THE FOUNDATIONS OF REASONING ABOUT SOCIAL HIERARCHY

by

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Abstract

Navigating the complexities of social relationships is a fundamental task that many animals face throughout life. Although social animals must cooperate, conflict over valuable resources such as food, territory, and mates is inevitable. To reduce conflict and facilitate group cohesion, social dominance hierarchies form readily and rapidly among social species, including humans. In this dissertation, I will explore human infants’ capacity to represent social dominance between groups. First, in a series of three studies, I will examine whether 6–12-month-old infants are sensitive to relative numerical group size. The first two studies suggest that infants expect an agent from a numerically larger group to be socially dominant. A third study ruled out lower-level alternative explanations for these findings. Building upon this work, I will investigate whether infants represent members of social groups as allies. Across three studies I will explore whether individual members of a social group are expected to assume specific roles and obligations during intergroup conflict. Together, the results from these studies suggest that infants as young as 9 months of age expect intervening agents to exclusively aid ingroup members during a conflict. However, it is also important to be able to assess whether allies have knowledge that there is a conflict and are present and available to intervene. In the final two studies I explored whether allies’ ability to see intergroup conflict occur would affect infants’ expectations of social dominance. These findings suggest that 9–12-month-old infants only expected the group with more agents that could see the conflict occur to prevail and be socially dominant. This suggests that infants are not only sensitive to the overall number of agents in each group, but also consider allies’ ability to provide aid during a conflict. Taken together, this
work provides novel insights into the phylogenetic and ontogenetic origins of infants’ capacity to represent social dominance relationships and hierarchies.
Lay Summary

Understanding the factors that shape the social landscape is essential for living in a group, where dominant individuals often have greater control over and access to desired resources such as food and mates. Recently, researchers have questioned whether humans, similar to their nonhuman primate relatives, represent social dominance relationships and hierarchies. In this dissertation, I show that infants as young as 6 months are capable of detecting dominance relations when provided with an ecologically relevant cue such as social group size. Furthermore, when an agent intervenes during a conflict, they are expected to exclusively aid ingroup members. These findings reveal that infants may have an evolutionarily ancient cognitive capacity to represent social dominance and hierarchies that is shared with other species within the animal kingdom.
Preface

I am the primary author of the work presented in this dissertation, which was conducted in collaboration with colleagues. I was responsible for study design, data collection, data analysis and drafting manuscripts. Additional contributions for each chapter are described below.

Chapter 1: Introduction

I am the primary author of this chapter, with contributions from my supervisor, A. S. Baron.

Chapter 2: Infants’ Understanding of Social Dominance (Studies 1-3)

A version of this chapter has been published:


I am the primary author of this work: I designed the studies, supervised data collection, conducted data analyses, and drafted the manuscript. A. S. Baron contributed to study design and data interpretation. All authors edited the manuscript.

Chapter 3: Infants' Expectations of Social Obligations During Intergroup Conflict (Studies 4-6)

A version of this chapter has been published:


I am the primary author of this work: I designed the studies, supervised data collection, conducted data analyses, and prepared the manuscript. A. S. Baron contributed to study design and data interpretation. All authors edited the manuscript.
Chapter 4: Infants Infer Third-Party Social Dominance Relationships Based on Visual Access to Intergroup Conflict (Studies 7-8)

A version of this chapter is under review:

Pun, A., Birch, S.A.J., & Baron, A.S. Infants infer third-party social dominance relationships based on visual access to intergroup conflict.

I am the primary author of this work: I designed the studies, supervised data collection, conducted data analyses, and drafted the manuscript. A. S. Baron contributed to study design and data interpretation. All authors edited the manuscript.

Chapter 5: General Discussion

I am the primary author of this chapter, with contributions from my supervisor, A. S. Baron.

The research presented in this dissertation was approved by the UBC Behavioural Ethics Board under certificate H10-00147.
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Dedication

To my husband, Michael Olson, for always believing in me.

To my son, Aaron Olson. I am continually inspired by your growth, development, love, and persistence. Each day, I am reminded of why am so passionate about learning more about children and their development.
Chapter 1: Introduction

1.1 Overview

Group-living provides greater protection from predation, which improves overall survivability (Shultz, Opie & Atkinson, 2011). At the same time, competition for limited resources such as food, territory, and mates is inevitable. How do agents learn to navigate social hierarchies, and decide whether to fight, or defer to an opponent? To minimize the cost of fighting (e.g., energy spent and personal injury or death), natural selection appears to have favored the emergence of psychological mechanisms that help individuals predict whether they stand a chance against a competitor. Such psychological mechanisms are posited to act as “information processing” systems, taking input that the organism has acquired from the environment and generating output (e.g., physiological signals, hormones, neurotransmitters) that ultimately influences motivation and behavior (e.g. Chase & Seitz, 2011; Dunbar, 1988; Gartlan, 1968; Hausfater, Altmann, & Altmann, 1982; Keeley, 1996; Maslow, 1936; Parker 1974; Schjelderup-Ebbe, 1935; Smith, 1974; Smith Parker, 1976; Wilson & Wrangham, 2003). To better understand the psychological processes that are engaged in reasoning about hierarchical relationships, it is important to investigate the phylogenetic and ontogenetic origins of social dominance reasoning.

In this dissertation, I explore how human infants begin to navigate social hierarchies through investigating their capacity to represent social dominance relationships. In introducing this dissertation, I will first review theories and evidence that explore how group living and competition may facilitate the recognition of social dominance relationships across a diverse range of species. To motivate the research questions that will be explored in the subsequent chapters, I will outline the goals of the current research and the empirical questions addressed in
this dissertation. In the chapters that follow, I will present three papers that explore how infants reason about dominance relationships between social groups. This includes exploring how numerical group size influences expectations of social dominance, as many species gain “strength in numbers” during conflict. Building upon this work, I will explore whether infants view members of a social group as social allegiances and expect allies intervene and aid members of their own group. Investigating these foundational questions will speak more generally to our understanding of the evolution of social behavior.

1.2 The Nature of Social Hierarchy

Social hierarchies may be a universal feature of social groups, as they are pervasive in non-human and human species (e.g., Hawley, 1999; John, Keltner & Kring, 2001; Magee & Galinsky, 2008; Sidanius & Pratto, 1999; van Vugt & Tybur, 2014) and form rapidly in nature and the laboratory (Anderson, John, Berger, Rosenholtz, & Zelditch, 1980; Chase, Bartolomeo, & Dugatkin, 1994; Chase, Tovey, Spangler-Martin, & Manfredonia, 2002; Chase & Seitz, 2011; Gould, 2002; Keltner, & Kring, 2001; Magee & Galinsky, 2008). Social hierarchies represent an organizational system in which some individuals or groups hold a higher relative “position” than others, and proportionally fewer individuals or groups can occupy the highest levels of the hierarchy (Axte et al. 2014; Jost et al. 2004; Sidanuis and Pratto 1999).

Within the social hierarchy, individuals and groups may be assessed based on their social status, which is broadly defined as a relative level of value an individual or group holds. Similarly, social rank often represents a position in which individuals or groups are placed along a valued dimension, akin to the way numbers are ordered along a number line (Chiao, Bordeaux, & Nalini Ambady, 2004; Chiao et al., 2009). Because social status and social rank are used to describe the relative positions of individuals and groups within a hierarchy, these terms have
been used interchangeably within the literature (Mazur, 1985). For example, social status or rank may be assessed based on cues that are socially constructed and/or reinforced, such as wealth, occupation, gender, education, race or age (e.g., Charafeddine et al., 2020; Mandalaywala, Tai, & Rhodes, 2020; Olson, Dweck, Spelke & Banaji, 2011; Yazdi, Barner, & Heyman, 2020).

To begin exploring the psychological underpinnings of social status reasoning and its influence on behavior, researchers across disciplines have examined humans’ sensitivity to hierarchical social relationships (Magee & Galinksy, 2008). Evidence of the persistence of social hierarchies is evident early in human development. Infants as young as 10 months of age detect differences between individuals based on cues to status (e.g., Cheng, Tracy, & Henrich, 2010; Henrich & Gil-White, 2001; Margoni, Baillargeon & Surian, 2018; Mascaro & Csibra, 2012; 2014; Thomsen et al., 2011) and continue to expect high status individuals and groups to be treated more favorably than lower status groups throughout adulthood (e.g., Dupree & Torrez, 2021; Hyde, 2012; Parker et al., 2016; Royce, 2018; Wu, 2016). For example, toddlers and young children expect dominant individuals to prevail in a competition and receive more resources in a third-party task (Enright, Gweon & Sommerville, 2017; Mascaro & Csibra, 2012; 2014). Children’s behavior towards high status vs low status individuals also differ as they are more likely to endorse the testimony of a dominant individual over a subordinate individual (Bernard et al., 2016).

Furthermore, school-aged children recognize group-based hierarchies when presented with both novel and real-world groups (e.g., race, gender) and tend to endorse and perpetuate these group-based inequalities themselves (Mandalaywala et al., 2020; Olson et al., 2011). For example, both male and female children expect males to hold higher rank, occupations, and leadership roles (Bos et al., 2021; Liben, Bigler & Krough, 2001; Mandalaywala, Tai & Rhodes,
In addition, children ages 11-12 (but not 6-8 years) expect men to be paid more than women for doing the same (fictional) job (Liben et al., 2001). These studies demonstrate that children endorse group-based structural hierarchies that are reflected in their culture.

Although the specific cues and categories in which individuals and groups are differentiated based on status may take time to learn (e.g., gender, race/lightness of skin tone, or accent), work from the biological, psychological, cognitive, and comparative sciences suggests that a neural network that is sensitive to status information may provide the foundation for status and hierarchy perception (see Koski, Xie & Olson, 2015 for a review). Understanding humans’ sensitivity and propensity to represent social status information early in development may have important implications for how humans evaluate and behave towards others. The implications for humans’ reasoning about social inequality and social group status will be discussed in greater detail in the Conclusion (Chapter 5).

### 1.3 Navigating Social Hierarchies: Dominance Relationships

Social dominance hierarchies are often established through agonistic competitions, where **social dominance** is the tendency or likelihood for an individual or group to prevail over another individual or group (e.g. Bernstein, 1981; Hand, 1986; Hawley, 1999; Mascaro & Csibra, 2012; Thomsen et al., 2011). To minimize the risk of injury or death, individuals can quickly use such cues that have been reliably associated with social dominance to decide whether to engage in or avoid a physical conflict (Batchelor & Briffa, 2011; Bowles, Choi & Hopfensitz, 2003; Elgar 1989; Lanchester, 1956; Wilson & Wrangham, 2003). Social dominance may be represented momentarily between individuals and/or groups (to quickly assess the likelihood of winning in a conflict) but also may represent a stable relationship that forms the basis of social dominance.
hierarchies in many species. Once a social dominance hierarchy has been established within a group, social dominance relationships tend to remain relatively stable across time and contexts, allowing individuals to observe social interactions and predict who is likely to prevail in subsequent contests, thereby reducing daily conflicts and enhancing within-group cohesion.

Many species, including ants, bees, birds, chimpanzees, and humans appear to represent social dominance relationships expressed through cues such as body size or strength, that may influence fighting capability (e.g. Addison and Simmel, 1980; Barkan et al., 1986; Beaugrand and Cotnoir, 1996; Chase, Bartolomeo & Dugatkin, 1994, 2002; Clutton-Brock, 1982; Goessmann, Hemelrijk, & Huber, 2000; Hammerstein 1981; Hausfater et al., 2000; Heinze & Smith, 1990; Hsu and Wolf, 1999; Moore and Bergman, 2005; Nelissen, 1985; Oliveira et al., 2009; Pereira 1995; Post, 1992; Sapolsky 1982; 2005; Savin-Williams, 1980; Schjelderup-Ebbe, 1922; Silk, Alberts & Altmann, 2003; Sloman and Armstrong 2002; Vannini and Sardini, 1971; Wilson, 1975). At an individual level, body size is often associated with dominance ranking in conflicts both within and between species, with individuals that appear larger relative to their opponent benefiting from greater strength. Furthermore, dominance displays exploit this inference, such that when individuals are threatened, they may adopt postures that make them appear bigger to intimidate their opponent. Relatedly, individuals that are subordinate often adopt postures that minimize their physical size, such as bowing or kneeling to convey deference (Brown & Maurer, 1986; Buston, 2003).

Importantly, social species also rely on other members of the group to share roles and responsibilities, from childrearing, hunting and defense against predators (Bissonnette et al., 2015; Byrne & Whiten, 1988; Chapais, 1995; Harcourt & deWaal, 1992). For example, evidence with both non-human primates (e.g. chimpanzees), social animals (e.g. lions) and humans reveal
that individuals often band together to form alliances when facing rival groups, or opponents they deem to be too formidable to defeat alone (Clark, 1993; Ghiglieri, 1984; Harcourt & DeWaal, 1992; Keely, 1996; Marler, 1976). Forming alliances often facilitates a group’s ability to acquire and maintain priority access to territory, feeding sites and provides better protection against rival groups. Consequently, these gains, achieved at a group-level may translate into greater individual fitness and reproductive success among group members (Chapais, 1992; 1995; Harcourt & deWaal, 1992; Kulik, Muniz, Mundry & Widdig, 2012; McComb, Packer & Pusey, 1994; Mitani, Watts & Amsler, 2010; Muller & Mitani, 2005; Pandit & Schaik, 2003; Pusey, Oehler, Williams & Goodall, 2005; Silk et al., 2003; Silk, 2007; Wilson & Wrangham, 2003).

Therefore, in addition to using individual traits that often serve as cues to dominance (e.g., body size or age), other cues, such as numerical group size may be used to predict whether a group of individuals are more likely to succeed relative to another. More specifically, in many social species, such as chimpanzees, lions, wolves and hyenas, groups will first assess whether they outnumber their opponents before engaging in a physical conflict. If a group believes that they have more agents that can compete relative to the opposing group (based on visual and/or auditory cues to advertise numerical strength), then individuals are more likely to approach rivals and engage in a conflict. However, if an individual or group believes they are outnumbered, then they will retreat or stay silent (Clark, 1993; Ghiglieri, 1984; Keely, 1996; Marler, 1976; McComb et al., 1994; Wilson & Wrangham, 2003).

In sum, the ability to detect social dominance relationships both within and across species provides a clear fitness advantage, as individuals or groups that are perceived to be less physically formidable than their opponent(s) will often defer rather than engage in conflict (e.g. Dunbar, 2013; Gilbert, 1992; Hausfater et al., 1982; Schjelderup-Ebbe, 1935).
1.3.1 Early Emergence of Reasoning about Social Dominance in Humans

Paralleling findings with nonhuman primates (Wilson, Hauser & Wrangham, 2001; Wilson & Wrangham, 2003), preverbal human infants use cues to physical strength to infer social dominance between competitors (Thomsen et al., 2011). In one study (Thomsen et al., 2011), preverbal infants inferred social dominance relationships by comparing the physical size of two competing agents. Infants were introduced to two agents (one twice as large as the other), each with the apparent goal of crossing to the opposite side of a platform. When both agents tried to cross at the same time, they met on the path. Then, infants were shown two scenarios: one in which the larger agent prevailed and one in which the smaller agent prevailed. Although 10- to 13-month-olds expected the larger agent to be dominant, 8- to 9-month-olds failed to demonstrate an expectation about which agent should prevail. This suggests that only older infants could use the relative physical size of two competing agents to infer which one would get the right of way.

As with nonhuman primates, humans recognize dominance relationships when agents forfeit desired resources to the dominant agent. For example, work by Mascaro & Csibra (2012) revealed that infants in the first year of life make predictions about resource allocations for dominant, relative to subordinate individuals, even in the absence of a physical conflict. In this study, 9- and 12-month-old infants were shown a video of one animated agent collecting small objects. When another agent entered, the first agent stopped collecting the desired objects, allowing the second agent to gather the remaining objects. By forfeiting the remaining objects, the first agent was shown to be subordinate to the second agent. At test, the two agents competed for a new type of desired object, and 12-month-olds (but not 9-month-olds) were more surprised when the subordinate was allowed to take the last object, compared to when the dominant agent...
was allowed to take the last object. The results of this study suggest that human infants, like non-human primates, recognize that when one individual submits or defers to another (even in the absence of a physical conflict), this indicates that the agent that has been deferred to is more socially dominant, and entitled to a greater share of the resources (e.g. Cheney & Seyfarth, 1992; Ghiglieri, 1984; Hand, 1986; Hawley, 1999; Smith, 1974). In sum, 12-month-olds expected the dominant agent to receive differential access to desired resources. Because competition over resources is something social animals face on a daily basis, the capacity to detect dominance relationships, even in the absence of physical conflict, is important to reduce the risks of engaging in a conflict.

In order to track dominance relationships effectively, humans should be able to learn that dominance relationships can remain stable over time and across different social contexts (rather than an individual trait). To begin investigating this question, 12- and 15-month-olds were first familiarized to a dominant agent monopolizing a bounded area (i.e., pushing the subordinate away); at test, the infants were shown a novel scenario in which the previously established dominant and subordinate agents competed for a desired object. Infants viewed two outcomes: one in which the previously dominant agent succeeded and one in which the subordinate succeeded (Mascaro & Csibra, 2012; 2014). A developmental trend in which older infants demonstrated an increased capacity to track dominance relationships across different contexts. More specifically, 12- month-old infants could represent the dominance relationship between two agents only when the test scenario was identical to the conflict scenario they had witnessed. But, 15-month-old infants could generalize the established dominance relationship to many scenarios. For example, if one agent had been shown to dominate a second in one setting, 15-month-old infants expected the dominant agent to obtain the desired objects in all settings.
(Mascaro & Csibra, 2012). This suggests that by 15 months, infants expect established dominance relations between two agents to persist over time and across contexts.

