within any of the four triadic interaction types. That is, they are substitutable across all roles, at least within the boundary conditions of their group membership (see below). That particular group’s interactions with other individual agents, or other groups, can then be represented using the same four triadic interaction types. This process can continue hierarchically, such that the logic that applies to individuals will also apply to groups—meaning there can be many nested layers of groups being in group roles with other groups, which in turn creates a superordinate group, and on

and on. This groups-to-agent-slot addition to the coalitional cognitive system allows these triadic interaction types to be quickly and easily applied to groups (or set of agents) of any size and scale. This has several implications:

(1) Because substitutability is situation specific, “groups” are also situation specific. Which agents will be allied or in a group (and thus substitutable with one another) is a function of who is involved in the conflict and what the nature of the conflict is (i.e., each event activates a unique set of probable paths through triadic state space). This means that there is not one group or alliance, but instead multiple, virtual sets of alliances and groups depending on the nature of the event that arises. This is a computational description of the more colloquial claim that there are multiple, nested coalitions and alliances, and that only certain coalitional cues or identities are relevant within a particular context (Pietraszewski et al., 2015).

(2) Because not all substitutable sets will be made up of individuals who are in all group roles with respect to each other, there will be a continuum of how much a substitutable set is a “group” (as defined as being in these roles). That is, different sets of agents may be comprised of agents who occupy a greater or lesser number of these group roles. (This and the preceding point that some “groups” may be more relevant across more situations than others provide a computational explanation for why people perceive different degrees of “groupishness” or entitativity across different sets of agents; Campbell, 1958; Hamilton, Sherman, & Castelli, 2002).

This in turn means that people can disagree as to whether—or to what degree across contexts—a set of agents are a group, or not. For example, agent 2, after having been defended by the agents in slot 3 in the above example, may hope (and signal) that they are all

now members of a group (that is, that this set of agents will now adopt all of the group roles with respect to her going forward). She may even try to demonstrate this to them, for example, by attacking anyone who imposes a cost on anyone in that set (placing herself in role C in Defense, and that set in role A). This attempt by 2 to act as if they are all now a group may occur for some time, even if the set of agents in slot 3 have no desire to be so obligated and, through their behavior, reject this framing. This suggests why there is often not a hard and fast line that can be drawn between “groups” and scaled-up sets when pointing to any one set of actual agents out in the world: Although the psychological representation of “group” is clear-cut (roles A & C in Alliance, B & C in Defense and Generalization, and A & C in Displacement), there are strategic conflicts of interest involved in representing and signaling what sets of agents are groups.

(3) The implications above in turn suggest that we cannot as scientists take for granted or assume which particular “groups” exist and are relevant to the proximate psychology when conducting studies, observing real world behavior, or creating theoretical models. That is, we cannot be *naïve realists* about the construct group. For example, groups may not always be obvious and spatially-bounded. This has important implications for selection dynamic modeling and theories of what group-identity contingent designs can be selected for.

For example, models of group-identity-contingent cooperation show that the option to “walk-away” from the group is a mechanism for providing contingency against exploitation—an important requirement for the evolvability of designs for cooperation (Efferson et al., 2016). However, walking away in many cases will not even be necessary if “groups” are represented pathways of cost/benefit flows; you don’t have to literally walk

away to contingently react against exploitation, you simply change your cost/benefit thresholds (see section 3 item 5, and section 8., and, in Efferson et al., 2016, page. 8). In many cases, engaging with or withdrawing from groups may be much more continuous and controllable than current selection dynamic models assume.

(5) *Social identities* (Brewer, 2001; Dawes, Van De Kragt, & Orbell, 1988; Park & Van Leeuwen, 2015; Tajfel, 1982) are placeholders for shared properties (whether concrete features or abstract representations) that cause agents to treat other agents as substitutable with one another with respect to these triadic interactions. For example,

if 3 shares a social identity with 2 (i.e., both have some attribute that could cause 1 to treat 2 and 3 as the same or similar with respect to these cost impositions), this will increase 3's probability assessment that 1's attack on 2 was because of that social identity (i.e., that 1 could have just as easily attacked 3 rather than 2). This will be true not just for 3, but any other agents who also share that same social identity. This is why conflict between agents with different social identities more strongly engages attribution motivations, particularly among larger sets of agents (Brewer, 2001; Dawes et al., 1988).