To further examine infants’ ability to track dominance relationships and their capacity to represent more complex social hierarchies, researchers tested whether infants could represent the dominance relationships among three agents (Mascaro & Csibra, 2014). In this study, 15-month-old infants were shown three pairs of agents, each of which wanted to monopolize a confined space. Infants could recognize the dominance relationship between each pair of agents, but only when it was presented incrementally and in a linear order. For example, if infants were shown that A was dominant to B, then B was dominant to C, and C was dominant to D, they understood that A was dominant to C. However, infants could not recognize the dominance relationships if they were established discontinuously. For example, if they were shown that C was dominant to D, then B was dominant to C, and A was dominant to B, infants could not recognize that A was dominant to C. This work demonstrates that in certain circumstances, infants may use a form of deductive reasoning called transitive inference to derive a relationship between agents that have not been compared to one another directly (Gazes, Hampton & Lourenco, 2015). This evidence supports the argument that transitive inference is central to social dominance cognition in humans, as it allows humans to represent the complex structures of their social groups beyond dyadic relationships.

It is important to acknowledge that certain cognitive and social capacities (e.g., memory, perceptual and numerical discrimination) that allow infants and children to differentiate individuals and groups, and keep them in memory undergo substantial changes over the first few years of life. However, this does not mean that the psychological mechanisms that have evolved to represent dominance relationships in our non-human primate ancestors do not play a role in
shaping infants’ reasoning about social structure and hierarchy. This issue will be discussed in greater detail in the Conclusion (Chapter 5).

1.4 The Current Research

In the studies presented within this dissertation, I have chosen to focus on infants’ representation of social dominance relationships between social groups. More specifically, my work explores how representations of social dominance is constrained by perceptions of social alliances. Consistent with the biological, cognitive and social sciences, I describe a behavioral definition of social dominance as the likelihood or tendency for an individual or group to prevail over another individual or group (e.g., Bernstein, 1981; Hand, 1986; Hawley, 1999; Mascaro & Csibra, 2012; Thomsen et al., 2011). In the studies described in my dissertation, an individual or group that succeeds at accomplishing their goals (at the expense of another individual or group) will be referred to as socially dominant. Therefore, social dominance relationships describe an asymmetry between individuals or groups, rather than an internal attribute or trait.

Together, evolutionary models and research with social animals and non-human primates suggest that the cognitive mechanisms underlying assessments of social dominance between individuals may be extrapolated to groups. Therefore, In Chapter 2, I explore whether infants, like non-human primates will assess social dominance between competing agents based on the relative numerical size of their respective groups. This raises the question of whether numerical group size has evolved as a reliable cue for fighting formidability in humans and is present early in life. Given that infants infer the goals of others and make inferences about the behavior of group members (Powell & Spelke, 2013) and infants as young as 10 months of age use relative physical body size to infer social dominance, I hypothesize that infants will expect an agent from a numerically larger group to be socially dominant.
Another important question to address is whether infants understand the significance of having more group members present during a conflict. In other words, do infants understand that group members have an obligation to help? To date, there is some evidence with toddlers and children that group membership facilitates expectations of ingroup support. For example, when 17-19 month olds observe an agent (e.g., a “Tig”) that is unable to reach a puzzle piece that they need, infants expect another agent that has been labeled as part of the same group (e.g., another “Tig”) to provide assistance and retrieve the puzzle piece for their group member. However, toddlers do not expect an agent to provide instrumental assistance to outgroup members (e.g., a “Wug”) or undefined agents. These results suggest that in the absence of conflict, an agent is expected to provide instrumental help to another ingroup member (but not an outgroup member) (Jin & Baillargeon, 2017). Furthermore, ingroup loyalty is expected to be maintained such that behaviors that harm the group are not permissible (Rhodes, 2012; 2013; Rullo, Presaghi, & Livi 2015; Ting, He and Baillargeon, 2019). For example, when ingroup loyalty is violated (e.g., without provocation, an ingroup member harms another ingroup member), infants and children expect ingroup members to refrain from helping the aggressor (as a form of third-party punishment) (Ting et al., 2019).

When a conflict occurs between individuals from opposing groups, infants expect the conflict to generalize to these individuals’ social partners (Chalik & Rhodes, 2014; Rhodes, Hetherington, Brink & Wellman, 2015). Furthermore, four-year olds are more likely to expect individuals to direct harmful actions towards opposing group members (Chalik & Rhodes, 2014) and 6-8 year-olds also use information about social alliances to predict the likelihood of winning a conflict, expecting two individuals that were aligned to win against a single individual (Pietraszewski & Shaw, 2015). Together, these findings suggest that infants and children can
represent social groups as social allegiances and expect members of the same group to be loyal to one another.

In Chapter 3, I explore whether intergroup conflict activates social obligations that group members are expected to uphold. Across 3 studies, I will expand upon the findings reviewed in Chapter 2 and other current developmental work to explore whether infants expect ingroup members to intervene and provide aid during a conflict. Previous work with adults and children have demonstrated that when members of social groups form coalitions or social allegiances, certain social obligations should be expected when faced with intergroup conflict (Haidt & Craig, 2008; Hauser, 2006; Pietraszewski, Cosmides & Tooby, 2014, Pietraszewski & Shaw, 2015; Pietraszewski, 2016; Rhodes & Brickman, 2011; Rhodes, 2012; Rhodes 2013). For example, a critical component of social allegiances is the expectation that when one member is threatened by an opposing group, members of the same group should come to their aid (Cheney & Seyfarth, 1986; Fiske, 2004; Harcourt & de Waal, 1992; Kurzban, Tooby, Cosmides, 2001; Perry et al., 2004; Pietraszewski et al., 2014; Rai & Fiske, 2011; Wilson & Wrangham, 2003). During intergroup conflict, I hypothesize that if social alliance members are aware of a conflict, infants will expect an ingroup member to exclusively aid another ingroup member and help them accomplish their goals. Furthermore, these set of studies may shed greater light on how the mind represents groups (Pietraszewski, 2016; 2021) and the types of expectations and obligations that may be inherent in the psychological representation of a group. This will be discussed in greater detail in Chapter 5.

In Chapter 4, I will build off the findings described in Chapters 2 and 3 and explore whether manipulating social allies’ ability to witness a conflict affects infants’ predictions of social dominance. By coordinating aggression during a conflict and providing aid to a social
partner, individuals can enhance the likelihood that their social partner will emerge victorious (Harcourt & DeWaal, 1992). However, observations with non-human primates suggest that a decision to initiate and engage in a physical conflict is not only dependent on the size of the group overall, but how many allies are able to help during a conflict. Importantly, only allies that know a conflict has occurred may be able to intervene during a conflict (e.g. Slocombe & Zuberbühler, 2007). For example, chimpanzees will significantly enhance their scream vocalizations when under attack, but only if they know that a social ally is nearby and is able to provide support (i.e. is an ally with equal or greater status). Consequently, who is in the ‘audience’ (or not) during an attack, will influence animals’ behavior (Wilson & Wrangham, 2003). This demonstrates that chimpanzees have a sophisticated understanding of third-party relationships. More specifically, they are capable of taking on the perspectives of other social group members and how they may respond, as well as how their status may influence their capacity to help. With this knowledge, individuals under attack will modify their own behavior during conflict.

However, no work to date has explored whether infants can understand the perspectives of multiple agents within a social group. And importantly, no one has investigated whether infants incorporate the perspectives of social allies during intergroup conflict. In Chapter 4, two experiments explore whether manipulating social allies’ ability to witness a conflict affects infants’ predictions of social dominance. If infants understand that only agents that can see the conflict can help, then only those social agents should be calculated in infants’ predictions of social dominance.

In summary, the research presented in this dissertation aims to explore infants’ capacity to reason about social dominance between social groups. I have chosen to focus on social
dominance relationships to explore the connections between cognition, social context and the evolution of sociality that has given rise to the formation and maintenance of social hierarchies over our evolutionary history.

The implications of my work will also be discussed in the Conclusion (Chapter 5). In hierarchical societies, groups that are perceived to be higher in status enjoy benefits (e.g., access to nutritious food, better living conditions and healthcare) that influences morbidity and mortality. At the same time, lower status groups not only face reduced access to resources and territory, they also often suffer negative social outcomes, such as harassment and discrimination (e.g., Dupree & Torrez, 2021; Hyde, 2012; Parker et al., 2016; Royce, 2018; Wu, 2016). This stratification of groups within society can promote and reinforce inequity over time. The studies reported in this dissertation promise to provide a better understanding of how group processes, such as the formation of social alliances may be important for maintaining the status and well-being (and fitness) of the group, and how intergroup relationships are perceived. These issues will be further discussed in the Conclusions section of this dissertation (Chapter 5).
Chapter 2: Infants’ Understanding of Social Dominance

2.1 Synopsis

Detecting dominance relationships, within and across species, provide a clear fitness advantage because this ability helps individuals assess their potential risk of injury before engaging in a competition. Previous research has demonstrated that 10–13-month-old infants can represent the dominance relationship between two agents in terms of their physical size (larger agent = more dominant), while younger infants fail to do so. It is unclear whether infants younger than 10 months fail to represent dominance relationships in general, or whether they lack sensitivity to physical size as a cue to dominance. Two studies explored whether infants, like many species across the animal kingdom, use numerical group size to assess dominance relationships and whether this capacity emerges prior to their sensitivity to physical size. A third study ruled out an alternative explanation for our findings. Across these studies, we report that infants 6-12 months of age use numerical group size to infer dominance relationships. Specifically, preverbal infants expect agents from a numerically larger group to win in a right-of-way competition against an agent from a numerically smaller group. In addition, this is the first study to demonstrate that infants 6-9 months of age are capable of understanding social dominance relations. These results demonstrate that infants’ understanding of social dominance relations may be based on evolutionarily relevant cues and reveal infants’ early sensitivity to an important adaptive function of social groups.
2.2 Introduction

Competition for valuable resources such as mates, food and territory is common place across the animal kingdom. To minimize the cost of fighting (e.g. energy spent and personal injury or death), natural selection appears to have favoured the emergence of cognitive adaptations that help individuals predict whether they stand a chance against an opponent. For example, many species, including ants, bees, birds, chimpanzees and humans appear to represent dominance relationships among conspecifics and use this information to decide whether to engage or avoid another in physical conflict (Axelrod & Hamilton, 1981; Geist, 1978; Smith, 1974). One such cue often associated with dominance ranking is physical size, with larger individuals often benefiting from greater strength and power over smaller individuals. Natural selection has also favoured adaptations that exploit this inference, such that under threat, certain species adopt postures that make them appear bigger to intimidate their opponent.

Underscoring the possibility that representations of social dominance may be part of human’s evolved psychology, recent evidence has demonstrated that preverbal human infants infer social dominance relationships by comparing the physical size of two competing agents (Thomsen et al., 2011). In this earlier study, infants were introduced to two agents (one twice as large as the other), each with the goal of crossing to the opposite side of a platform. When both agents tried to cross the platform at the same time, their paths conflicted. Infants were shown two scenarios; one in which the larger agent yielded to the smaller agent, and one in which the smaller agent yielded to the larger agent. Although 10–13-month-olds expected that a smaller agent should yield to a larger agent, younger infants (8-9 months) failed to show any systematic belief about which agent should prevail. Therefore, only older infants were able to use the relative physical size of two competing agents to infer which one would get the right of way.
Since younger infants did not reliably use physical size as a cue to social dominance, it remains unclear whether the younger infants were incapable of representing dominance relationships in general, or if they lacked sensitivity to this particular cue. To address this issue, the present study examined whether infants’ understanding of social dominance extends to cues beyond physical size, namely to numerical group size, and if so, whether such a sensitivity emerges earlier in development.

For many group-living animals, including social insects (Batchelor & Briffa, 2011), wolves (Mech, Adams, Meier, Burch & Dale, 1998), hyenas (Boydston, Morelli, & Holekam, 2001), lions (McComb et al., 1994), primates (Wilson & Wrangham, 2003), and human children and adults (Lanchester, 1956; Pietraszewski & Shaw, 2015), the ability to infer social status by assessing the numerical size of one’s own group relative to another is particularly important for survival. The importance of this capacity to evaluate one’s own group size relative to another is illustrated by groups of chimpanzees patrolling their territory borders. To advertise the numerical strength of their group to others (Clark, 1993; Ghiglieri, 1984) and deter opposing groups from approaching (Boesch-Boesch-Achermann, 2000; Marler, 1976), both males and females will engage noisy pant-hoot calling. In general, both chimpanzees and lions are also more likely to approach if they outnumber intruders, but will stay silent and refrain from engaging in intergroup conflict if they do not (Heinsohn, 1997; McComb et al., 1994; Wilson, Hauser & Wrangham, 2001; Wilson & Wrangham, 2003). Consequently, a group’s decision to engage in competition is more likely to occur if there are more individuals in one’s own group than in the opposing group (Goodall, 1986; Wilson et al., 2001). Further, the relationship between numerical group size and inferences about social dominance has also been recently observed among children ages 6-8 years (Pietraszewski & Shaw, 2015). School-aged children predicted that alliance strength would
determine the likelihood of success in a conflict, such that two individuals aligned together were expected to win against a single individual. Coupled with the evidence reviewed from behavioural ecology, numerical size of groups may constitute a good cue to social dominance that may be part of humans’ early emerging reasoning about social dominance relationships.

Indeed, if young human infants have core knowledge of social relationships as some have argued (Mascaro & Csibra, 2012; Thomsen et al., 2011) along with the capability to track the numerical size of small groups (Feigenson, Dehaene, & Spelke, 2004), it is possible that infants may be able to draw on both capacities to support inferences about the social dominance relationship between groups that differ in numerical size. If infants infer that individuals from larger groups are more dominant than individuals from smaller groups, this would demonstrate that infants’ understanding of social dominance can extend beyond the direct relationship between two competing individuals. Specifically, such a finding may shed light on whether infants already have an understanding of how social alliances operate, namely that group members may help their own during a conflict, which confers a benefit to having more alliance members in close proximity during a conflict (Lanchester, 1956).

Here, we explored whether infants can infer the dominance relationship between two agents from groups that differ in numerical size by modifying the methodology designed (Thomsen et al, 2011). In our study, infants were first introduced to two groups that differed in numerical size (but equated for total surface area) and color. Next, infants were familiarized to an agent from both a smaller and larger group independently completing their goal of crossing a platform. When both of these agents attempted to cross the platform simultaneously, they bumped into one another. Therefore, the only way an agent could continue along their goal path was if the other agent yielded to the other by moving out of the way. Infants in Studies 1 and 2
viewed the same sequence of events.

In Study 1, we investigated whether 9–12-month-old infants use numerical group size as a cue to social dominance. In Study 2, we examined whether 6–9-month-old infants (who have not yet been shown to represent social dominance relationships between individuals) would also be sensitive to the cue of numerical group size.

2.3 Study 1

2.3.1 Method

2.3.1.1 Participants

Forty-eight infants for each age group were recruited from a local science center and tested in a sound proof testing room located on site. A legal guardian provided consent on behalf of each participant. In Study 1, we analyzed the data from infants between the ages of 9 and 12 months (mean age =10.68 mos, range = 9.36 -12.00 mos, SD = 25 days, 25 females). This sample size is consistent with prior infant work, which included 16 infants per age group (e.g., Jin & Baillargeon, 2017; Thomsen et al., 2011). According to parental report, 47% of infants included in the final sample were classified as Caucasian, 32% as East Asian, and 21% as other ethnicities. An additional 28 participants were excluded from the sample because they did not watch the screen during both sequences in which one of the agents bowed down and moved out of the other agent’s path of motion (n = 12), fussed out (n = 10), or because of sibling or parental interference (n = 6). These exclusion rates are typical for studies with infants in community-based testing centers where infants are removed from otherwise highly stimulating environments prior to their participation in the study, and is comparable to the exclusion rate for the study
conducted by Thomsen et al. (2011), which also investigated infant’s understanding of social
dominance in a museum setting.

2.3.1.2 Procedure

We presented forty-eight infants between the ages of 9 and 12 months (mean age = 10.68 mos, SD = 25 days, 25 females) with short animations that depicted the actions and goals of two novel agents, each belonging to a group that differed in numerical size and color (see Figure 2.1). Crucially, whereas the two groups differed in numerical size, the total surface area of the groups was matched. Therefore, only numerical size (and not continuous extent) could be used to determine the dominance relationship among individuals from these groups. For each of the studies presented in this dissertation, the violation of expectation paradigm has been implemented. This method was originally established by Baillargeon, Spelke & Wasserman (1985) and has been reliably used to study infant cognition. In such paradigms, the infant is familiarized to a novel event, which is repeatedly shown until infants choose to look away from the scene for a minimum amount of time (seconds) or number of trials that is predetermined prior to the experiment. This is done to ensure that infants have cognitively processed the event, and no longer find it novel. Infants are subsequently shown two test trials, in which the length of time infants watch the event is recorded. In one trial, an event is shown that is (hypothesized to be) in violation of the viewer’s expectations, which should generate more “surprise”, and consequently, result in a longer looking time compared to a second trial, which depicts an event that is (hypothesized to be) consistent with the viewer’s expectations. Infants’ looking time responses are compared between the “unexpected” and “expected” trials, which means that the violation of expectation paradigm is a within-subjects design. This paradigm is believed to capitalize on the idea that infants will look longer to impossible or unexpected events, as it takes longer to
cognitively process such events. The specific details of the study design and corresponding looking criteria are detailed below.

**Group Introduction Sequence.** All participants were first familiarized to two groups of novel animated characters – one group of blue characters and one group of green characters similar to the animations designed by Thomsen et al., (2011) (see Figure 2.1). To introduce these groups, the green characters appeared on the opposite side of the screen from the blue characters and infants observed each set of characters bounce in synchrony with other members of their group for a duration of 3 seconds. For example, members of the green group bounced together, followed by members of the blue group (order was counterbalanced across participants). One group was always numerically larger than the other, and this was counterbalanced between participants. We chose numerical groups consisting of two agents and three agents, because previous research has demonstrated that infants as young as six months of age are able to reliably distinguish between the ratio of 2:3 individual objects in a variety of contexts and methodologies (Feigenson et al., 2004). To ensure that infants’ attention was exclusively drawn to numerical magnitude and not overall continuous extent (Feigenson, Carey & Spelke, 2002) we equated the amount of surface area occupied by each group on the screen.

**Goal Familiarization Trials.** Following the Group Introduction Sequence, participants observed one agent from one of the groups move to a platform on the bottom of the screen and then move to the opposite side of the screen. To ensure that infants understood that the agent had the goal of crossing the platform, this sequence repeated for a minimum of 2 trials and a maximum of four trials. The total number of trials depended on whether the infant looked away from the screen (for at least one second) as others have previously done (Thomsen et al., 2011)
Next, infants observed one agent from the other group perform the same actions, albeit moving across the screen in the opposite direction as the first agent, once again for a maximum of four repetitions of the same sequence, or until the infant looked away for at least one second. The order in which infants viewed the agent from the numerically larger (or numerically smaller) group cross the platform first in the first set of familiarization trials was counterbalanced across participants. Importantly, both agents who crossed the platform were identical in physical size (Supplementary Videos S2.1 and S2.2).

**Inter-Trial.** The Inter-Trial began with infants viewing the Group Introduction sequence, in which both groups bounced one at a time. After the Group Introduction trial, one agent from each group (the same agents viewed in the Goal Familiarization Trials) moved to the platform below simultaneously and proceeded to move to the opposite side from which they came. Moving across the platform, albeit in opposing directions, the two agents bumped into each other in the middle of the platform, slightly backed up, and then bumped into each other again. For a third and final time the agents slightly backed up and then bumped into each other again. (See Figure 2.2 and Supplementary Video S2.3). This inter-trial firmly established that when each agent pursued their goal of crossing the platform at the same time, a conflict ensued.

**Test Trials.** Following the inter-trial event, infants viewed two test trials, in which one agent on the platform yields to the other agent. Thus, after the two agents bumped into each other a third time during the inter-trial event, one of the agents bowed down and moved out of the way so the other agent could cross to the other side of the platform. Based on our hypothesis that infants may use the numerical size of two groups to infer dominance relationships among individuals from those groups, in the Unexpected Outcome trial, the agent from the numerically larger group moved out of the way so that the agent from the numerically smaller group could
cross the platform (Supplementary Video S2.5). In the Expected Outcome trial the agent from the numerically smaller group moved out of the way to allow the agent from the numerically larger group could cross the platform (Supplementary Video S2.4). The order of these two trials were counterbalanced. After the agent crossed the platform, the animation froze and total looking duration for that trial was recorded until the infant looked away for more than two consecutive seconds, or until 30 seconds had elapsed.

The methods described in the goal familiarization trial, inter-trial and test-trials described each agent moving in an identical manner to Thomsen et al., (2011). The only modifications made to the stimuli were done to address our particular research question, such that the two competing agents were of the same physical size and were first shown bouncing exclusively with the color-matched group members from which they belonged (either in the upper left and right hand corners of the screen).

2.3.2 Results

We ran an ANOVA with a difference score (calculated from infants’ looking times to the Unexpected and Expected Outcomes) entered as the dependent variable, and entered 2 between subjects factors: trial order (Expected Outcome trial first, vs. Unexpected Outcome trial first) and gender. No main effect of trial order was found \( (F_{1,47} = 1.04, p = .31) \). In addition, no main effect of gender \( (F_{1,47} = .004, p = .95) \) or interaction between trial order and gender \( (F_{1,47} = 0.32, p = .58) \) was observed. To rule out the possibility of age differences we ran the same analysis, and entered age as a covariate. We found no significant differences due to age \( (F_{1,47} = 0.52, p = .47) \).

As predicted, infants looked longer to the Unexpected Outcome trial, in which an agent from a numerically larger group yielded to an agent from a numerically smaller group \( (M = 9.72 \)
sec) compared to the Expected Outcome trial ($M = 5.86$ sec), 95% CI [1.43, 6.30], $t(47) = 3.19$, $p = .003$, $d = .62$ (See Figure 2.3). Our main finding was further supported when the data were examined non-parametrically. Out of 48 participants, 36 (75% of the sample) looked longer to the Unexpected Outcome trial in comparison to the Expected Outcome trial, $\chi^2(1,47) = 12.00$, $p = .001$.

2.3.3 **Discussion**

This study is the first to demonstrate that infants use the numerical size of a group as a cue to social dominance, and expect an agent from a numerically larger group to be dominant. Although physical size and numerical group size are both sufficient cues to dominance, our study shows that physical size is not a necessary cue, as the two competing agents in our study were matched along this dimension. Importantly, infants are not only capable of differentiating between the numerical quantity of groups and determining whether one group is larger or smaller (Feigenson et al., 2004) but they use this information to infer the dominance relationship between competing individuals from those groups. Furthermore, it is important to note that the non-competing group members from both groups did not assist in any way during the conflict. Thus, infants could only have inferred which competing agent would be dominant through their alliance with a numerically larger group. This may suggest that infants understand that the presence of alliance members confer a competitive advantage, even if they are not directly involved in an observed conflict.

2.4 **Study 2**

It is possible that the reported failure of infants’ ability to reason about social dominance relationships before 9-months-of-age reflects a genuine lack of infants’ capacity to establish such representations. Alternatively, younger infants may be capable of understanding social
dominance relations, but simply do not use physical size to infer dominance. To determine whether infants’ ability to infer social dominance from the numerical size of a group emerges prior to their sensitivity to relative physical size, we conducted the same experiment as in Study 1 with a sample of forty-eight infants between the ages of 6 and 9 months. Importantly, this sample included the age ranges that reportedly fail to use physical size to reason about social dominance (Thomsen et al., 2011).

2.4.1 Method

2.4.1.1 Participants

In Study 2, we analyzed the data from with a sample of forty-eight infants between the ages of 6 and 9 months infants (mean age = 7.40 mos, SD = 30 days, 20 females). This sample size is consistent with prior infant work, which included 16 infants per age group (e.g., Jin & Baillargeon, 2017; Thomsen et al., 2011). According to parental report, 66% of infants included in the final sample were classified as Caucasian, 18% as East Asian, and 16% as other ethnicities. An additional 21 participants were excluded from the sample because they did not watch the screen during both sequences in which one of the agents bowed down and moved out of the other agent’s path of motion (n = 11), fussed out (n = 7), or because of sibling or parental interference (n = 3).

2.4.1.2 Procedure.

Identical to Study 1.

2.4.2 Results

We ran an ANOVA with a difference score (calculated from infants’ looking times to the Unexpected and Expected outcomes) entered as the dependent variable, and entered 2 between subject factors: trial order (Expected Outcome trial first, vs. Unexpected Outcome trial first) and
gender. A main effect of trial order was found ($F_{1, 47} = 9.37, p = .004, \eta_p^2 = .18$). This effect was mainly driven by infants viewing the Unexpected Outcome trial first, such that infants looked longer on average when viewing the Unexpected Outcome trial first, as opposed to viewing the Unexpected Outcome trial second (See Table S1). No main effect of gender ($F_{1,47} = 2.14, p = .15$) or interaction between trial order and gender ($F_{1,47} = 0.00, p = .98$) was observed. To rule out the possibility of age differences we ran the same analysis and entered age as a covariate. We found no significant differences due to age ($F_{1,47} = 1.45, p = .24$).

A paired-samples t-test comparing the mean looking time (seconds) that infants ages 6-9 months spent looking at the screen following the Unexpected Outcome trial ($M = 10.41$ sec) and the Expected Outcome trial ($M = 6.75$ sec) was significant, 95% CI [1.37, 5.95], $t(47) = 3.22, p = .002, d = 0.57$ (See Figure 2.4), replicating our finding observed with the older sample from Study 1. Thus, even younger infants are more surprised when an agent from a numerically smaller group prevails at the expense of an agent from a numerically larger group. As with Study 1, this finding was further supported when the data were examined non-parametrically. Out of 48 participants, 35 (73% of the sample) looked longer to the Unexpected Outcome trial in comparison to the Expected Outcome trial, $\chi^2 (1,47) = 10.08, p = .001$.

Collapsing the results from Studies 1 and 2, a paired samples t-test comparing the mean looking time (seconds) that infants ages 6-9 months spent looking at the screen following the Unexpected Outcome trial ($M = 10.07$ sec) and the Expected Outcome trial ($M = 6.30$ sec) was significant, 95% CI [2.12, 5.41], $t(47) = 4.56, p < .001, d = .60$). This finding was further supported when the data were examined non-parametrically. Out of 96 participants, 71 (74% of the sample) looked longer to the Unexpected Outcome trial in comparison to the Expected Outcome trial, $\chi^2 (1,95) = 22.04, p < .001$. This suggests that by six months of age, infants
expect an agent from a numerically larger group to be socially dominant.

2.4.3 Discussion

Results from Study 2 demonstrate once again that infants can use the relative numerical size of two groups to infer the social dominance relationship between competing individuals from those groups. Like older infants, younger infants expect an agent from a numerically larger group to be socially dominant. This result is especially interesting in light of previous experiments where infants’ younger than 10 months of age failed to represent social dominance relationships among two competing individuals that differed in their physical size (Thomsen et al., 2011).

2.5 Study 3

In Studies 1 and 2, we presented infants with two groups varying in numerical size, but matched in total surface area. Infants looked longer when an agent from the numerically larger group yielded to a same sized agent from the numerically smaller group. While we interpret this result as evidence that infants use numerical size of a group to reason about the dominance relationship between individuals from those groups, there is another possible interpretation to consider. With the limited cues to depth inherent in our computer display, the relative size vs distance of each individual on the screen might have been difficult to discern after viewing one agent yielded to the other agent on the platform. It is possible that infants noticed this change in state and remained fixated on the screen in order to compare the relative size and distance of the agent that yielded to the remaining individual(s) from the agents’ own group. Accordingly, this account would predict that infants looked longer to our Unexpected Outcome trial, because there were more size and depth comparisons to assess between the individuals in the larger group (3 individuals) relative to the smaller group (2 individuals).
To address this alternative hypothesis, we conducted a study with forty-eight infants between the ages of 6 and 12 months (mean age = 8.40 mos, SD = 1.44 mos, 22 females). In this study, we modified the stimuli presented in Studies 1 and 2 by eliminating the conflict between an agent from each group. To begin, participants viewed the Group Introduction Sequence (same as Studies 1 and 2). Then, participants observed one agent from each group move simultaneously to the platform below. In one trial, infants viewed the agent from the numerically larger group attempt to cross the platform. However, a barrier already present in the middle of the platform obstructed the agent’s path (See Figure 2.5). Once the agent reached the middle of the platform, the agent bumped into the barrier three times. Then, the agent bowed down and retreated towards the back of the platform (in a manner identical to the retreating motion observed in Studies 1 and 2) (See Supplementary Video S2.6). In the other trial, infants viewed the same sequence of events when the agent from the numerically smaller group attempted to cross the platform (See Supplementary Video S2.7). Since this new stimuli eliminated conflicting goals between agents, infants should not automatically reason about social dominance relationships. Thus, if infants’ attention to each trial is driven by an effort to compare the relative size and distance of the retreating agent to the remaining individual(s) from the agents’ own group, then infants should look longer to the trial in which the agent from the numerically larger group retreats towards the back of the platform.

2.5.1 Method

2.5.1.1 Participants

For Study 3, 48 infants were recruited from a local science center and tested in a soundproof testing room located on-site. We analyzed the data from 48 infants between the ages of 6 and 12 mo (mean age = 8.40 mo, range = 6.12–11.52 mo, SD = 1.44 mo, 22 females). This
sample size is consistent with prior infant work, which included 16 infants per age group (e.g., Jin & Baillargeon, 2017; Thomsen et al., 2011). According to parental report, 41% of infants included in the final sample were classified as Caucasian, 24% as East Asian, and 35% as other ethnicities. An additional 20 participants were excluded from the sample because they did not watch the screen during both sequences in which one of the agents bowed down and moved away from the platform (n = 7), fussed out (n = 8), or because of sibling or parental interference (n = 5).

2.5.1.2 Procedure.

Identical to Study 1 and 2.

2.5.1.3 Stimuli

In Study 3, infants saw two test trials. Each trial began with infants viewing the Group Introduction Sequence (see Study 1 and 2 methods). After the Group Introduction Sequence, one agent from each group (the same agents viewed in the Goal Familiarization Trials in Study 1 and 2) moved simultaneously to the platform below. One agent remained stationary, while the other proceeded to move to the opposite side from which they came. In one trial, infants viewed the agent from the numerically larger group attempt to cross the platform. However, a barrier placed in the middle of the platform obstructed the agent’s path. Once the agent reached the middle of the platform, the agent bumped into the obstacle for a total of three times. Then, the agent bowed down and moved along the platform (in a direction perpendicular from which they were moving previously) (Supplementary Video S2.6). Once the agent bowed and moved to the back of the platform, the animation froze and total looking duration for that trial was recorded until the infant looked away for more than two consecutive seconds, or until 30 seconds had elapsed. In the other trial, infants viewed the agent from the numerically smaller group attempt to cross the
platform, who was also obstructed by the barrier (Supplementary Video S2.7). The order of these two trials were counterbalanced across participants.

2.5.2 Results

We ran an ANOVA with a difference score (calculated from infants’ looking times to the trial in which an agent from the larger group retreats and the trial in which an agent from the smaller group retreats) entered as the dependent variable, and entered 2 between subject factors: trial order (Agent from larger group retreats first, vs. Agent from smaller group retreats first) and gender. A main effect of trial order was found ($F_{1,47} = 6.27, p = .016, \eta^2_p = .13$). This effect was mainly driven by infants looking longer in general, to the second trial presented (See Table 2.1). No main effect of gender ($F_{1,47} = 0.12, p = .73$) or interaction between trial order and gender ($F_{1,47} = 0.37, p = .55$) was observed. To rule out the possibility of age differences we ran the same analysis, and entered age as a covariate. We found no significant differences due to age ($F_{1,47} = 0.23, p = .63$).

A paired-samples t-test comparing the mean looking time (seconds) to each trial type revealed that infants did not look significantly longer to the trial in which the agent from the larger group retreated ($M = 10.53$ sec) compared to the trial in which the agent from the numerically smaller group retreated ($M = 10.20$ sec), 95% CI [-2.20, 2.86], $t(47) = 0.26, p = .79, d = .04$. Furthermore, when the data was examined non-parametrically, half of the infants ($N = 24$) looked longer to the trial in which the agent from the larger group retreated, and half looked longer to the trial in which the agent from the smaller group retreated, $\chi^2 (1,47) = 0.00, p = 1.00$. Therefore, infants’ mean looking times were not driven by one particular trial type.
2.5.3 Discussion

Although a null result, this finding suggests that it is unlikely infants in Studies 1 and 2 looked longer to an agent from a numerically larger group yielding to an agent from a numerically smaller group because participants were trying to use changes in apparent physical size to make sense of the size and or depth of the two-dimensional characters on the screen.

2.6 General Discussion

This is the first study to demonstrate that infants as young as 6 months of age can represent the dominance relationship between two competing agents in terms of the numerical size of their respective social groups. Whereas previous research has demonstrated that 10-13-month-olds are capable of using physical size to predict whether an individual should be dominant or subordinate to another, younger infants were unable to do so (Thomsen et al., 2011). Thus, our data suggest that the reported failure among younger infants to represent social dominance in this earlier study may have been due to the specific cue tested – specifically, understanding the relationship between physical size and social dominance may require more time for infants to learn.

Why might numerical group size be an earlier emerging cue to social dominance than physical size? Interestingly, perceptual cues such as physical size may not always serve as a reliable indicator of social dominance – especially among species that form cooperative social relationships with conspecifics. For example, in non-human primates, male chimpanzees striving to achieve a higher status position cannot attain this on their own, and must rely on the support of other males (deWaal, 1984; Nishida & Hosaka, 1996) Supporting a male that achieves a higher status position confers benefits to the subordinate males as well. Specifically, higher status males can provide greater mating opportunities to coalition partners as well as support and protection.
during a conflict against other coalitions or neighboring groups (Duffy, Wrangham & Silk, 2007; Nishida & Hosaka, 1996; Wilson & Wrangham, 2003). Therefore, higher status positions are not necessarily reserved for the largest individuals, but rather can be achieved by smaller (and/or younger) individuals that can successfully cultivate social alliances (Cheney & Seyfarth, 1992; Hand, 1986). In comparison to physical size, numerical group size may be a more reliable or salient indicator of social dominance. Often the consequences of being out-numbered are greater than the consequences of being out-sized. The mob behavior of several avian species on larger birds of prey being just one example where group size trumps physical size (Lorenz, 1966).

Another possibility is that infants respond to group size earlier than physical size not because of conceptual changes in their representations of social dominance, but because infants find number more salient than physical size (which corresponds with surface area). For instance, Brannon, Abbott & Lutz (2004) showed that 6-month-old infants could discriminate a 2-fold increase in number but not a 2-fold increase in surface area.