The content or basis of the social identity is an open parameter, and anything that allows agents to mark themselves or one another within these dynamics can fill it (Bar-Tal, 2001). Individual identities (i.e., that Bob, Joe, and Ralph are allied against Sven, Larry, and Dennis) are sufficient. The additional use of cues—either concrete or abstract, volitionally-signaled or obligatory and unchangeable—arise out of attempts to pick out shared properties

that will create self-beneficial social identities within a particular social context and time-horizon, and importantly, that will be mutually-represented by all involved (i.e., will be common knowledge; Thomas, DeScioli, Haque, & Pinker, 2014).

The social identities that stabilize for any length of time is a consequence of conflict, negotiation, and social-selection processes (Abrams & Rutland, 2008; Puurtinen, Heap, & Mappes, 2015; Walter, 2004; 2009). Violence, for instance, can be used to unilaterally force others to represent (although not necessarily accept) one's framing of the social identities in the world. (For, instance, Agent 1 attacks Agent 2, and then Agent 10, and then broadcasts that they will continue to attack all even number agents. This will cause others to represent Agent 1's "evens versus odds" way of carving up the social world, even if they do not themselves act on this framing. Those who find this framing agreeable join Agent 1.) This "broadcast and recruit" dynamic seems to underlie a wide range of entrepreneurial aggression, from playground bullying to terrorism. Conflict based on abstract social identities is a consequence of the open parameters in the proximate system, and the ability to entertain counterfactual triadic state spaces.

(6) Substitutability can be corroded. Cues that agents are *not* in roles A & C in Alliance, B & C in Defense and Generalization, and A & C in Displacement will corrode the representation that those agents should be treated as substitutable. For example, observing a change in dynamics away from these roles will lead to a representation that a group is dissolving and its members becoming disloyal.

(7) Any substitutable agent set (group, alliance, etc.) can be broken up into individual agent representations. In other words, triadic representations featuring a group in one or more agent slots can be expanded into representations that feature individual agents within each

agent slot. This will be necessary when tracking who within the set has acted (for instance, which individuals within set C have actually defended A against B), and also when calculating weaknesses within a group (i.e., areas where conflicts of interest and loyal concerns will arise—either out of an interest in keeping the group together, or breaking it apart). Because situations can be framed in either a “group” or “individual” way, the use of narratives that involve one or the other framing can additionally diagnose someone’s interest in breaking up or perpetuating a group. For instance, if someone with attribute X is attacked by someone with attribute Y, and they want others to retaliate against others with attribute Y (or at least monitor others with attribute Y), then they should describe the event in terms of the social identities involved, not the individual agents. Group-level framings are recruitment devices.

7. Additional considerations

7.1. Attack and cost imposition are on a continuum

Here cost imposition has been kept all or none (attack or not), which simplifies description, but costs imposed will be on a continuum, and therefore retaliatory responses will be as well. Many costs will also not meet the threshold of warranting an overt response (and the decision threshold about when an overt response is warranted will itself not even be stable over time, because it will depend on relative ability to impose costs, cues to how many others will join, etc.), and so a continuous tally of something like “coalitional stance towards me” (similar to a Welfare Tradeoff Ratio; Delton & Robertson, 2012; 2015; Sznycer et al., 2015; Tooby et al., 2008) will need to be how the proximate psychology actually tallies costs and benefits, and decides to respond.

7.2. Behavioral versus representational responses

Similarly, there can be behavioral neutrality *without* representational neutrality. For instance, extended kin may sit out on a raid of a neighboring village that contains their own relatives. Nevertheless, they will still calculate how this raid will affect their welfare landscape, and there should be some representation of this on the part of those going on the raid (i.e., those individuals raiding the village with Y's relatives should still represent that this is a cost to Y, even if Y is sitting out, and should take Y's representation into account).

7.3. *Costs and benefits have their own evolved grammar*

In this framework, the motivation behind these behaviors are costs and benefits (potential costs have to be traded off with expected social and material benefits from conflict; Glowacki & Wrangham, 2013). Costs and benefits are not synonyms for folk preferences or desires, but instead correspond to classes of outcomes which relate to differential reproductive success over multiple generations (Tooby et al., 2008). Proximate calculations of costs and benefits are made by evolved, cue-based adaptations, and it would therefore be a mistake to take a *naive realist* approach to coalitional costs and benefits when making predictions about the design of this proximate psychology, especially when the cue-structure and dynamics are evolutionarily-novel. (Of course, mapping the design means being able to predict how this proximate psychology will perform and react to evolutionarily-novel cues as well, which is important to understand, but such evolutionarily-novel dynamics and cues should not be used to model how the proximate psychology would be optimally-designed over evolutionary time. This is the proximate-ultimate distinction (Cosmides & Tooby, 1987)). Therefore, a separate, necessary enterprise will be to take an adaptationist approach towards a *theory of costs and benefits*: a description of the proximate valuation of cues and situations that stand in for ultimate (evolutionary) dynamics over phylogenetic time. This

will likely include valuation calculations that are unique to coalitional contexts and dynamics (Boyer, Firat, & van Leeuwen, 2015; Glowacki & Wrangham, 2013; Macfarlan et al., 2014; Patton, 1996; 2000; Tooby & Cosmides, 1988; 2010).