The early sensitivity to the relationship between numerical size and social status may in part be due to both judgments sharing a common representational system. Specifically, in adults, social status comparisons (e.g. military rank) are processed in the same brain region (inferior parietal cortex) in which numerical ratio discrimination is computed (Chiao et al., 2009; Chiao, 2010). Further, judgments of numerical quantity and social status exhibit a similar constraint. This is known as the numerical distance effect and semantic distance effect respectively, where individuals take longer to compare two points closer on a scale (e.g., 34 vs. 35; associate professor vs. assistant professor) than points further on the same scale (e.g., 30 vs. 50; associate professor vs. janitor) (Chiao, Bordeaux & Ambady, 2004; Chiao et al., 2009; Chiao, 2010).

Although infants appear to attribute greater dominance to an individual from a
numerically larger group, it is unclear what kinds of inferences infants make about group members that do not directly participate in the conflict, and how this may influence infants’ looking times to each test trial. For example, might infants have looked longer to the “unexpected” trial, because there were more “objects” (i.e., six eyes) to look at in the group that had three agents, compared to the group that had only two agents (i.e., four eyes). However, this lower-level alternative cannot fully explain our pattern of results, as Study 3 revealed that infants did not look longer to a trial in which an agent from a larger, or smaller group attempted to cross the platform (but was obstructed by a barrier). Therefore, perceptual differences between the groups cannot be the main factor driving these effects.

However, even though the two competing agents in Studies 1 and 2 were physically the same size, the relative size of these individuals with respect to their own group members differed. More specifically, the competing agent from the numerically larger group was always physically larger than the other members of her group, and the competing agent from the numerically smaller group was always physically smaller than the other member of her group. Given the differences in relative physical size within groups, it is possible that infants used relative physical size to evaluate within-group dominance rankings first, before using these rankings to predict the outcome of a between-groups competition. Consequently, infants may expect an agent with a higher within-group dominance ranking (i.e. the largest individual within the group) to also have a between-groups advantage, even when facing an opponent that is identical in size.

Although future research will need to explore this possibility, this account cannot fully explain our findings based on the methodology we employed. First, Thomsen et al., (2011) showed that infants younger than 10-months-of-age infants were unable to use physical size of
agents to represent dominance relationships. Thus, if infants relied on physical size to evaluate within group dominance relationships prior to assessing between group dominance relationships, only infants older than 10 months of age would have expected an individual from a numerically larger group to be dominant over an individual from a numerically smaller group in our study. However, we found that 6–9-month-old infants can use the relative numerical size of two groups to infer the social dominance relationship between competing individuals from those groups. Second, Mascaro & Csibra (2012) demonstrated that 12- and 15-month-old infants have to witness one agent prevail over another agent when encountering competing goals, in order to make inferences about the agents’ dominance relationship. Since none of the infants in our study observed a direct competition between agents within the same group, our infants would not have enough information to assess dominance relationships within each group.

Future research may also want to examine infants’ expectations of the behaviour of group members during a conflict. It is possible that infants may expect individuals from the same group to help an own group member during a perceived conflict. Consistent with this hypothesis, in a recent study with 6–8-year-olds, alliance strength was found to be an important predictor of a group’s success, such that allies were expected to win against a single individual with no allies (Pietraszewski & Shaw, 2015). Since infants as young as 3-months of age are capable of understanding that an agents’ goals (such as trying to climb up a hill) can be helped or hindered by another individual (Hamlin, Wynn, & Bloom, 2010; Powell & Spelke, 2013) and also expect social group members to act alike at 7 months (Feigenson, Carey & Spelke, 2002), it is possible that infants may expect additional members of a group to help one another during a conflict. This hypothesis could be directly tested by examining infants’ surprise when an individual from one group refrains from helping someone from their group or who helps someone from an opposing
Furthermore, how infants weigh the benefits of increased group size with the potential cost of loss or injury to group members can speak to theories of intergroup conflict that posit distinct functional roles for different members of a group. For example, Lanchester (1956) proposed that the Linear and Square law can help assess the benefits of increased group size with the cost of losing individuals in battle. More specifically, the Linear Law is based on the assumption that there is little to no fitness advantage for individuals from the numerically larger group to concentrate attacks on individuals of the smaller numerical group until they are needed to replace others that have been removed from the battle (owing to injuries or fatalities). According to the Linear Law, both individual fighting abilities and the number of individuals in a group will influence the group’s Resource Holding Potential (the capacity for one’s group to impose costs on the other group), such that the Resource Holding Potential of the larger group will increase as a linear function of their numerical size advantage. Therefore, a larger group may strategize to send out their “best” fighters first, to eliminate more members of the smaller group.

Conversely, the Square Law assumes that all individuals from the numerically larger group will simultaneously attack the individuals from the smaller numerical group (Lanchester, 1956). According to the Square Law, numerical group size has the greatest influence on the group’s Resource Holding Potential and is less dependent on individual fighting ability. Consequently, the Resource Holding Potential of the larger group will increase as a square function of their numerical size advantage. Therefore, working together as a unit provides the greatest advantage when fighting a smaller group of individuals.

Studies with infants’ and young toddlers’ expectations of the behaviour of group
members during an intergroup conflict may help reveal the extent to which they hold beliefs about the timing of when a group member will intervene (before or after a group member is defeated), how many group members will intervene on behalf of a compatriot (one or many), and the particular order with which group members may intervene (larger individuals first or random). Identifying the constraints on infants’ reasoning about the role of group members in intergroup conflict may help to clarify which (or whether) such laws are part of an early emerging system for reasoning about intergroup cognition.
Chapter 3: Infants’ Expectations of Social Obligations During Intergroup Conflict

3.1 Synopsis

Many species of animals form social allegiances to enhance survival. Across disciplines, researchers have suggested that allegiances form to facilitate within group cooperation and defend each other against rival groups. Here, we explore humans’ reasoning about social group obligations beginning in infancy, long before they have experience with intergroup conflict. In Study 4 and 5, we demonstrate that when infants (17-19 months, and 9-13 months, respectively) witness an agent intervene during a conflict, that aide should be exclusively provided to ingroup members. Study 6 conceptually replicated the results of Study 4 and 5. Together, this set of experiments reveal that humans’ understanding of social obligation and loyalty may be innate and supported by infants’ naïve sociology.

3.2 Introduction

To aid survival, cognitive adaptations have evolved to support the formation and participation in social allegiances (Cheney & Seyfarth, 1986; De Waal, & Waal, 2007; Harcourt and de Waal, 1992; Tomasello, 2014; Wilson & Wrangham, 2003). Work in the social sciences has begun investigating the psychological underpinnings of such an alliance detection system: a neurocognitive system that is attune to cues and categories that are likely to be indicative of a cooperative social allegiance. This cognitive capacity serves to help individuals detect, track, store and retrieve relevant social information across various contexts (Harcourt & de Waal, 1992; Kurzban, Tooby, Cosmides, 2001; Perry, Barrett & Manson 2004; Pietraszewski, Cosmides & Tooby, 2014; Sidanius & Pratto, 1999). In addition, research has suggested that representations
of social allegiances constrain expectations about the social group’s identity, roles and moral obligations (Haidt & Craig, 2008; Hauser, 2006; Pietraszewski et al., 2014; Pietraszewski & Shaw, 2015; Pietraszewski, 2016; Rhodes & Brickman, 2011; Rhodes, 2012; Rhodes 2013). For example, a critical component of social allegiances is the expectation that when one member is threatened by an opposing group, members of the same group should come to their aid (Cheney & Seyfarth, 1986; Harcourt & de Waal, 1992; Kurzban et al., 2001; Perry et al., 2004; Pietraszewski et al., 2014; Rai & Fiske, 2011; Wilson & Wrangham, 2003). Thus, knowing who is willing to help or hinder you, or whom to align with or avoid, is critical for safely navigating the social world.

To begin exploring the developmental origins of reasoning about social allegiances, Pun, Birch & Baron (2016) investigated whether infants, like non-human primates, use numerical group size to predict the outcome of a conflict between two agents. The results revealed that 6-12 month old infants expected an agent from a numerically smaller group to submit, and defer to an agent from a numerically larger group. Such a finding is consistent with evidence from non-human animals and suggestive of a foundational capacity to reason about social allegiances (Fiske, 2004; Harcourt & de Waal, 1992; Lanchester, 1956; Mech, Adams, Meier, Burch & Dale, 1998; Perry et al., 2004; Pietraszewski & German, 2013; Pietraszewski & Shaw, 2015; Rai & Fiske, 2011; Rhodes, 2012; Sidanius & Pratto, 1999; Wilson & Wrangham, 2003). However, this result was particularly intriguing in light of the fact that a) both competing agents were identical in physical size and b) social group members only observed the conflict, and did not intervene. This finding raises the question of why infants expected an agent from a numerically larger group to win over an agent from a numerically smaller group. More specifically, did infants view social groups as social allegiances, such that the larger group entails more allies that would be able to
intervene and provide aid during the conflict? Currently, this is just speculation, as Pun et al.
(2016) did not directly test infants’ expectations of whether a social group member would
intervene. The goal of the present research is to investigate whether young infants make rich
inferences about social group behavior based on group membership. More specifically, whether
infants understand that ingroup members must uphold certain obligations, such as providing
support to one another during intergroup conflict.

Recent work demonstrates that toddlers can make some predictions about an individual’s
behavior based on their group membership (Bian, Sloane & Baillargeon, 2018; Jin &
Baillargeon, 2017; Ting et al., 2019). For example, in the absence of conflict, 17-month-old
infants expect ingroup members to provide instrumental support (e.g. physically retrieving an
object) to another ingroup member. In this context, however, simply delineating group
membership (through labeling) did not facilitate infants’ expectations about how ingroup
members should treat outgroup members, as they were equally surprised when an ingroup
member helped or ignored an outgroup member (Jin & Baillargeon, 2017). In addition, Rhodes,
et al., (2015) demonstrated that 16-month-olds monitor the experiences of individuals from
opposing groups to predict how their social partners will behave. They found that infants were
more surprised when agents from opposing groups (whom had never previously interacted)
cooperated, as opposed to conflicted, suggesting that infants expected the initial state of conflict
to generalize across social partners. Together, these findings suggest that toddlers’ expectations
of how an individual will behave toward others is shaped by an understanding of the social
relationships among those individuals.

These findings notwithstanding, no studies (to the best of our knowledge) have
specifically investigated whether infants expect an agent to intervene during a conflict to help an
ingroup member accomplish their goal. This is an important ecologically valid context to study, as allegiances often form to facilitate within group cooperation and defend each other against rival groups (Harcourt & de Waal, 1992; Lanchester, 1956; Mech et al., 1998; Perry et al., 2004; Pietraszewski & German, 2013; Pietraszewski & Shaw, 2015; Tomasello, 2014; Wilson & Wrangham, 2003). As such, our aim was to explore infants’ reasoning about within and between group helping (and harm) during an episode of intergroup conflict. More specifically, we investigated whether infants understand that if an agent intervenes during intergroup conflict, that they should uphold an obligation to assist only members of their in ingroup.

In Study 4, we investigated whether 17–19-month-old infants would expect group members to intervene during a conflict and indirectly help an own group member complete their goal. In addition, to begin exploring infants’ tolerance for outgroup harm, aiding an ingroup member required performing an antisocial action towards an outgroup member. More specifically, in this violation of expectation paradigm, infants observed third-party interactions between members of two novel social groups. After witnessing a conflict between two opposing group members, infants saw two outcomes: one in which an agent helps an ingroup member accomplish their goal (by hindering an outgroup member), and one in which an agent helps an outgroup member accomplish their goal (by hindering an ingroup member). If infants expect an intervening agent to exclusively help an ingroup member, then they should be more surprised and look longer when an intervening agent helps an outgroup member during intergroup conflict.

We chose to conduct this experiment first with 17–19-month-olds, given recent evidence that similar aged infants have some expectations about individuals providing instrumental assistance to ingroup members (Jin & Baillargeon, 2017). In Study 5, we sought to extend this investigation with younger infants (9-13 months). Finally, Study 6 was conducted to rule out a
potential alternative explanation for the results obtained in Study 4 and 5.

3.3 Study 4

3.3.1 Method

3.3.1.1 Participants

36 infants were recruited from our university database. In Study 4, we analyzed the data from infants between the ages of 17 and 19 mo (mean age = 18.00 mo, range = 16.92 mo–19.08 mo, SD = 20 d, 16 females). This sample size is on par with the sample sizes of prior infant work, which included 16 infants per age group (e.g., Jin & Baillargeon, 2017; Thomsen et al., 2011). According to parental report, 55% of infants included in the final sample were classified as Caucasian, 28% as East Asian, and 17% as other ethnicities. An additional 10 participants were excluded from the sample because they did not watch the screen during the critical sequence in which an agent pushed another agent off the platform (n = 3), fuss ed out (n = 4), or experienced sibling or parental interference (n = 3).

3.3.1.2 Procedure

For all experiments, the procedure was identical. Each participant was seated on the lap of their caregiver in a sound proof testing room for the duration of the experiment, ~140 cm from the center of a television screen measuring 48” in diameter. To ensure that caregivers would not influence their child’s behavior, they were instructed to either keep their eyes closed or were asked to wear a pair of opaque glasses. Caregivers were also asked to remain silent and to not otherwise direct the child’s’ attention. The experimenter sat adjacent to the infant and caregiver, separated by a distance of ~4 feet and hidden behind a black curtain. The experimenter remained behind the curtain and out of the infants’ line of sight for the duration of the experiment. In all experiments, infants viewed a series of animations that depicted third-party
interactions between members of two opposing social groups. As in the previous studies described in Chapter 2, a violation of expectation paradigm was implemented, such that infants’ looking times to the outcomes of the two test trials were recorded (see Baillargeon, Spelke & Wasserman, 1985). Details of the study design and looking criteria are described below.

3.3.1.3 Stimuli and Coding

Group introduction sequence

All participants were first familiarized to two groups of novel animated characters – one group of blue characters and one group of green characters (similar to the animations designed by Pun et al., (2016)). Similar to the paradigm used by Pun et al (2016), infants were introduced to two novel social groups that infants did not share similarities with (e.g. race and language), thereby eliminating the possibility of infants forming a “like me” or “ingroup” bias (Mahajan & Wynn, 2012; Meltzoff, 2007). Group size was equated, such that there were three members in each group, and each individual was identical in physical size. To introduce these groups, the green characters appeared on the opposite side of the screen from the blue characters, and infants observed each set of characters bounce in synchrony with members of their group for a duration of 3s. More specifically, all three members of the green group bounced together, followed by the other three members of the blue group (order was counterbalanced across participants).

Goal familiarization

Following the group introduction sequence, participants observed an agent from one of the groups move to the platform (on the bottom of the screen) and proceed to move to the opposite side of the platform (Supplementary Video S3.1). To ensure that infants understood that the agent had the goal of crossing the platform, this familiarization sequence (19 s) was repeated in its entirety for a minimum of two trials. If an infant looked away during a familiarization trial
for a minimum of 1s, the familiarization sequence was repeated (up to a maximum of four trials). Next, infants observed another familiarization sequence (19 s) in which one agent from the other group perform the same actions, albeit moving across the screen in the opposite direction as the first agent (Supplementary Video S3.2). Once again, this familiarization sequence was presented for a minimum of two, and maximum of four times. The order in which these two familiarization sequences were presented were counterbalanced across participants.

*Inter-trial* (Supplementary Video S3.3)

The *inter-trial* (22 s) began with infants viewing the *group introduction sequence*, in which both groups bounced one at a time. After the *group introduction sequence*, one agent from each group (the same agents viewed in the *goal familiarization* trials) simultaneously moved to the platform. Then, both agents moved across the platform at the same time, albeit in opposing directions. However, when the two agents reached the middle of the platform, they bumped into each other, slightly backed up, and then bumped into each other again (for a total of three times). This *inter-trial* served to establish that when the two agents from opposing groups each pursued their goal of crossing the platform at the same time, a conflict ensued. Therefore, infants were required to view the conflict, depicted by the agents bumping into one another. The inter-trial was only presented once, unless an infant looked away during the conflict. In this case, the inter-trial was presented a second time.

*Test trials*

Each infant saw a total of two test trials. The test trials began with the same actions depicted in the *inter-trial*. Infants then witnessed an observing member from one of the groups move down to the middle of the platform and stand between the two competing agents. In one test trial (30 s), this third agent pushed the *opposing* group (ie. outgroup) member off of the
platform, thereby allowing their own group (ie. ingroup) member to achieve their goal of crossing the platform (Expected Outcome) (Supplementary Video S3.4). In the other test trial (30 s), this third agent pushed their ingroup member off the platform, thereby allowing the outgroup member to achieve their goal of crossing the platform (Unexpected Outcome) (Supplementary Video S3.5). After the infant viewed the test event, the animation froze and a static image of the characters remained. Infants’ looking times were measured to the static outcomes of the test trials. Therefore, as soon as the animation froze, looking time was recorded until the infant looked away for two consecutive seconds, or until 30s had elapsed. The order of these two test trials were counterbalanced across participants. Only infants that viewed both the conflict and critical sequence in which the intervening agent pushed another agent off the platform (for each test trial) were included in the final sample. We reasoned that if infants expect members of the same group to be part of a social allegiance, and help each other during a conflict, then infants should be more surprised and look longer when the intervening agent helps an outgroup member (Unexpected Outcome), compared to when they help an ingroup member (Expected Outcome).

Coding

For all experiments, coders used the computer application jHaB (Casstevens, 2007) to record the duration of infants’ looking times. For all experiments, infants’ looking times were recorded by a primary online coder. Data from the primary coder was used in the results. A naive secondary offline coder re-coded 50% of the videos for Study 4. For videos that were re-coded, looking times between the two coders were correlated $r = .98$ across all trials.

3.3.2 Results

Across all experiments, looking times from each test trial were first log-transformed. Inferential statistics (eg. model estimates, CIs) were fit to log-transformed looking times (see
Csihra, Hernik, Mascaro, Tatone & Lengyel, 2016). Nevertheless, for ease of communication and interpretation, descriptive statistics (e.g., Means, Standard Deviations and Standard Errors) and plots feature raw looking times (in seconds) (e.g., similar to Kibbe & Leslie, 2019; Stavans & Baillargeon, 2019).

We ran an ANOVA with a difference score (calculated from infants’ transformed looking times to the Unexpected and Expected Outcomes) entered as the dependent variable, and entered two between subjects factors: trial order (Expected Outcome trial first vs. Unexpected Outcome trial first) and gender. No main effect of trial order was found ($F_{1,35} = 0.24, p = .63$). In addition, no main effect of gender ($F_{1,35} = 0.27, p = .61$) or interaction between trial order and gender ($F_{1,35} = 0.95, p = .34$) was observed. To rule out the possibility of age differences, we ran the same analysis and entered age as a covariate. We found no significant differences due to age ($F_{1,35} = 1.44, p = .24$).

As predicted, a paired-samples $t$ test (2-tailed) revealed that 17-19 month olds looked significantly longer to the Unexpected Outcome trial, in which an intervening agent helped an outgroup member ($M = 15.97$ s, $SD = 8.00$) compared with the Expected Outcome trial, in which an intervening agent helped an ingroup member ($M = 12.24$ s, $SD = 8.74$), 95% CI [1.38, 3.12], $t(35) = 2.54, p = .016, d = 0.55$ (Figure 3.1). Similar results are found using the raw data (See Appendix A).

Moreover, during an episode of intergroup conflict (and in contrast to the absence of conflict as in Jin & Baillargeon (2017)), 17-19-month old infants were more surprised when an ingroup member aids an outgroup member. Our main finding was further supported when the data were examined nonparametrically. Of 36 participants, 27 (75% of the sample) looked longer
to the Unexpected Outcome trial in comparison with the Expected Outcome trial: $\chi^2_{(1, 35)} = 9.00, p = .003$.

3.3.3 Discussion

Our findings suggest that when groups are in conflict with one another, 17-19-month-old infants expect an intervening agent to exclusively help an ingroup member complete their goal—even if this requires harming an outgroup member (by pushing them out of the way).

3.4 Study 5

To further examine the development of infants’ reasoning about social obligations during intergroup conflict, we presented younger infants (9-13-months) with the same stimuli as in Study 4.

3.4.1 Method

3.4.1.1 Participants

60 infants were recruited from our research database. In Study 8, we analyzed the data from infants between the ages of 9 and 13 mo (Age groups: 9-9.99 mos; 10-10.99 mos; 11-11.99 mos, 12-12.99 mos (mean age = 11.04 mo, range = 9.00 mo–12.78 mo, SD = 36 d, 32 females). This sample size is on par with the sample sizes of prior infant work, which included 16 infants per age group (e.g., Jin & Baillargeon, 2017; Thomsen et al., 2011). We set our sample size to reflect a comparable number of infants per each month of age as in Study 4. According to parental report, 50% of infants included in the final sample were classified as Caucasian, 32% as East Asian, and 18% as other ethnicities. An additional 17 participants were excluded from the sample because they did not watch the screen during the critical sequence in
which an agent pushed another agent off the platform (n = 5), fussed out (n = 9), or experienced sibling or parental interference (n = 3).

3.4.1.2 Procedure

Identical to Study 4.

3.4.1.3 Stimuli and Coding

The stimuli and looking time criteria for Study 5 was identical to Study 4.

Coding

Coders used the computer application jHaB (Casstevens, 2007) to record the duration of infants’ looking times. Infants’ looking times were recorded by a primary online coder. Data from the primary coder was used in the results. A naive secondary offline coder re-coded 50% of the videos for Study 5. For videos that were re-coded, looking times between the two coders were correlated $r = .97$ across all trials.

3.4.2 Results

As in Study 4, looking times from each test trial were first log-transformed. Inferential statistics (eg. model estimates, CIs) were fit to log-transformed looking times (see Csibra et al., 2016). Nevertheless, for ease of communication and interpretation, descriptive statistics (eg. Means, Standard Deviations and Standard Errors) and plots feature raw looking times (in seconds).

We ran an ANOVA with a difference score (calculated from infants’ transformed looking times to the Unexpected and Expected Outcomes) entered as the dependent variable, and entered two between subjects factors: trial order (Expected Outcome trial first vs. Unexpected Outcome trial first) and gender. As with Study 4, no main effect of trial order was found ($F_{1,59} = 0.81, p = .37$). In addition, no main effect of gender ($F_{1,59} = 0.002, p = .96$) or interaction between trial
order and gender ($F_{1,59} = 0.20, p = .66$) was observed. To rule out the possibility of age differences, we ran the same analysis and entered age as a covariate. We found no significant differences due to age ($F_{1,59} = 0.13, p = .72$).

A paired-samples t test (2-tailed) comparing the mean looking times to each trial type revealed that 9-13-month-olds looked significantly longer to the Unexpected Outcome trial, in which the intervening agent helped an outgroup member ($M = 13.21$ s, $SD = 7.05$) compared with the Expected Outcome trial, in which the intervening agent helped their ingroup member ($M = 10.84$ s, $SD = 8.00$), 95% CI [1.20, 2.11], $t(59) = 3.06, p = .003, d = 0.43$ (Figure 3.1). Similar results are found using the raw data. (See Appendix A).

Our main finding was further supported when the data were examined nonparametrically. Of 60 participants, 39 (65% of the sample) looked longer to the Unexpected Outcome trial in comparison with the Expected Outcome trial: $\chi^2_{1,59} = 5.40, p = .02$, replicating our findings observed with the older sample from Study 4.

### 3.4.3 Discussion

Younger infants (like older infants in Study 4) were more surprised when an intervening agent indirectly helped an outgroup member accomplish their goal during intergroup conflict. Infants’ responses suggest that this outcome violated infants’ expectation of ingroup support. These findings suggest that within the first year of life, infants understand social group obligations that help them predict how ingroup members should behave towards one another. More specifically, social group members that intervene during a conflict are expected to provide aid exclusively to an ingroup member.
3.5 Study 6

Infants in the previous experiments looked longer to the trial in which an intervening agent indirectly helps an outgroup member complete their goal (by pushing the ingroup member out of the way), compared to the trial in which an intervening agent indirectly helps an ingroup member complete their goal (by pushing the outgroup member out of the way). Although we interpreted this finding as evidence that infants expect an agent to intervene and provide aid to an ingroup member during a conflict, another lower-level counterhypothesis required consideration. It is possible that infants in Study 4 and 5 looked longer to the Unexpected Outcome trial because of the manner in which the agents physically engaged with one another. In the inter-trial, collisions between two different colored agents were established to demonstrate a conflict between opposing groups. Therefore, it is possible that infants may have looked longer to the Unexpected Outcome trial in Study 4 and 5 because it featured collisions between two same colored agents (ie. two ingroup members).

To address this potential alternative explanation, we presented infants with two new test trials that featured the same collisions as in Study 4 and 5. In one test trial, an ingroup member collided with an outgroup member (thereby helping the outgroup member accomplish their goal of crossing the platform). In the other test trial, an ingroup member collided with another ingroup member (thereby helping the ingroup member accomplish their goal of crossing the platform). It is important to highlight that the same collisions that were directed towards an ingroup member in Study 4 and 5 (which hindered the ingroup member), directly helped the ingroup member accomplish their goal of crossing the platform in Study 6.

If infants find collisions between two same colored agents (ie. two ingroup members) more surprising (independently of the goal they enable), then they should look longer when two
same colored agents collide, compared to when two different colored agents collide (ie, in-group vs out-group member). However, if infants have expectations that an in-group member should provide support to another in-group member during a conflict, then they should be sensitive to whether an agent intervenes to help facilitate the goal of the in-group member (even if this requires colliding with a same colored agent (ie. in-group member)). If infants respond in line with our original hypothesis, infants in Study 6 should be less surprised when two same colored agents collide (ie. two in-group members), as these collisions directly help the in-group member accomplish their goal of crossing the platform.

3.5.1 Method

3.5.1.1 Participants

88 infants were recruited from a local science center and tested in a soundproof testing room located onsite. Since we did not find significant age differences across our two samples in Study 4 and 5 (17-19, and 9-13 mos, respectively), in Study 6, we collected and analyzed data from infants aged 9-20 months (mean age = 13.92 mo, range = 9.34 mo – 19.56 mo, SD = 9.125 d, 33 females). Since no age differences were found in Study 4 and 5, a larger age range was included in the sample. According to parental report, 51% of infants included in the final sample were classified as Caucasian, 19 % as East Asian, and 30% as other ethnicities. An additional 27 participants were excluded from the sample because they did not watch the screen during the critical sequence in which an agent pushed another agent off the platform (n = 14), fussed out (n = 5), or because of sibling or parental interference (n = 3), or technical error (n = 5).

3.5.1.2 Procedure

The procedure was identical to Study 4 and 5.
3.5.1.3 Stimuli and Coding

In Study 6, the actions performed by the agents in the Group introduction sequence, Goal Familiarization and Inter-trial were identical to those described in Study 4 and 5. See Goal familiarization (Supplementary Video S3.1 and S3.2) and Inter-trial (Supplementary Video S3.3).

Test trials

The two test trials began with the same actions depicted in the Inter-trial of Study 4 and 5. Then, infants witnessed an observing member from one of the groups come down to the platform and stand next to one of the competing agents. In one test trial (36 s), this intervening agent directly helped their ingroup member complete their goal of crossing the platform (by colliding with and pushing their ingroup member across the platform). Note: this trial featured collisions between two same-colored agents (ie. two ingroup members) (Supplementary Video S3.6). In line with our original hypothesis, this would be the Expected Outcome trial. In the other test trial (36 s), this intervening agent directly helped the outgroup member complete their goal of crossing the platform (by colliding with and pushing the outgroup member across the platform). Note: this trial featured collisions between two different-colored agents (ie. ingroup and outgroup member) (Supplementary Video S3.7). In line with our original hypothesis, this would be the Unexpected Outcome trial. After an infant viewed a test trial, the animation froze and a static image of the characters remained. As soon as the animation froze, looking time was recorded until the infant looked away for two consecutive seconds, or until 30s had elapsed. The order of these two test trials were counterbalanced across participants. Only infants that viewed both the conflict and critical sequence in which the intervening agent pushed another agent off the platform (for each test trial) were included in the final sample.
Coders used the computer application jHaB (Casstevens, 2007) to record the duration of infants’ looking times. Infants’ looking times were recorded by a primary online coder. Data from the primary coder was used in the results. A naive secondary offline coder re-coded 50% of the videos for Study 6. For videos that were re-coded, looking times between the two coders were correlated $r = .98$ across all trials.

3.5.2 Results

As in Study 4 and 5, looking times from each test trial were first log-transformed. Inferential statistics (eg. model estimates, CIs) were fit to log-transformed looking times (see Csibra et al., 2016). Nevertheless, for ease of communication and interpretation, descriptive statistics (eg. Means, Standard Deviations and Standard Errors) and plots feature raw looking times (in seconds).

We ran an ANOVA with a difference score (calculated from infants’ transformed looking times to the Unexpected and Expected Outcomes) entered as the dependent variable, and entered two between subjects factors: trial order (Expected Outcome trial first vs. Unexpected Outcome trial first) and gender. No main effect of trial order was found ($F_{1, 87} = 2.88, p = .94$). In addition, no main effect of gender ($F_{1, 87} = 0.002, p = .97$) or interaction between trial order and gender ($F_{1, 87} = 0.58, p = .45$) was observed. To rule out the possibility of age differences, we ran the same analysis and entered age as a covariate. We found no significant differences due to age ($F_{1, 87} = 2.68, p = .11$).

A paired-samples t test (2-tailed) comparing the mean looking times to each trial type revealed that 9-20-month-olds looked significantly longer to the Unexpected Outcome trial in which the intervening agent helped an outgroup member (ie. two different colored agents collided), ($M = 11.60$ s, $SD = 7.21$) compared with the Expected Outcome trial, in which an
intervening agent helped their own group member (ie. two same colored agents collided) \( M = 9.17 \text{ s}, SD = 6.39 \), 95\% CI \[ 1.13, 1.49 \], \( t(87) = 4.30, p < .001, d = 0.42 \) (Figure 3.1). Similar results are found using the raw data. (See Appendix A).

Our main finding from Study 6 was further supported when the data were examined nonparametrically. Of 88 participants, 65 (74\% of the sample) looked longer to the Unexpected Outcome trial in comparison with the Expected Outcome trial: \( \chi^2(1, 87) = 20.05, p < .001 \).

Collapsing the results from Studies 4-6, a paired samples t-test comparing the mean looking time (seconds) that infants ages 9-20 months spent looking at the screen following the Unexpected Outcome trial \( M = 12.98 \text{ sec} \) and the Expected Outcome trial \( M = 10.32 \text{ sec} \) was significant, 95\% CI \[ 1.55, 3.77 \], \( t(47) = 4.73, p < .001, d = .36 \). This finding was further supported when the data were examined non-parametrically. Out of 184 participants, 131 (71\% of the sample) looked longer to the Unexpected Outcome trial in comparison to the Expected Outcome trial, \( \chi^2(1,183) = 33.07, p < .001 \). This suggests that by 9 months of age, infants expect an intervening agent to exclusively help an ingroup member.

3.5.3 Discussion

Taken together, the results of Study 6 help to rule out the possibility that infants looked longer in Study 4 and 5 because they witnessed two ingroup members (or two same-colored group members) bumping into each other. Importantly, data from all 3 experiments demonstrate that infants appear to be sensitive to whether an agent intervenes to help facilitate the goal of the ingroup member (even if this requires colliding with a same colored agent (ie. ingroup member)). Therefore, Study 6 provides additional evidence supporting our original interpretation of the findings: intervening agents should exclusively help an ingroup member during intergroup conflict.
3.6 General Discussion

Across three experiments, we demonstrated that infants as young as 9 months of age use social group membership to predict how ingroup members should behave during an episode of intergroup conflict. More specifically, Study 4 and 5 investigated whether infants (17-20 months, and 9-13 months, respectively) expect an intervening agent to indirectly help an ingroup member complete their goal of crossing a platform. Infants were introduced to two groups (equal in physical size and number). After viewing a conflict of goals between agents from opposing groups, infants looked significantly longer when an intervening agent indirectly helped an outgroup member complete their goal (by pushing their ingroup member off the platform) compared to when an ingroup member indirectly helped their own member complete their goal (by pushing the outgroup member off the platform). This suggests that an intervening agent is expected to help an ingroup member accomplish their goal (even if this requires hindering an outgroup member). Study 6 provided a conceptual replication of Study 4 and 5 and helped to rule out the possibility that infants’ looking times at test were primarily driven by lower-level factors, such as whether two same, or different colored agents collided. Taken together, our results suggest that infants’ responses were primarily driven by the expectation that ingroup members should exclusively support one another during an episode of intergroup conflict.

These findings provide further evidence that within the first year of life, infants have an abstract expectation of ingroup obligations. Importantly, infants in these experiments are making third-party judgements about social group behavior, that is not influenced by a “like me” or “ingroup” preference or bias (Mahajan & Wynn, 2012; Meltzoff, 2007). In line with socio-moral-expectation accounts, this research suggests that the representing a set of individuals as a group may automatically activate an expectation that individuals are obligated to support their
ingroup. Such reasoning may possibly have evolved as a part of human’s naïve sociology (Baillargeon et al., 2015; Rhodes, 2012; Rhodes, 2013). Indeed, some researchers have proposed that relational structures exist across cultures (Fiske, 1991, 1992, 2000; Fiske & Haslam, 2005; Rai & Fiske, 2011) that may serve as the building blocks for reasoning about social allegiances.

Consequently, understanding whom is obligated to whom may serve to facilitate expectations about whom will help vs hinder another. For example, Rai and Fiske’s moral motive of Unity encompasses social obligations that are expected to be upheld by social allegiances. “Unity is directed toward caring for and supporting the integrity of in-groups through a sense of collective responsibility and common fate. If someone is in need, we must protect and provide for that person; if someone is harmed, the entire group feels transgressed against and must respond…A threat to the group or its integrity, or to any member of it, is felt to be a threat to all” (Rai & Fiske, 2011, p. 61). In line with this account, results from Study 4 and 5 revealed that infants expected an intervening agent to hinder an opposing agents’ goals in order to help their own group member. Thus, in line with previous work with non-human primates and other social species (Harcourt & de Waal, 1992; Lanchester, 1956; Mech et al., 1998; Wilson & Wrangham, 2003) our work suggests that infants appear to tolerate outgroup harm (ie. hindering an opposing group members’ goal), at least during intergroup conflict.

Future work should continue to investigate the development of infants’ reasoning about ingroup obligations. For example, by exploring infants’ reactions towards individuals that fail to fulfill social obligations. Indeed, in both human and other social species, failure to provide support for social group members during intergroup conflict is often considered grounds for ostracism and may even invite direct physical punishment or death (Fantina, 2006; Mathew & Boyd, 2011; Wesselmann, Wirth, Pryor, Reeder, & Williams, 2013). Given that 17-month-olds
expect third-party punishment (in the form of withholding help) for individuals that have harmed an ingroup member (Ting et al., 2019), it is possible that infants will expect an individual that abandons or deserts their group to be punished. This hypothesis could be tested, first, by establishing that an ingroup member chooses to desert an ingroup member during intergroup conflict. Then, infants would be shown one scenario in which this individual is punished, and one in which they do not receive punishment. If infants expect punishment (for disloyalty to the ingroup) to be enforced, then they should be more surprised, and look longer when the deserter is not punished.