7.4. *Gene-level selection is neither individual, nor group*

It would also be a mistake to think that the entities whose benefits are being maximized refer to *either* an individual or to a group—it is neither. Instead, the level of selection is the inheritable substrate of proximate design over evolutionary time (i.e., genes; e.g., Maynard Smith, 1987). Therefore, individually costly outcomes will be produced by these systems, even when responding to evolutionarily valid inputs (see Tooby & Cosmides, 1988 for an example in the context of warfare). Of course, in many cases the proximate design will cause the body it is residing in to collect benefits, and to fight for the groups that the body belongs to (Akçay & Van Cleve, 2012). The proximate designs being considered here occur within individual bodies, which in turn interact in groups, and this happens in every generation, so the dynamics imposed by embodiment in an individual participating in groups is the selective landscape that selection dynamics act on. Therefore individual and group dynamics have to be taken into account when considering what design natural selection would produce via-gene-level selection (the point of this paper). But the design *criteria* (what counts as a good design, and what outcomes count as benefits and costs) refers to how that design will spread through the population over multiple generations via the differential reproductive success of its inheritable substrate (i.e., genes), *not* which design will maintain the existence of each and every individual or group (see Tooby & Cosmides, 1988, for an intuitive example). In other words, designs—extending across bodies within a generation, and across generations—are competing against alternative designs within the entire population, and “individuals” and

694 “groups” are classes of selection pressures on those designs.

695 *7.5. Biological phenotypes and group-structured cultural selection*

696 Systems that calculate costs and benefits through triadic state space are biological
 697 phenotypes designed by natural selection. Once biological phenotypes exist, non-entropic
 698 outcomes can also be produced by group-structured cultural selection (Zefferman &
 699 Matthew, 2015). This process affects *cultural* phenotypes (e.g., institutions, beliefs, customs,
 700 norms, etc.), such that they are non-randomly composed of features that propagate
 701 themselves via their interaction with proximate phenotypes (Henrich & Boyd, in press)². The
 702 biological triadic proximate systems described here would be part of the selective landscape
 703 for these cultural selection processes.

704 Group-structured cultural selection interfacing with naturally-selected proximate
 705 cost/benefit contingency systems may be part of the process that produces the structure of
 706 large-scale militaries and warfare (see Zefferman & Matthew, 2015). For instance, in
 707 militaries with hierarchical rank, cost/benefit contingencies are cordoned off from each other
 708 and nested hierarchically during combat, such as when officers are ordered to kill soldiers
 709 who try to retreat or desert (see also Zefferman & Matthew, 2015). In this case, the
 710 proximate systems in the soldiers during battle with the enemy deliver cues that retreat would
 711 be beneficial; the officers are positioned such that they are kept separated from those cues,
 712 and because the officer’s threat of death is present, the cost/benefit calculations of the
 713 soldiers changes, causing them to continue to fight. This institutional structure for delivering
 714 within-group punishment during conflict ratchets up group benefits (Sääksvuori, Mappes, &

² This is a separate process from those cultural invariances that are enduring enough to “seen” by natural selection (i.e., gene/culture co-evolution), which describes classes of selection pressures acting on biological phenotypic design (Boyd & Richerson, 2010; Tooby & DeVore, 1987; Zefferman & Matthew, 2015). This falls under the category of natural selection.

Puurttinen, 2011) and is an example of a solution to a large-scale second-order dilemma of collective action (Zefferman & Matthew, 2015). This is just one example, and there are likely many more. An evolved proximate psychology that creates and represents open-parameter social identities for coalitional entrepreneurship in a small-scale social world (Macfarlan et al., 2014; Patton, 1996, 2000), for example, will enable large-scale social identities to exist, which can then be exploited by cultural selection processes.

Because the proximate phenotype is designed to be very flexible and have many open parameters, even in a small-scale social world, it is not likely that the *design* of the system is influenced significantly by the cultural dynamics of large scale warfare and conflict. In particular, given the polymorphic nature of complex cognitive adaptations (Tooby & Cosmides, 1990) and the evolutionary recency of large scale warfare (Zefferman & Matthew, 2015), any non-entropic effects of large-scale warfare on phenotypic *design* would most likely be on *limited functional variation*: small quantitative effects involving a small number of alleles (e.g., things like decision-thresholds). However, the cues that the proximate system is taking in—and therefore the behavioral *outcomes* subsequently produced by it—would be affected by cultural phenotypes (as in the officer/soldier example). The more we know about the design of these proximate systems (what cues they are sensitive to, and what outputs they produce) the better able we will be able to identify and model cultural selection processes and outcomes (Barrett, 2015; Henrich & Boyd, in press; Matthew & Boyd, 2014).

8. Conclusion

Sequences of cost impositions across triads of agents can describe any n-person conflict, including intergroup conflicts, and therefore may be part of the computational grammar underlying coalitional prediction and decision-making. In the future this framework may be useful for (1) reproducing coalitional conflict behaviors and dynamics in a virtual environment by building model agents that embody these triadic dynamics in their decision and expectation rules, (2) more precisely describing and modeling coalitional dynamics, both in the field and in the lab, and (3) better understanding the psychology of coalitional conflict through the creation and testing of more precise models of how the proximate systems work.

References

- 743
744 Abrams, D., & Rutland, A. (2008). The development of subjective group dynamics. In S. R.
745 Levy & M. Killen (Eds.), *Intergroup attitudes and relations in childhood through*
746 *adulthood* (pp.47-65). New York: Oxford University Press.
- 747 Akçay, E., & Van Cleve, J. (2012). Behavioral responses in structured populations pave
748 the way to group optimality. *The American Naturalist*, 179, 257-269.
- 749 Allport, G. W. (1954/1958). *The nature of prejudice*. Garden City, NY: Doubleday.
- 750 Axelrod, R., & Hamilton, W. D. (1981). The evolution of cooperation. *Science*, 211(4489),
751 1390-1396.
- 752 Barrett, H. C. (2001). On the functional origins of essentialism. *Mind & Society*, 3, 1-30.
- 753 Barrett, H. C. (2006). Development as the target of evolution: A computational approach to
754 developmental systems. *The evolution of mind: Fundamental questions and*
755 *controversies*, 186-92.
- 756 Barrett, H. C. (2015). *The shape of thought*. New York: Oxford Press.
- 757 Bar-Tal, D. (Ed.) (2001). *Intergroup conflicts and their resolution: A social psychological*
758 *perspective*. New York: Taylor & Francis.
- 759 Böhm, R., Rusch, H., Gülerk, Ö. (in press). What makes people go to war? Defensive
760 intentions motivate retaliatory and preemptive intergroup aggression. *Evolution*
761 *and Human Behavior*. doi: <http://dx.doi.org/10.1016/j.evolhumbehav.2015.06.005>
- 762 Boone, J. L. (1992). Competition, conflict, and the development of social hierarchies.
763 *Evolutionary ecology and human behavior*, 301-337.
- 764 Boyer, P., Firat, R., & van Leeuwen, F. (2015). Safety, threat, and stress in intergroup
765 relations: A coalitional index model. *Perspectives on Psychological Science*, 10,

- 766 434-450.
- 767 Boyer, P., & Liénard, P. (2006). Systems and action parsing in developmental, pathological,
768 and cultural rituals. *Behavioral and Brain Sciences*, 29, 1-56.
- 769 Boyd, R., & Richerson, P. (2010). Transmission coupling mechanisms: cultural group
770 selection. *Philosophical Transactions of the Royal Society B*, 365, 3787-3795.
- 771 Brewer, M. B. (2001). Identity and conflict. In D. Bar-Tal (Ed.), *Intergroup conflicts and*
772 *their resolution: A social psychological perspective* (pp.125-143). New York:
773 Taylor & Francis.
- 774 Brown, R. (2000). *Group processes: Dynamics within and between groups. 2nd Edition.*
775 Malden, Mass: Blackwell.
- 776 Brown, R. (2011). *Prejudice: Its social psychology.* Malden, Mass: Blackwell.
- 777 Buss, D. M. (Ed.). (2016). *The Handbook of Evolutionary Psychology, 2nd Edition.*
778 Hoboken, NJ: John Wiley & Sons.
- 779 Byrne, R. W., & Whiten, A. (Eds.). Machiavellian intelligence: Social expertise and the
780 evolution of intellect in monkeys, apes, and humans. Oxford: Clarendon.
- 781 Campbell, D. T. (1958). Common fate, similarity, and other indices of the status of
782 aggregates of persons as social entities. *Behavioral science*, 3(1), 14-25.
- 783 Cosmides, L. (1989). The logic of social exchange: Has natural selection shaped how humans
784 reason? Studies with the Wason selection task. *Cognition*, 31, 187-276.
- 785 Cosmides, L. & Tooby, J. (1987). From evolution to behavior: Evolutionary psychology
786 as the missing link. In J. Dupré (Ed.), *The latest on the best: Essays on evolution*
787 *and optimality* (pp. 277-306). Cambridge, MA: MIT Press.
- 788 Cosmides, L. & Tooby, J. (1989). Evolutionary psychology and the generation of culture,