Our work also contributes to the ongoing investigation of infants’ and toddlers’ expectations of whom should (or should not) intervene across different contexts. Thus far, only two studies to date (to our knowledge) have investigated infants’ responses to third-party intervention (Kanakogi, Inoue, Matsuda, Butler, Hiraki & Myowa-Yamakoshi, 2017; Stavans & Baillargeon, 2019). More specifically, when group membership is undefined (ie. agents were not established as part of the same group) infants do not appear to expect a bystander to intervene, but during within-group conflict only high status leaders (not members of equal status) are expected to intervene. In our current experiments, all of the individuals were of equal size, and were not differentiated based on status. Therefore, this is the first study to demonstrate that during intergroup conflict, infants expect equally ranked agents to intervene on behalf of ingroup members. Together, these experiments reveal that the same action (intervention) may be interpreted differently and have different consequences depending on the context and status of social group members. For example, when group members are of equal status, banding together against an outgroup may serve to unite and enhance cooperation between groups during intergroup conflict (Cheney & Seyfarth, 1986; Fiske, 2004; Harcourt & de Waal, 1992; Kurzban...
et al., 2001; Perry et al., 2004; Pietraszewski et al., 2014; Rai & Fiske, 2011; Wilson & Wrangham, 2003). In contrast, when there is within-group conflict, intervening without the status or authority to do so may create discord and lead to negative social consequences (Stavans & Baillargeon, 2019). Together, these experiments suggest that infants’ expectations of whom should intervene may be influenced by various factors, such as whether the individuals are part of the same social group, the status of individuals within a social group, and the type of conflict that occurs (Kanakogi et al., 2017; Stavans & Baillargeon, 2019).

In conclusion, given that an expectation of ingroup help appears to emerge within the first year of life, and occurs both in the absence of (Jin & Baillargeon, 2017) and during conflict, these results suggest that ingroup loyalty may be a primary moral motivation that drives human behavior.
Chapter 4: Infants Infer Third-Party Social Dominance Relationships Based on Visual Access to Intergroup Conflict

4.1 Synopsis

A greater number of allies can improve one’s success in a conflict. However, not all of one’s allies may know that they should provide aid, as they may not have witnessed the conflict occur in the first place. Here, we explored whether infants’ assessment of social dominance is directly influenced by whether or not social allies have visual access to an episode of intergroup conflict. In Study 7, 9-12-month-olds only expected an agent to be socially dominant when their allies were able to witness the conflict. Study 8 provided further support for this finding, as infants did not expect an agent from a numerically larger group to be socially dominant when allies were unable to witness the conflict. Together, these results suggest that infants do not simply use a heuristic in which “numerically larger groups are always more dominant”. Importantly, infants are able to incorporate social allies’ ability to witness conflict when predicting social dominance between groups.

4.2 Introduction

Social dominance based on relative numerical group size is a critical cue that helps various social species assess their risk of engaging in a conflict. Indeed, observations of non-human primates, lions, hyenas and even insects have revealed that attacks against outgroup members are more likely to occur when opponents are outnumbered, or when individuals stray from their allies (eg. Cheney & Seyfarth, 1986; Wilson & Wrangham, 2003). This suggests that when facing a conflict, individuals can gain “strength” in numbers when allied with others, and numerically larger groups are often perceived to be socially dominant over numerically smaller
However, it is important to emphasize that social dominance based on relative numerical group size is a derived form of dominance (Hand, 1986), which changes across time and contexts (ie. not a stable trait). For example, even if individuals have many social allies within their community, not all allies may be present or bear witness to a conflict. And, individuals often make decisions about how they should behave (e.g. retrieving food, defending territory), and how others are likely to behave towards them (ie. will I be attacked, and how likely am I to win?) based on the present circumstances (Hare, Call & Tomasello, 2001). Therefore, it is critical to keep track of whom is watching, and whether they can witness one’s actions. The present study explores whether infants incorporate the perspectives of multiple agents when deriving social dominance between groups, or whether their judgments are predicated solely on a mathematical assessment of numerical majority.

Data from studies with non-human animals underscores the importance of attending to others’ eyes during social reasoning (see Ghazanfar & Santos, 2004; Grossman, 2017 for reviews of the literature). Indeed, interpreting what others know based on their eye cues (eg. eye gaze, joint attention) is essential when coordinating non-verbal collaborative interactions such as hunting, gathering and soliciting social allies (e.g. Emery, 2000; Grossman, 2017; Itier & Batty, 2009; Kobayashi & Kohshima, 1997, 2001; Marlowe, 2005; Tomasello, Hare, Lehmann, & Call, 2007).

However, the developmental origins of such “mind reading” based on visual access requires further investigation. Some developmental work reveals that human infants understand that an agents’ presence or absence may affect their knowledge and behavioral expectations (e.g., Choi & Luo, 2015; Meristo & Surian, 2013; Sloane, Baillargeon, & Premack, 2012; Ting et al.,
2019). For example, after a friendship had been established between agent A and B, 13 month-old infants saw agent B hit another agent, C. When A was present to witness B’s harmful actions, infants expected A to alter their behavior and avoid B. In contrast, when A was absent and did not witness B’s transgression, infants expected A to continue their friendship with B. Similarly, 1-year-old infants’ expectation of third-party punishment was influenced by whether a bystander was present, or absent during a wrongdoer’s transgression towards the bystanders’ ingroup member. When the bystander was present, infants expected the bystander to punish the wrongdoer. In contrast, when the bystander was absent and did not witness the transgression against their ingroup member, infants did not expect the bystander to punish the wrongdoer. Together, these results suggest that infants within the first year of life appear to understand that an agent’s knowledge and subsequent behavior is influenced by what they do, or do not witness.

Indeed, humans’ preferential attention to eyes (from birth) may help facilitate the ability to interpret and predict others’ behavior (Grossman, 2017). However, the aforementioned studies cannot speak directly to whether infants understand what an agent sees specifically through the eyes is critical for reasoning about others’ perspectives. Furthermore, nothing is currently known about infants’ capacity to infer the knowledge of social groups based specifically through others’ eyes, and what they can see. Whereas previous work has focused on infants’ ability to use eye gaze to track objects or an individual’s behavior e.g. (e.g. Johnson, Ok and Luo 2007; Meltzoff, 2002; Tomasello et al., 2007), the current research explores for the first time how visual access influences infants’ third-party evaluations of multiple agents that belong to social groups.

The present study examined whether infants’ predictions about social dominance is directly influenced by whether social allies see (or do not see) intergroup conflict occur. Because infants within the first year of life expect a group with more social allies to be dominant (Pun et
al., 2016) and also understand that barriers can obstruct what one is able to see (Kovács, Téglás, E., & Endress, 2010; Luo & Johnson, 2009) we reasoned that only social allies that witness the conflict should be incorporated into infants’ predictions of social dominance (regardless of the overall group size). However, if judgments of social dominance are derived solely through mathematical comparison, then infants should expect the majority group to be dominant (regardless of whether social group members are able to witness the conflict or not).

To test this hypothesis, we conducted two experiments. In Study 7, 9–12-month-old infants were introduced to two groups that were identical in numerical and physical size (3 agents in each group). When two identically sized agents from opposing groups attempted to cross a platform at the same time, a conflict occurred. Importantly, only one group could witness the conflict, as the other groups’ eyes were obstructed by a barrier. Although overall group size was equated, we hypothesized that only the agent whose social allies were able to view the conflict would be expected to prevail and be socially dominant. In Study 8, we introduced 9-12-month-old infants to two groups, differing in numerical size. As in Pun et al., (2016), one group had more members than the other (3 agents vs. 2 agents). However, in this current experiment, no social allies were able to witness the conflict, as their eyes were obstructed by barriers. This resulted in two identically sized agents engaged in a conflict while their respective allies remained unaware of the ensuing conflict. Consequently, we hypothesized that the agent with more allies present (but unable to see the conflict) would be no more likely to be dominant than the agent with fewer allies. What ultimately matters is who has more allies ‘in the know’. This is because only the social allies that are aware that their group member is engaged in a conflict would know to intervene and provide aid (Pun et al., 2021). However, if infants instead rely on
simple numerical majority when computing social dominance, they should expect the agent from the numerically larger group to prevail and be socially dominant.

4.2.1 Method

4.2.1.1 Participants

For Study 7, data from 48 infants (mean age = 10.54 mo, range = 9.00 mo–12.00 mo, SD = 26 d, 25 females) were recruited from a university database and informed consent from each participants’ legal guardian was provided. This sample size is consistent with prior infant work, which included 16 infants per age group (e.g., Jin & Baillargeon, 2017; Thomsen et al., 2011). Reports from the legal guardian indicated that our final sample was composed of 42% Caucasian, 34% East Asian and 24% that identified as other ethnicity/ethnicities. Consistent with the inclusion criteria used in Thomsen et al., (2011) and Pun et al., (2016), an additional 11 participants were excluded from the sample because they did not watch the screen during the critical sequence in which one of the agents bowed down and moved out of the other agent’s path of motion (n = 5), fussed out (n = 5), or because of sibling or parental interference (n = 1).

4.2.1.2 Procedure

The University of British Columbia and the Behavioral Research Ethics Board approved all methods and experimental protocols (approval no. H10-00147). All research methods and experimental protocols described in this manuscript were conducted in accordance with the University of British Columbia’s Behavioral Research Ethics Board guidelines and regulations (approval no. H10-00147). For both experiments, the procedure was identical. As in the procedure implemented by Pun et al., (2016;2021), each participant was seated on the lap of their caregiver in a sound proof testing room for the duration of the experiment, ~140 cm from the center of a television screen measuring 48” in diameter. To ensure that caregivers would not
influence their child’s behavior, they were instructed to either keep their eyes closed or were asked to wear a pair of opaque glasses. Caregivers were also asked to remain silent and not direct the child’s’ attention. The experimenter sat adjacent to the infant and caregiver, separated by a distance of ~4 feet and hidden behind a black curtain. The experimenter remained behind the curtain and out of the infants’ line of sight for the duration of the experiment.

As in the previous studies described in Chapters 2 and 3, a violation of expectation paradigm was implemented, such that infants’ looking times to the outcomes of the two test trials were recorded (see Baillargeon, Spelke & Wasserman, 1985). Details of the study design and looking criteria are described below.

4.2.1.3 Stimuli and Coding

Stimuli used were modified from those used in Pun et al. (2016), and therefore have been described similarly below. In Study 7 of the current work, each group had the same number of agents (3 in each group). Therefore, to equate the number of agents and overall surface area for each group in Study 7 (and also maintain consistency between past (Pun et al., 2016) and present work) we used the same character dimensions from the group of three agents presented in Pun et al. (2016) (Figure 2.1).

As in Pun et al. (2016), infants were first introduced to two groups taking turns jumping in synchrony. Then, two agents from each group jumped behind a barrier, which obscured the agents’ vision. Infants then watched a series of goal Familiarization trials (Supplementary Video S4.1 and S4.2) to demonstrate that one agent from each group had the goal of crossing the platform. Infants saw one agent cross the platform a minimum of two times. This sequence repeated until infants looked away for two consecutive seconds, or had watched four trials in its entirety. Then, infants saw the other agent cross the platform a minimum of two times. This
sequence repeated until infants looked away for two consecutive seconds, or had watched four trials in its entirety. Next, infants saw an Inter-trial (Supplementary Video S4.3) that established a conflict between the two agents when they both attempted to complete their goal of crossing the platform at the same time. Importantly, only one group was able to see the conflict, as the other group members’ eyes were obscured by an opaque barrier. Following the inter-trial, infants saw a total of two test trials. The test trials began with the same actions depicted in the inter-trial. In one trial, infants watched an agent that had social allies witnessing the conflict prevail (Expected outcome) (Supplementary Video S4.4). In the other trial, infants watched an agent that did not have any social allies witnessing the conflict prevail (“Unexpected” Outcome) (Supplementary Video S4.5). After the infant viewed the test event, the animation froze and a static image of the characters remained. Infants’ looking times were measured to the static outcomes of the test event until the infant looked away for two consecutive seconds, or until 30s had elapsed. The order of these two test trials were counterbalanced across participants. Only infants that viewed both the conflict and the critical sequence in which one of the agents bowed down and moved out of the other agents’ path of motion were included in the final sample (see Pun et al., 2016; 2021).

As in Pun et al. (2016; 2021), coders used the computer application jHaB (Casstevens, 2007) to record the duration of infants’ looking times. For all experiments, infants’ looking times were first recorded by a primary online coder. Data from the primary coder was used in the results. A naive secondary offline coder re-coded 50% of the videos for Study 7. For videos that were re-coded, looking times between the two coders were correlated $r = .98$ across all trials.
4.2.2 Results

An Analysis of Variance (ANOVA) was run. The dependent variable entered was a difference score between infants’ looking times to the test trials (Unexpected Outcome minus Expected Outcome). Two between subjects factors were entered: gender and trial order (Unexpected Outcome first vs. Expected Outcome first). There was no main effect of gender ($F_{1,47}=0.14, p=.71$), trial order ($F_{1,47}=1.60, p=.21$) or interaction between gender and trial order ($F_{1,47}=0.045, p=.83$). We also ran the same analyses entering age as a covariate. These analyses revealed no significant differences due to age ($F_{1,47}=0.001, p=.98$). Please see Supplementary Information for analyses performed with log-transformed data, which reveal similar results. (See Appendix B). Planned comparisons comparing the mean looking times to each trial type (Unexpected Outcome vs. Expected Outcome) revealed that 9-12-month-old-infants looked significantly longer to the Unexpected Outcome trial, in which an agent whose allies were unable to witness the conflict prevailed ($M=13.62$ s, $SD=9.04$), compared with the Expected Outcome trial, in which an agent whose allies were able to witness the conflict prevailed ($M=9.68$ s, $SD=7.81$), 95% CI [1.31, 6.57], $t(47)=3.02, p=.004, d=.47$ (Figure 2).

Our main finding was further supported when the data were examined nonparametrically. Out of 48 participants, 36 infants (75% of the sample) looked longer to the Unexpected Outcome trial in comparison to the Expected Outcome trial, $\chi^2_{(1,47)}=12.00, p<0.001$.

4.2.3 Discussion

These results suggest that infants are capable of assessing the relative number of agents that are aware of the conflict and prioritize this information over the total number of allies that are present. Importantly, by taking into consideration which agents witnessed (and therefore had knowledge of) the conflict, infants used this information to predict which agent would be more
socially dominant. More specifically, these results demonstrate that infants expected the group with social allies that witnessed the conflict to be socially dominant, even though the overall number of agents in each group were equal. This is the first study to demonstrate that infants are able to understand the perspectives of multiple agents based on what they can or cannot see (i.e. their knowledge of conflict), and use this information to predict social outcomes (e.g. social dominance).

4.3 Study 8

Even when overall group size was equated (3 agents in each group), infants expected the agent that had more social allies that could see the conflict to be socially dominant. In essence, Study 7, coupled with past research (Pun et al., 2016), demonstrated infants’ appreciation that social dominance based on relative numerical group size is a derived form of dominance. Importantly, it appears to be contingent on whether allies are aware that a group member is engaged in intergroup conflict. However, how robust is this ‘visual awareness’ effect? It is possible that when infants are shown discrepancies between group size (i.e. one group has more members than the other), numerical information will be prioritized over eye cues. Further, it is possible that eye cues are only used when numerical group size is equated (as was the case in Study 7). To address this outstanding tension, we conducted a second experiment. Similar to the study conducted by Pun et al. (2016), infants were introduced to two groups that differed in numerical size (3 agents vs 2 agents). Then, two identically sized agents from opposing groups engaged in a conflict. However, in contrast to Pun et al. (2016; 2021), no social allies in Study 8 were able to witness the conflict, as their vision was obstructed. If infants’ expectations of social dominance is contingent on whether allies are aware that a group member is engaged in intergroup conflict, then in this case, two identically sized agents (with no allies that can see the
conflict) should be evenly matched. Therefore, neither agent should be considered to be socially dominant. However, if infants do not consider the perspectives of social allies and predict social dominance simply by comparing the number of agents that are in each group overall, then the agent from the numerically larger group should be perceived as socially dominant.

4.3.1 Method

4.3.1.1 Participants

For Study 8, data from 48 infants (mean age = 10.08 mo, range = 8.64 mo–11.76 mo, SD = 2.8 d, 24 females) were recruited from a university database and informed consent from each participants’ legal guardian was provided. This sample size is consistent with prior infant work, which included 16 infants per age group (e.g., Jin & Baillargeon, 2017; Thomsen et al., 2011). Reports from the legal guardian indicated that our final sample was composed of 44% Caucasian, 34% as East Asian, and 22% that identified as other ethnicity/ethnicities. Consistent with the inclusion criteria used in Thomsen et al., (2011) and Pun et al., (2016), an additional 13 participants were excluded from the sample because they did not watch the screen during the critical sequence in which one of the agents bowed down and moved out of the other agent’s path of motion (n = 5), fussed out (n = 5), or because of sibling or parental interference (n = 3).

4.3.1.2 Procedure

The University of British Columbia and the Behavioral Research Ethics Board approved all methods and experimental protocols (approval no. H10-00147). All research methods and experimental protocols described in this manuscript was conducted in accordance with the University of British Columbia’s Behavioral Research Ethics Board guidelines and regulations (approval no. H10-00147). Procedure was identical to Study 7.
4.3.1.3 Stimuli and Coding

Stimuli used were modified from those used in Pun et al. (2016), and therefore have been described similarly below. To maintain consistency between the stimuli presented in previous work and our current experiments, the same number of agents and overall surface area that the characters occupied were the same as in Pun et al. (2016) (see Figure 2.1).