- 789 Part II. Case study: A computational theory of social exchange. *Ethology &*
790 *Sociobiology*, 10, 51-97.
- 791 Cosmides, L., & Tooby, J. (1994). Beyond intuition and instinct blindness: toward an
792 evolutionarily rigorous cognitive science. *Cognition*, 50, 41-77.
- 793 Cosmides, L., Barrett, H. C., & Tooby, J. (2010). Adaptive specializations, social exchange,
794 and the evolution of human intelligence. *Proceedings of the National Academy of*
795 *Sciences*, 107, 9007-90014.
- 796 Coutant, D. K., Worchel, S., Hanza, M. (2001). Pigs, slingshots, and other foundations of
797 intergroup conflict. In D. Bar-Tal (Ed.), *Intergroup conflicts and their resolution:*
798 *A social psychological perspective* (pp.39-60). New York: Taylor & Francis.
- 799 Costin, S. E., & Jones, D. C. (1992). Friendship as a facilitator of emotional responsiveness
800 and prosocial interventions among young children. *Developmental Psychology*, 28,
801 941-947.
- 802 Daly, M., & Wilson, M. (1988). Homicide (reprint ed.). New Brunswick: Transaction.
- 803 Dawes, R. M., Van De Kragt, A. J. C., Orbell, J. M. (1988). Not me or thee but we: The
804 importance of group identity in eliciting cooperation in dilemma situations:
805 Experimental manipulations. *Acta Psychologica*, 68, 83-97.
- 806 Delton, A. W., & Krasnow, M. M. (2015). *Adaptationist approaches to moral psychology*.
807 In J. Decety & T. Wheatley (Eds.), *The moral brain* (pp.19-34). Cambridge, MA:
808 MIT Press.
- 809 Delton, A., & Robertson, T. E. (2012). The social cognition of social foraging: Partner
810 selection by underlying valuation. *Evolution and Human Behavior*, 33, 715-725.
- 811 Delton, A., & Robertson, T. E. (2015). How the mind makes welfare tradeoffs: Evolution,
812 computation, and emotion. *Current Opinion in Psychology*, 7, 12-16.

- 813 DeScioli, P., & Kurzban, R. (2009). Mysteries of morality. *Cognition*, 112, 281-299.
- 814 DeScioli, P., & Kurzban, R. (2013). A solution to the mysteries of morality. *Psychological*
815 *Bulletin*, 139, 477-496.
- 816 Faulkner, J., Schaller, M., Park, J. H., & Duncan, L. A. (2004). Evolved disease-
817 avoidance mechanisms and contemporary xenophobic attitudes. *Group Processes*
818 *& Intergroup Relations*, 7, 333-353.
- 819 Fisher, R. J., & Kelman, H. C. (2001). Perceptions in conflict. In D. Bar-Tal (Ed.),
820 *Intergroup conflicts and their resolution: A social psychological perspective* (pp.
821 61-82). New York: Taylor & Francis.
- 822 Glowacki, L., & Wrangham, R. W. (2013). The role of rewards in motivating participation in
823 simple warfare. *Human Nature*, 24, 444-460.
- 824 Grammer, K. (1992). Intervention in conflicts among children: Contexts and consequences.
825 In A. H. Harcourt, & F. B. M. de Waal (Eds.), *Coalitions and alliances in humans*
826 *and other animals* (pp. 259-283). New York: Oxford University Press.
- 827 Hagen, E. (1999). The functions of postpartum depression. *Evolution and Human Behavior*,
828 20, 325-359.
- 829 Hagen, E. (2002). Depression as bargaining: The case postpartum. *Evolution and Human*
830 *Behavior*, 23, 323-336.
- 831 Hagen, E. (2016). Evolutionary psychology and its critics. In D. Buss (Ed.), *The Handbook*
832 *of Evolutionary Psychology, 2nd Edition* (pp.136-160). New Jersey: Wiley.
- 833 Haselton, M. G., Nettle, D., & Murray, D. (2016). The evolution of cognitive bias. In D.
834 Buss (Ed.), *The Handbook of Evolutionary Psychology, 2nd Edition*. Volume 2.
835 (pp.968-987) New Jersey: Wiley.

- 836 Hamilton, D. L., Sherman, S. J., & Castelli, L. (2002). A group by any other name—The role
837 of entitativity in group perception. *European review of social psychology*, 12(1), 139-
838 166.
- 839 Hamlin, J. K., & Wynn, K. (2011). Young infants prefer prosocial to antisocial others.
840 *Cognitive Development*, 26, 30-39.
- 841 Hamlin, J. K., Wynn, K., & Bloom, P. (2007). Social evaluation by preverbal infants.
842 *Nature*, 450, 557-559.
- 843 Harcourt, A. H. (1988). Alliances in contests and social intelligence. In R.W. Byrne, &
844 A. Whiten (Eds.), *Machiavellian Intelligence* (pp. 132-152). New York:
845 Clarendon Press.
- 846 Harcourt, A. H., & deWall, F. B. M. (Eds.). (1992). *Coalitions and alliances in humans*
847 *and other animals*. New York: Oxford University Press.
- 848 Heider, F. (1958). *The psychology of interpersonal relations*. New Jersey: Laurence
849 Erlbaum.
- 850 Henrich, J., & Boyd, R. (in press). How evolved psychological mechanisms empower
851 cultural group selection. *Behavioral and Brain Sciences*.
- 852 Hirshleifer, J. (1987). On the emotions as guarantors of threats and promises. In J. Dupré
853 (Ed.), *The latest on the best: Essays on evolution and optimality* (pp. 307-326).
854 Cambridge, MA: MIT Press.
- 855 Jackendoff, R. S. (1992). *Languages of the Mind: Essays on Mental Representation*.
856 Cambridge, MA: MIT Press.
- 857 Johnson, D. D. P. (2016). Leadership in war: Evolution, cognition, and the military
858 intelligence hypothesis. In D. Buss (Ed.), *The Handbook of Evolutionary Psychology*,

- 859 2nd Edition, Volume 2 (pp.722-744). New Jersey: Wiley.
- 860 Johnson, D. D. P., & MacKay, N. J. (2015). Fight the power: Lanchester's laws of combat
861 in human evolution. *Evolution and Human Behavior*, 36, 152-163.
- 862 Keeley, L. H. (1996). *War before civilization*. New York: Oxford University Press.
- 863 Kydd, A. H., & Walter, B. F. (2006). The strategies of terrorism. *International Security*,
864 31, 49-80.
- 865 Kurzban, R., & Neuberg, S. L. (2005). Managing ingroup and outgroup relationships. In D.
866 M. Buss (Ed.), *Handbook of evolutionary psychology* (pp.653-675). New York:
867 Wiley.
- 868 Krasnow, M. M., Cosmides, L., Pedersen, E. J., & Tooby, J. (2012). What are punishment
869 and reputation for? *PLoS ONE* 7(9): e45662. doi:10.1371/ journal.pone.0045662
- 870 Lopez, A., McDermott, R., & Petersen, M. B. (2011). States in mind: Evolution, coalitional
871 psychology, and international politics. *International Security*, 36, 48-83.
- 872 Macfarlan, S. J., Walker, R. S., Flinn, M. V., & Chagnon, N. A. (2014). Lethal coalitionary
873 aggression and long-term alliance formation among Yanomamö men. *Proceedings of*
874 *the National Academy of Sciences*, 111, 16662-16669.
- 875 Marr, D. (1982). *Vision: A computational investigation into the human representation and*
876 *processing of visual information*. New York: Henry Holt and Co.
- 877 Mathew, S., & Boyd, R. (2014). The cost of cowardice: Punitive sentiments towards free
878 riders in Turkana raids. *Evolution and Human Behavior*, 35, 58-64.
- 879 Maynard Smith, J. (1987). Reply to sober. In J. Dupré (Ed.) *The latest on the best: Essays*
880 *on evolution and optimality* (pp.147-149). Cambridge, MA: MIT Press.
- 881 McCullough, M. E., Kurzban, R., Tabak, B. A. (2013). Cognitive systems for revenge and