As in Pun et al., (2016), infants were introduced to two groups that differed in numerical group size (3 agents vs 2 agents) and saw each group take turns jumping in synchrony. Then, they watched some of the agents jump behind a barrier (two agents from the larger group, and one from the smaller group), which obscured the agents’ vision. The Familiarization trials (see Supplementary Video S4.6 and S4.7) were then shown to demonstrate that one agent from each group had the goal of crossing the platform. Infants saw one agent cross the platform, a minimum of two times. This sequence repeated until infants looked away for two consecutive seconds, or had watched four trials in its entirety. Then, infants saw the other agent cross the platform a minimum of two times. This sequence repeated until infants looked away for two consecutive seconds, or had watched four trials in its entirety. Next, infants saw an Inter-trial (Supplementary Video S4.8) that established a conflict between the two agents when they both attempted to complete their goal of crossing the platform at the same time. Importantly, no social allies were able to see the conflict occur, as their eyes were obscured by an opaque barrier. Following the intertrial event, infants viewed two test trials. In one trial, the agent from the numerically smaller group moved out of the way to allow the agent from the numerically larger group could cross the platform (Supplementary Video S4.9). In the other trial, the agent from the numerically larger group moved out of the way so that the agent from the numerically smaller group could cross the platform (Supplementary Video S4.10). After the agent crossed the
platform, the animation froze and total looking duration for that trial was recorded until the infant looked away for more than two consecutive seconds, or until 30 s had elapsed. The order of these two trials was counterbalanced. After the infant viewed the test event, the animation froze and a static image of the characters remained. Infants’ looking times were measured to the static outcomes of the test trials until the infant looked away for two consecutive seconds, or until 30s had elapsed. The order of these two test trials were counterbalanced across participants. Only infants that viewed both the conflict and the critical sequence in which one of the agents bowed down and moved out of the other agents’ path of motion were included in the final sample (see Pun et al., 2016; 2021).

As in Pun et al. (2016; 2021) and Study 7, coders used the computer application jHaB (Casstevens, 2007) to record the duration of infants’ looking times. Infants’ looking times were recorded by a primary online coder. Data from the primary coder was used in the results. A naive secondary offline coder re-coded 50% of the videos for Study 8. For videos that were re-coded, looking times between the two coders were correlated $r = .97$ across all trials.

### 4.3.2 Results

An Analysis of Variance (ANOVA) was run. The dependent variable entered was a difference score between infants’ looking times to the test trials (larger group wins minus smaller group wins). Two between subjects factors were entered: gender and trial order (larger group wins first vs. smaller group wins first). There was no main effect of gender ($F_{1,47} = 0.029, p = .87$), trial order ($F_{1,47} = 2.58, p = .12$), or interaction between gender and trial order ($F_{1,47} = 0.013, p = .91$). We also ran the same analyses entering age as a covariate. These analyses revealed no significant differences due to age ($F_{1,47} = 1.63, p = .21$). Please see Supplementary
Material for analyses performed with log-transformed data, which reveal similar results. (See Appendix B).

Planned comparisons comparing the mean looking times to each trial type (larger group wins vs smaller group wins) revealed that 9-12-month-olds did not look significantly longer to the trial in which the agent from the numerically larger group prevailed \((M = 10.96 \text{ s}, SD = 8.35)\), compared to the trial in which the agent from the numerically smaller group prevailed \((M = 12.47 \text{ s}, SD = 8.93)\), 95% CI [1.36, 4.38], \(t(47) = 1.06, p = .29\) (Figure 4). This null result is consistent with our original hypotheses, as infants did not expect an agent from either group to be more socially dominant when social allies were unable to witness the conflict. Nevertheless, to provide a more direct test of the null hypothesis, we ran a Bayesian paired-samples t test (Dienes, 2014; Jarosz & Wiley, 2014). The Bayes factor was 5.13, which predicted that infants should look equally long at either outcome trial (when social allies are unaware of the conflict). This provides substantial evidence in favour of the null hypothesis (Jeffreys, 1939/1961).

**4.3.3 Discussion**

These results demonstrate that when social allies did not witness the conflict, infants did not expect an agent from a numerically larger group to be socially dominant. This contrasts with previously published findings, which demonstrated that when social allies are aware of the conflict, infants expect an agent from a numerically larger group to be socially dominant (Pun et al., 2016). Further, these data extend the results of Study 7 by demonstrating that infants are sensitive to whether or not social allies have visual access to the conflict when forming judgments about social dominance relationships. Therefore, these data suggest that simply having more individuals in one’s group does not confer a competitive advantage.
4.4 General Discussion

The present research reveals that 9-12 month-old infants are sensitive to whether or not social allies witness intergroup conflict occur, and as a result, this influences expectations of social dominance. In Study 7, infants were introduced to two groups. Then, two identically sized agents from opposing groups engaged in a conflict. Although each group had the same number of agents in total (3 in each group), only one group was able to view the conflict at test. This meant that one of the competing agents had two social allies watching the conflict occur, while the other competing agent had two social allies that did not see the conflict occur. The results of Study 7 revealed that infants only expected the competing agent that had social allies witnessing the conflict to prevail, even though the overall group size was equated. Importantly, these results suggest that infants are not only capable of using eye cues to determine which agents can see the conflict, but are able to ‘take on’ the perspectives of multiple agents to predict the outcome of a dominance contest. In other words, infants understood that only the social allies could see (and therefore had knowledge) of the conflict could be included in their prediction of social dominance.

In Study 8, infants were introduced to a group that had more individuals relative to another group (3 vs 2 agents). When intergroup conflict arose between two identically sized agents, no social allies were able to witness this occur (as their vision was obstructed by a barrier). At test, infants had no expectations about who should prevail. This suggests that infants do not rely on a simple heuristic of ‘she who has more allies will prevail’ (i.e. that the majority will always win over a minority, regardless of whether allies were aware of the conflict).

Furthermore, variation in bystander’s physical size (designed to ensure that the overall surface area of each group was equated) did not appear to influence infants’ expectations of
social dominance. There may be a number of reasons for this. First, 12–15-month-old infants must observe a direct competition between agents, in order to infer the rank ordering of individuals. Since we did not establish rank order within each group in our study, it is unlikely that infants would have been able to infer within-group status differences based on physical size (ie. no clear leaders vs followers). Second, it is possible that relative differences in physical size may not have been salient enough to predict dominance during group conflict. Third, during intergroup conflict, considerations of within-group size/ rank may be less critical than outnumbering the opposing group. For example, evidence from social species such as lions and chimpanzees reveals that when faced with a conflict, having more allies than the opposing group is the greatest predictor of whether a group will engage in, and win a conflict (Cheney & Seyfarth, 1992; Hand, 1986; McComb et al., 1994; Wilson et al., 2001). Therefore, individual status or physical size may be less predictive of fighting ability when one is able to form a coalition (Cheney & Seyfarth, 1992; Hand, 1986).

Taken together, the results of Study 7 and 8 demonstrate that infants prioritize information about allies’ awareness of a conflict when making predictions of social dominance. Why might infants predict that the presence of allies that can see (vs. not see) the conflict confers a competitive advantage, even when overall group size is equated? By synthesizing our results with that of Pun et al. (2016; 2021), we may generate some plausible hypotheses. One potential explanation is that infants may expect social allies that have witnessed the conflict to intervene (see Pun et al., 2021). As evidenced in various species from insects to non-human primates, having more allies that are able to witness the conflict (compared to the opposing group) should also result in more support and help (compared to the opposing group) (e.g. Batchelor & Briffa, 2011; Cheney & Seyfarth, 1986; Lanchester, 1956; Wilson & Wrangham, 2003). Consequently,
having additional allies that are aware of the conflict and able to provide aid, can improve the group’s chances of succeeding if they outnumber the opposing group.

In line with the aforementioned work with non-human animals, previous work with infants suggests that when all allies within each competing group are able to witness a conflict, an agent from a numerically larger group is expected to be dominant (Pun et al., 2016). However, because our current study design pitted one group where all allies could witness the conflict against a group where no allies could witness the conflict, it is possible that infants simply inferred social dominance based on one ally’s ability to witness the conflict (and did not need to consider whether additional allies within the group witnessed the conflict). To further demonstrate that having additional allies that witness the conflict (relative to an opposing group) provides a greater competitive advantage, a follow up study could be conducted. For example, infants could be introduced to Group A and B, each composed of 4 agents. During a conflict, only 1 agent would able to witness the conflict in Group A, while in Group B, 2 agents would be able to witness the conflict. If infants expect the agent that has more agents that can witness the conflict to prevail in a dominance contest (as in Pun et al 2016), then infants should expect the agent in Group B to prevail, because they have two agents that can witness the conflict (compared to Group A, which only has one).

Importantly, infants may expect an agent with more agents that are able to witness the conflict to be more socially dominant (Pun et al., (2016)) because they expect those allies to intervene and provide aid during the conflict (Pun et al., 2021). Although our current design did not directly test this hypothesis, we can expand upon previous work to deepen our understanding of infants’ reasoning about social dominance between groups. If infants expect a group that has more agents that witness the conflict to succeed because they gain “strength” in numbers, infants
should only expect social allies that are aware of the conflict to intervene. To directly test this, we could pit group size and ability to witness the conflict. For example, as in Pun et al. (2016) and in Study 8, infants could be introduced to two groups: Group A with 3 agents, and Group B with 2 agents. However, during the conflict, only Group B’s sole ally would be able to witness the conflict, while Group A’s two allies would be unable to witness the conflict. Infants would then watch two test trials: a trial in which one of Group A’s ally intervenes (even though they did not witness the conflict) and a trial in which Group B’s sole ally (that witnessed the conflict) intervenes. Infants should only expect the agent from Group B to be dominant, because this was the only ally in either group that was able to witness the conflict. They should not expect agents that are unable to witness the conflict to intervene. Therefore, even if a group has a larger overall group size (relative to the opposing group), only agents that are able to witness and intervene during a conflict should be calculated in infants’ expectations of social dominance.

Importantly, this study expands upon previous work by demonstrating that infants are not only capable of using a single agents’ knowledge to predict behavior, but are able to integrate the perspectives of multiple agents. Further, to our knowledge this is the first study to demonstrate that manipulating the visual access of social allies (ie. what they could or could not see through their eyes) influences infants’ third-party evaluations of social groups and expectations of social dominance. Our study provides important confirmation that social dominance is not inferred simply by comparing the number of individuals present, but is contingent upon whether or not social allies are able to witness the conflict. This is an important distinction, as it suggests that infants not only track agents based on their bodies, but have to pay attention to whether their eyes are visible, and capable of knowing that a conflict has occurred.
Crucially, for human infants, attention to eyes is evident at birth (e.g. Farroni, Csibra, Simion, & Johnson, 2002) and may have an important role in inferring the mental states of other agents. From an evolutionary perspective, attention to the eyes as a means of communication and signaling may be necessary, and ultimately critical for success when attempting to ambush or hide from prey or rivals (Keely, 1996; Tomasello et al., 2007). Although our study did not specifically track where and how long infants looked at the eyes of the agents, it is an interesting question for future research. For example, future studies employing eye-tracking technology could investigate infants’ attention to the eyes when searching for social allies.

This work, in conjunction with previously published work, suggests that infants within the first year of life understand that the interplay between agents engaged in conflict and social allies/bystanders is dynamic (Pun et al, 2016; 2021). In addition, results from these experiments have provided greater insight into infants’ representation of knowledge (obtained through visual access) and their capacity to reason about the perspectives of social group members during intergroup conflict. More specifically, infants only incorporate agents that can see (and therefore are aware) of a conflict in their predictions of social dominance. This awareness, which appears to emerge in the first year of life, suggests that what others can/ or cannot see through their eyes may be critical to understanding others’ mental states, as it directly impacts what they know, or do not know. Therefore, attention to the eyes may lay the foundations for interpreting and predicting social behaviors (Grossman, 2017).
Chapter 5: Conclusion

5.1 Summary of Key Findings

Like many social species, from insects, birds, chimpanzees, to adult humans, infants appear to represent social dominance relationships within the first year of life (i.e. the tendency to prevail in a competition) (Axelrod & Hamilton, 1981; Geist, 1978; Mascaro & Csibra, 2012; 2014; Smith, 1974; Thomsen et al., 2011). While current research has demonstrated that humans are adept at using individual traits (e.g. physical size) to infer social dominance, it is also important to understand whether infants are capable of representing dominance relationships between groups. Therefore, in this dissertation, I have presented three sets of studies that have explored how infants begin to reason about social hierarchy. In particular, I investigated how humans begin to reason about and navigate social relationships both within and between groups.

To understand the developmental trajectory of humans’ ability to recognize social dominance relationships, in Chapter 2, I examined whether 6–12-month-old infants are sensitive to relative numerical group size. Infants were first introduced to two novel groups that differed in numerical size (3 agents vs 2 agents), but importantly, were equated for total surface area. Across two studies, I found that 6–12-month-old infants expected an agent from a numerically larger group to win in a right-of-way competition against an agent from a numerically smaller group, even though the two competing agents were identical in physical size. No age or gender differences were observed, and a control condition ruled out the possibility that infants were responding to perceptual changes (e.g. size of the agent as they bowed and made way for the other agent). This was the first study to demonstrate that infants as young as 6 months of age can represent social dominance relationships. Furthermore, this work demonstrates that infants’ reasoning about social dominance extends beyond the direct relationship between two competing
individuals, suggesting that infants can make inferences about the hierarchical relationship between social groups.

Being part of a social group requires individuals to learn whom to cooperate with and when, and whom they are likely to conflict with. This process is dynamic and may change across time and contexts. This suggests that humans, like other group-living animals, must have an awareness of the structure of social relationships that will make it more, or less likely for individuals to cooperate vs conflict in certain contexts (Pietraszewski, 2021). To defend against rival groups, social allegiances form to facilitate within group cooperation and coordinate action. While Chapter 2 demonstrated that infants predict that the larger numerical group should win in a right of way competition, these set of studies did not explore whether infants hold this expectation because they expect members of social groups to be social allies.

Building off the series of experiments conducted in Chapter 2, I explored whether infants understand the relationship between individuals within social groups. More specifically, if infants understand that individual members of a social group are expected to assume specific roles and obligations during intergroup conflict. Across three experiments, I demonstrated that infants as young as 9 months of age expect intervening agents to exclusively help members of their own group, even if this requires hindering members of the opposing group. Together, these results suggest that infants expect ingroup members to be loyal.

It is also important to be able to assess whether allies have knowledge that a conflict is occurring between group members, and are present and available to intervene. This has important consequences, as it may affect one’s decision to engage in or retreat from conflict (e.g., McComb et al., 1994; Wilson & Wrangham, 2003). Building off my previous findings detailed in Chapter 2 and 3 (Pun et al., 2016; Pun et al., 2021), I explored whether allies’ ability
to witness intergroup conflict occur would affect infants’ expectations of social dominance. As in the previous studies, infants were introduced to two groups. When two equally sized agents from opposing groups attempted to cross a platform, this resulted in a conflict, as neither agent could pass. When overall group size was equated (but only one group could see the conflict occur), 9-12-month-old infants only expected the group with more agents that could see the conflict occur to prevail and be socially dominant. However, when social allies were unable to see the conflict occur, infants did not expect either agent to win (even though one of the groups had more agents than the other). This suggests that infants are not only sensitive to the overall number of agents in each group, but also consider an ingroup members’ ability to provide aid during a conflict.

5.2 Implications and Future Directions

The research presented in this dissertation explores the foundation of reasoning about social hierarchies, primarily through social dominance relationships. My work demonstrates that infants represent hierarchical relationships between groups. This requires an understanding that a conflict of goals occurs between agents, and that one agent will prevail (dominant) at the expense of the other (subordinate). In line with other work, our results suggests that infants’ sensitivity to social dominance relationships may be grounded in the naïve psychology of actions (Fiske, 1992; Hirschfeld 1994; Jackendoff, 1992; Mascaro & Csibra, 2012; Thomsen et al., 2011). Furthermore, my findings are consistent with work on non-human primates, suggesting that the cognitive capacities that facilitate the recognition and representation of social dominance relationships may be evolutionarily ancient.

Nevertheless, some researchers and philosophers have presented arguments against the genetic inheritance of evolutionarily ancient cognitive mechanisms that facilitate social-
cognition. For example, Heyes (2018; 2019b) adopts a more empiricist stance, suggesting that basic mechanisms that have been genetically inherited from our non-human vertebrate ancestors, such as attentional, learning and motivational mechanisms, have been modified in such a way that makes humans more attune to social cues, such as faces and voices. Consequently, Heyes proposes that social interaction and cultural selection are primarily responsible for the ways in which social-cognitive mechanisms operate today. Similar empiricist approaches to explaining the development of specific cognitive capacities, such as the ability to represent number, are also a matter of debate within the literature (Leibovich, Katzin, Salti & Henik, 2017; Skinner, 2014; Verguts & Fias, 2004). For example, empiricists argue that if infants are not born with certain mental or physical capacities, then such representations and abilities cannot be innate. Specifically, Leibovich et al., (2017) argues that humans’ capacity to represent number cannot be innate, because newborns have not been shown to be able to individuate objects at birth and have poor visual acuity.