- 882 forgiveness. *Behavioral and Brain Sciences*, 36, 1-58.
- 883 McCullough, M. E., Pedersen, E. J., Tabak, B. A., & Carter, E. C. (2014). Conciliatory
884 gestures promote forgiveness and reduce anger in humans. *Proceedings of the*
885 *National Academy of Sciences*, 111, 12111-12116.
- 886 Moffett, M. W. (2013). Human identity and the evolution of societies. *Human Nature*, 24,
887 219-267.
- 888 Paez, D. R., & Liu, J. H. (2001). Collective memory of conflicts. In D. Bar-Tal (Ed.),
889 *Intergroup conflicts and their resolution: A social psychological perspective*. (pp.
890 61-82) New York: Taylor & Francis.
- 891 Park, J. H., & Van Leeuwen, F. (2015). Evolutionary perspectives on social identity. In V.
892 Zeigler-Hill, L. Welling, & T. Shackelford (Eds.), *Evolutionary perspectives on*
893 *social psychology* (pp. 115-125). New York: Springer.
- 894 Patton, J. Q. (1996). *Thoughtful warriors: status, warriorship, and alliance in the*
895 *Ecuadorian Amazon*. PhD dissertation, University of California Santa Barbara.
- 896 Patton, J. Q. (2000). Reciprocal altruism and warfare: A case from the Ecuadorian Amazon.
897 In L. Cronk, N. Chagnon, & W. Irons (Eds.), *Adaptation and human behavior: An*
898 *anthropological perspective* (pp.417-436). New York: Aldine de Gruyter.
- 899 Perry, S., Barrett, H. C., Manson, J. H. (2004). White-faced capuchin monkeys show
900 triadic awareness in their choice of allies. *Animal Behaviour*, 67, 165-170.
- 901 Petersen, M. B. (2013). Moralization as protection against exploitation: do individuals
902 without allies moralize more? *Evolution and Human Behavior*, 34, 78-85.
- 903 Pietraszewski, D. (2012). The elementary dynamics of intergroup conflict and revenge.
904 *Behavioral and Brain Sciences*, 36, 32-33.

- 905 Pietraszewski, D. (2013). What is group psychology? Adaptations for mapping shared
906 intentional stances. In M. Banaji, & S. Gelman (Eds), *Navigating the social world:
907 What infants, children, and other species can teach us* (pp. 253-257). New
908 York: Oxford University Press.
- 909 Pietraszewski, D., Curry, O., Peterson, M. B., Cosmides, L. & , Tooby, J. (2015).
910 Constituents of political cognition: Race, party politics, and the alliance detection
911 system. *Cognition*, 140, 24-39.
- 912 Pietraszewski, D., & German, T. C. (2013). Coalitional psychology on the playground:
913 Reasoning about indirect social consequences in preschoolers and adults.
914 *Cognition*, 126, 352-363.
- 915 Pinker, S. (2016). Foreward. In D. M. Buss, (Ed.). *The Handbook of Evolutionary
916 Psychology, 2nd Edition*. (pp.ix-xiv Hoboken, NJ: John Wiley & Sons.
- 917 Price, M. E., & Van Vugt, M. (2014). The evolution of leader-follower reciprocity: The
918 theory of service-for-prestige. *Frontiers in Human Neuroscience*, 8, 363.
- 919 Puurtinen, M., Heap, S., Mappes, T. (2015). The joint emergence of group competition
920 and within-group cooperation. *Evolution and Human Behavior*, 36, 211-217.
- 921 Rusch, H. (2014a). The evolutionary interplay of intergroup conflict and altruism in
922 humans: A review of parochial altruism theory and prospects for its extension.
923 *Proceedings of the Royal Society B*, 281: 20141539.
- 924 Rusch, H. (2014b). The two sides of warfare. *Human Nature*, 25, 359-377.
- 925 Rusch, H. (2013). Asymmetries in altruistic behavior during violent intergroup conflict.
926 *Evolutionary Psychology*, 11, 973-993.
- 927 Sääksvuori, L., Mappes, T., Puurtinen, M. (2011). Costly punishment prevails in intergroup

- 928 conflict. *Proceedings of the Royal Society B*, 278: 20110252.
- 929 Sell, A. (2011). The recalibrational theory and violent anger. *Aggression and Violent*
- 930 *Behavior*, 16, 381-389.
- 931 Sherratt, T. M., & Mesterton-Gibbons, M. (2013). *Models of group or multi-party contests*.
- 932 In I. C. W. Hardy & M. Briffa (Eds.), *Animal Contests* (pp. 33-46). Cambridge:
- 933 Cambridge University Press.
- 934 Strayer, F. F., & Noel, J. M. (1986). The prosocial and antisocial functions of preschool
- 935 aggression: An ethological study of triadic conflict among young children. In C.
- 936 Zahn- Waxler, E. M. Cummings, & R. Iannotti (Eds.), *Altruism and aggression:*
- 937 *Biological and social origins* (pp. 107-131). New York: Cambridge University
- 938 Press.
- 939 Stephens, D. W., & Krebs, J. R. (1986). *Foraging Theory*. Princeton, NJ: Princeton
- 940 University Press.
- 941 Sznycer, D., Schniter, E., Tooby, J., & Cosmides, L. (2015). Regulatory adaptations for
- 942 delivering information: The case of confession. *Evolution and Human Behavior*,
- 943 36, 44-51.
- 944 Tajfel, H. (1982). Social psychology of intergroup relations. *Annual Review of Psychology*,
- 945 33, 1-39.
- 946 Thomas, K. A., DeScioli, P., Haque, O. S., & Pinker, S. (2014). The psychology of
- 947 coordination and common knowledge. *Journal of Personality and Social Psychology*,
- 948 107, 657-676.

- 949 Tooby, J., & Cosmides, L. (1988). The evolution of war and its cognitive foundations
950 (Institute for Evolutionary Studies Tech. Rep. No. 88-1). Palo Alto, CA: Institute
951 for Evolutionary Studies.
- 952 Tooby, J. & Cosmides, L. (1990). The past explains the present: Emotional adaptations and
953 the structure of ancestral environments. *Ethology and Sociobiology*, 11, 375-424.
- 954 Tooby, J. & Cosmides, L. (1992). The psychological foundations of culture. In J. Barkow,
955 L. Cosmides, & J. Tooby (Eds.), *The adapted mind: Evolutionary psychology and the*
956 *generation of culture*. New York: Oxford University Press.
- 957 Tooby, J., & Cosmides, L. (2010). Groups in mind: The coalitional roots of war and morality.
958 In H. Høgh-Olesen (Ed.), *Human morality and sociality: Evolutionary and*
959 *comparative perspectives* (pp.91-234). New York: Palgrave MacMillan.
- 960 Tooby, J., Cosmides, L., & Price, M. (2006). Cognitive adaptations for n-person exchange:
961 The evolutionary roots of organizational behavior. *Managerial and Decision*
962 *Economics*, 27, 103-129.
- 963 Tooby, J., Cosmides, L., Sell, A., Lieberman, D. & Sznycer, D. (2008). Internal regulatory
964 variables and the design of human motivation: A computational and evolutionary
965 approach. In A. J. Elliot (Ed.), *Handbook of approach and avoidance motivation* (pp.
966 251-271). New Jersey: Lawrence Erlbaum.
- 967 DeVore, I., & Tooby, J. (1987). The reconstruction of hominid behavioral evolution through
968 strategic modeling. In W. G. Kinzey (Ed.), *The Evolution of Human Behavior:*
969 *Primate Models* (pp.183-237). New York: SUNY Press.
- 970 Vaglio, S. (2009). Chemical communication and mother-infant recognition. *Communicative*
971 *& Integrative Biology*, 2, 279-281.

- 972 von Rueden, C., Gurven, M., Kaplan, H., Stieglitz, J. (2014). Leadership in an egalitarian
973 society. *Human Nature*, 25, 538-566.
- 974 Walter, B. F. (2004). Does conflict beget conflict? Explaining recurring civil war. *Journal*
975 *of Peace Research*, 41, 371-388.
- 976 Walter, B. F. (2009). *Reputation and civil war*. New York: Cambridge University Press.
- 977 Wertz, A. E., & German, T. C. (2007). Belief-desire reasoning in the explanation of
978 behavior: Do actions speak louder than words? *Cognition*, 105, 184-194.
- 979 Wertz, A. E., & German, T. C. (2013) Theory of Mind in the Wild: Toward Tackling the
980 Challenges of Everyday Mental State Reasoning. PLoS ONE 8(9): e72835.
- 981 Wittig, R. M., Crockford, C., Langergraber, K. E., & Zuberbühler, K. (2014). Triadic social
982 interactions operate across time: A field experiment with wild chimpanzees.
983 *Proceedings of the Royal Society B*, 281: 20133155.
- 984 Wrangham, R. W., & Glowacki, L. (2012). Intergroup aggression in chimpanzees and war
985 in nomadic hunter-gatherers. *Human Nature*, 23, 5-29.
- 986 Zefferman, M. R., Mathew, S. (2015). An evolutionary theory of large-scale human warfare:
987 Group-structured cultural selection. *Evolutionary Anthropology*, 24, 50-61.