Such arguments present some challenges to the interpretation of results presented in this dissertation. More specifically, in Chapter 2, I have argued that by 6 months of age, infants are able to use numerical group size to determine the outcome of social dominance relationships. In Studies 1 and 2, infants were presented with two groups, which differed in numerical size (3 agents vs. 2 agents), but was equated for surface area. Although some research has shown that six month old infants may have difficulty distinguishing between a ratio of 2:3 when presented in larger numerical sets (e.g., 6:9) (Xu and Spelke 2000; Xu et al. 2005), other research suggests that both monkeys and infants as young as 6 months of age are capable of discriminating small numbers (one, two and 3). More specifically, monkeys who had been shown different quantities of apple slices placed in containers were more likely to choose the container that had a larger
number of apple slices inside (rather than choosing based on the volume of apples) (Hauser et al., 2000). Relatedly, infants as young as six months of age will choose a container containing three crackers, over a container with two crackers (Feigenson et al. 2002) and can discriminate between two and three squares (Cordes & Brannon, 2009). Given that infants in our study were shown a comparison of two vs. three agents (and kept surface area constant throughout), it is unlikely that infants were unable to discriminate between the larger, and smaller group. An open question for future research would be to address whether infants are capable of discriminating between ratios with a larger number of individual agents, and whether this affects their inferences about social groups.

5.2.1 Social Hierarchy and the Representation of Groups

Infants’ capacity to represent hierarchical relationships between social groups also helps inform our understanding of how the mind represents groups, and the types of behaviors and obligations ingroup members must uphold. In this dissertation, studies 1-3 and 7-8 suggest that when an agent comes to conflict with an opposing group member, the agent that has more members present to call upon for aid will gain a competitive advantage. Collectively, these results suggest that infants have an abstract representation of *ingroup rights*, such that during a conflict, an agent can call upon other ingroup members to help them fight against other agents that pose a threat. Furthermore, studies 4-6 reveal that when an agent intervenes during a conflict, they should only provide aid to *ingroup* members (not outgroup members). This suggests that infants have an abstract representation of *ingroup obligations*, such that when a bystander chooses to intervene during a conflict, they are obligated to demonstrate loyalty by acting in the interest of an ingroup member.

Previous work with children has also shown that group membership (e.g., novel groups,
race, gender, language etc) can influence both implicit and explicit bias (e.g., Baron & Dunham, 2015; Dunham, Baron & Carey, 2011; Rhodes & Baron, 2019; Sherif & Sherif, 1966; Tajfel, 1982). In addition, a growing body of theoretical and empirical work has proposed that humans have evolved a “coalitional psychology” that facilitates the representation of individuals as a collective ‘group’. Importantly, this coalitional psychology should facilitate the way groups are represented by assessing the likelihood that certain individuals will coordinate with one another (Cikara, 2021; Pietraszewski et al., 2014).

A recent article by Pietraszewski (2021) has proposed that a set of triadic primitives that serve as the building blocks for representing groups during conflict. Importantly, a “group” is not necessarily synonymous with a social category (e.g., race) (Pietraszewski et al., 2014; 2021). To be considered part of a group, he argues that during conflict, individuals are obligated to occupy certain roles that shows support for or aids an ingroup member. More specifically, if a conflict occurs between agent A and B, agent C may become involved if they are also attacked by A (Generalization), agent C attacks agent A (Defense), agent C and B attack agent A together (Alliance) or following B’s attack on A, A attacks C (Displacement). Based on these group-constitutive roles that help the mind define a “group” in the context of conflict, one could infer that agent B and C were part of a “group”, and that B and C must behave in ways that are consistent with expectations of group members (i.e., the “ingroup”).

Consistent with the triadic primitives outlined by Pietraszewski, developmental work, including the studies presented in this dissertation, infants form expectations about the types of behaviors that should be directed towards ingroup vs outgroup members (Pun et al., 2016; 2021; Rhodes et al., 2015). For example, when 16-month-old infants witnessed a conflict between two agents from opposing groups, they were more surprised when these agents’ social partners
cooperated (instead of conflicted) with one another (Rhodes et al., 2015). This result is consistent with Pietraszewski’s triadic primitive generalization, in which a conflict between two agents from opposing groups can be extended to another, uninvolved member of a group.

In my work, infants as young as 9 months of age appear to hold expectations about social group behavior that is consistent with the triadic primitives defense and alliance (see Chapter 3; Pun et al., 2021). Specifically, after watching two agents from opposing groups come into conflict, infants expected an ingroup member (that was not part of the initial conflict) to harm an outgroup member (by pushing them off the platform). Similar findings have been observed with non-human primates, children and adults (e.g., De Dreu et al., 2016; Rhodes & Brickman, 2011; Rusch, 2013). This suggests that when defending the interests of the group, individuals may be obligated to help ingroup members (i.e. be allies), even if it requires harming outgroup members. Relatedly, my work also demonstrates that 6-month-old infants understand that there is “strength in numbers”. After observing two agents compete with one another, infants expected the agent with more group members to prevail over an agent with fewer group members (see Chapter 2; Pun et al., 2016). To be able to make this inference, infants may have inferred that group members acted as allies, banding together to support one another against an opposing group, as demonstrated in the experiments reviewed in Chapter 3. Consistent with this argument, recall that infants were more surprised when a group member did not provide aid to an ingroup member (see Chapter 3; Pun et al., 2021).

Together, these findings suggest that infants and children can represent social groups as social allegiances and expect members of the same group to be loyal to one another. While ingroup support may be expected across various contexts, conflict situations may define expected behaviors towards both ingroup and outgroup members, such that ingroup members are
expected to be supported \textit{and} outgroup harm may be tolerated.

Other studies with infants and non-human species suggest that variation in ecological conditions (e.g. competition, cooperation, resource acquisition, and predation) may activate different computations for ingroup and outgroup members, that ultimately influences behavior (e.g. Aviles, 2002; Bian et al., 2018; Bonner 1982; Chapman & Teichroeb, 2012; Krause & Ruxton, 2002; Lindstedt et al., 2018). This raises the possibility that any computational theory of groups needs to account for the influence of these conditions. For example, 18-month-old infants expect ingroup and outgroup members to be treated equally when resources are abundant. In contrast, ingroup members are expected to be prioritized when resources are limited (Bian et al., 2018), suggesting that competition promotes ingroup favoritism. Relatedly, in the absence of conflict, 17-19-month-olds expect ingroup members to provide instrumental help to another ingroup member (but not an outgroup member) (Jin & Baillargeon, 2017).

Furthermore, behaviors that harm the ingroup are not permissible (Rhodes & Chalik, 2012; Rhodes & Brinkman, 2015; Rullo, Presaghi, & Livi 2015; Ting et al., 2019). For example, when ingroup loyalty is violated (e.g. an ingroup member harms another ingroup member), infants in their first year of life expect ingroup members to refrain from helping the aggressor (as a form of punishment) (Ting et al., 2019). However, it is not clear whether committing this transgression leads infants to infer that this disloyal individual should be ostracized from the group. Future work may want to consider the possibility that additional primitives independently shape expectations about ingroups and outgroups.

Social Dominance: Implications for inequality

As the work in this dissertation has reviewed and demonstrated, infants use cues to dominance to predict the outcome of a competition between individuals and social groups
(Enright et al., 2017; Mascaro & Csibra, 2012; 2014; Pun et al., 2016; 2021; Thomsen et al., 2011). Like other social animals and non-human primates, social dominance appears to be the primary way in which human infants recognize differences in the social status/rank of individuals and groups. Human infants’ expectations that one individual or group is more likely to be dominant than another may reveal an early, tacit awareness of inequality in social relationships.

Whether such an awareness of asymmetrical relationships in infancy contributes to children’s and adults’ tendency to reinforce, provide justification for, and even favor inequality is a complex question that requires further exploration. To date, some studies have investigated whether an individual or groups’ social status affects children’s social preferences (Baron & Banaji, 2009; Charafeddine et al., 2015; Jost, Pelham & Carvallo, 2002; Olson et al., 2011). In one study, researchers investigated whether 2-year-olds preferred a dominant agent over a subordinate agent (Thomas, Abramyan, Lukowski, Thomsen & Sarnecko, 2016). To accomplish this, they modified the dominance paradigm (Thomsen et al., 2011) with one important change: both agents were equal in size. After establishing that one agent was dominant over another, researchers presented both agents to the children, placing them side by side. Two-year-olds preferred the dominant agent. This suggests that children not only recognize dominance relationships, but also expect dominant individuals to be favored. In addition, children are willing to maintain and perpetuate this inequality themselves, by ensuring that the dominant individual always has more resources than the subordinate individual (Charafeddine et al., 2016).

Why are young children willing to perpetuate inequality in this context? One reason may stem from our nonhuman primate ancestors, who affiliate with dominant individuals to increase access to coveted resources, thereby improving their dominance rank and fitness for survival. For
example, male chimpanzees with lower status attempt to develop alliances with dominant individuals by attending to and appeasing the dominant chimpanzees (e.g., through grooming; Schino, 2007; Seyfarth, 1977; Slater, Snowdon, Rosenblatt & Malinski, 1997; Tiddi, Aureli & Schino, 2012). Exploring the underlying motivations for children’s preferences for dominant individuals requires further investigation.

Group-based Hierarchies

Some work has also begun to investigate children’s capacity to recognize and reason about group-based hierarchies. Over time, children begin to learn and associate other markers of social status (e.g., wealth, decision making power, with certain groups, such as race, gender) (e.g., Charafeddine et al., 2020; Mandalaywala et al., 2020; Olson et al., 2011; Yazdi et al., 2020). Higher status individuals and groups are evaluated more positively, and interestingly, even override strong “ingroup” preferences. For example, studies have shown a very robust same-gender preference in school-aged children. However, both boys and girls evaluate boys as higher status and more likely to hold higher ranked occupations (Gülgoz et al., 2019; Halim et al., 2017). While the development of race preferences is more nuanced and becomes more pronounced after age 5, ingroup preferences may also be overridden when a historically lower-status social group is compared to a higher-status social group (Baron & Banaji, 2009; Dunham, Baron & Banaji, 2007).

Together, this work demonstrates that group-based hierarchies often reflect inequality that has been historically and culturally reinforced. This suggests that while attention to and recognition of asymmetric relationships may be innate, the specific groups that become associated with higher vs lower status are learned. However, it is unclear how and when infants begin to stratify certain social categories (e.g., race, gender) hierarchically. Future work should
investigate whether computations, such as statistical learning mechanisms, facilitates the recognition of structures that are relevant to status recognition. Overall, the questions addressed in this Chapter require further exploration, and may contribute to our understanding of why prejudice is so widespread, and why fairness and tolerance can sometimes be difficult to attain.

5.2.2 **Hierarchy Differentiation: Leaders and Followers**

Although hierarchies are ubiquitous, there are still many open questions about how hierarchies are constructed and maintained across species. More specifically, there is still debate over the types of strategies and social contexts that humans implement to improve their social status. For example, some theories propose that through repeated, and often aggressive physical encounters, a relative ranking system is formed in which some individuals and groups are subordinate to others (e.g., Buss & Duntley, 2006; Griskevicius et al., 2009; Hill & Hurtado, 1996; Kyl-Heku & Buss, 1996; Lee & Ofshe, 1981; Mazur, 1973). Others propose that the group comes to a consensus about which individuals should receive greater status, based on prestige. In humans, status may also be obtained through prestige, by providing knowledge and skills to others. Often, traits such as warmth and competence are associated with prestigious leaders, who garner respect (Cheng, Tracy, & Henrich, 2010; Cheng, Tracy, Foulsham, Kingstone & Henrich, 2013; Henrich & Gil-White, 2001). Importantly, for prestige, higher status is willingly conferred by followers, and therefore cannot be obtained through force and coercion (i.e. dominance) (Competence-based model); (e.g., Anderson and Kilduff, 2009; Barkow 1975; Ridgeway 1987; Ridgeway and Diekema 1989).

To reconcile findings from both human and non-human species, others argue that humans have evolved a dual-pathway model in which both dominance and prestige are viable
strategies to improve social status (Dominance-Prestige model; Cheng et al., 2013). While some leaders rise to power through more coercive and manipulative means (i.e. dominance), others may garner more respect by demonstrating useful skills and mentorship (i.e. prestige). According to the Dominance-Prestige Account, both dominant and prestigious strategies are viable ways in which an individual can acquire greater social status. In addition, rather than pitting one form of strategy against one another, Cheng and colleagues suggest that both strategies may be implemented by the same individual. However, they do not outline the specific contexts in which an individual may be more likely to exert dominance vs prestige, and individuals may not be consciously aware of the type of strategy they adopt (Cheng et al., 2013; Cheng & Tracy 2014).

It is possible that toddlers may be able to differentiate between the types of behaviors that are typically associated with dominant, vs. prestigious individuals. Furthermore, they expect others to behave differently towards high status individuals that use brute force and aggressive behaviors (Margoni, Baillargeon, and Surian, 2018), and appear to avoid individuals that hurt or “bully” others to get their way (Thomas, Thomsen, Lukowski, Abramyan & Sarnecka, 2018).

For example, 20-24 month old toddlers prefer an agent that completes their goal at the expense of another agent (ie. zero-sum conflict), but only when an agent willingly defers/ submits. When an agent is pushed out of the way, infants do not prefer the agent that has accomplished their goal. The authors suggest that infants choose to avoid individuals that physically “bully” or harm others, even if such individuals are successful. The authors compare this physically aggressive individual to high status dominant individuals, and imply that avoiding such an individual indicates fear.

In another study by Margoni et al. (2018), 21-month-olds observed a high status individual interacting with three lower status individuals. Then, the high status individual gave
directives/orders to the lower status individuals. Researchers were interested in whether toddlers expected them to obey the orders both in the presence, and absence of the high-status individual. Importantly, two different conditions were run that displayed either a high status individual using physical force (eg. striking lower status individuals with a baton) or an individual that possessed characteristics of a leader that had supposedly earned their rank (eg. high status individual wore a large headdress, and followers willingly bowed). Infants in both conditions expected lower status individuals to obey when the high-status individual was present and watching them comply. However, they found conflicting results when the high status leader left the scene. Infants expected the low status individuals to continue obeying a larger high-status individual whom had been willingly deferred to, regardless of whether they were present or absent in the scene. In contrast, they did not expect low status individuals to comply when the high status “bully” left the scene. The researchers suggest that compliance based on fear is only expected (and perhaps will only occur) when the high status “bully” is present. This suggests that infants may understand that individuals that use physical force to achieve higher status may be recognized as legitimate in their presence, perhaps because such individuals are feared. Whereas, low status individuals are expected to comply with high status individuals that have “earned” their status and respect, and therefore physical force is not required to ensure obedience. Together, the results from Thomas et al. (2019) and Margoni et al. (2018)’s work provide some consistency with the accounts of dominance, which suggests that high status is maintained through fear, in both non-human primates (e.g. Hare et al., 2002) and humans.

Beyond recognizing cues to status, it is also important to understand the kinds of strategies children implement in their social world. Observations of preschool children (Hawley, 1999) have shown that individuals that use coercion and manipulation (which is often used by
individuals that are classified as dominant) and cooperation (often used by individuals that are classified as Prestigious by Cheng et al. and others) are able to attain higher status, which may provide some evidence in support of the Dominance-Prestige model. However, there may be developmental changes. For example, some observations of preschoolers in Western societies suggest that younger children appear to be more influenced by and accepting of tactics such as aggression, coercion and manipulation. As children get older, they become less tolerant of aggression towards their peers, and more cooperative strategies appear to be more effective at gaining and maintaining higher social status (Hawley, 1999). This suggests that in general, children in Western cultures may recognize status attainment strategies that are consistent with both dominance and prestige, but become less tolerant of dominant leaders. More research is needed to explore the developmental changes and social influences (e.g., culture) that affect children’s perception of status attainment strategies for leaders.

5.2.3 Influence of Dominant and Prestigious Leaders on their Followers

In addition to greater access to valuable resources, dominant individuals also directly influence their subordinate counterparts, as evidenced by studies with other social animals and nonhuman primates (Chance, 1967; Douglas-Hamilton & Douglas-Hamilton, 1975; Kendal, 2015). For example, subordinate baboons appear to willingly (i.e., without force or coercion) accept and follow despotic decisions about foraging patches made by dominant baboons, even if this results in a short-term cost for subordinates (Chance, 1967). In addition, Kendal et al., (2015) found that chimpanzees were more inclined to learn from a dominant individual, compared to a subordinate individual. In this study, researchers devised a task in which chimpanzees could acquire desired food from a box with two openings. Dominant chimps did
not prefer to obtain the food from either opening. However, subordinates paid more attention to
the dominant individual and appeared to imitate her manner of interacting with the box.
Therefore, subordinates naive to the box task were more likely to obtain the food from the same
opening as the dominant individual they had observed, even though either opening would have
provided food. This demonstration of deference to the dominant, not only in competitive
scenarios but in foraging choices and cultural learning, may reflect an evolved tendency to
follow the leadership of dominant individuals.

Evidence of preferential learning from dominant individuals may reflect an expectation
that dominant individuals are more optimal sources of information, all else being equal. Indeed,
some research with human adults seems to support this view. In one study, human adults rated
high in trait dominance were perceived as more competent by their peers, randomly assigned
group members, and even researchers blind to the hypotheses of the study (Anderson & Kilduff,
2009). This suggests that individuals higher in trait dominance may attain social influence
because they are perceived to be more competent, even when no evidence of competence is
provided.

Like nonhuman primates, 3- and 4-year-olds show a similar learning bias, favoring the
labels provided by a socially dominant individual over those of a subordinate individual in a
novel word learning task (Pun, Lee, Birch & Baron, in prep). In this study, children were naïve to
individuals’ previous knowledge or history of accuracy, and only knew that one individual was
dominant over the other because he had been given the right of way to cross a platform (see Pun
et al., 2016; 2021; Thomsen et al., 2011). At a minimum, these results show that children are
more likely to learn new information from more dominant individuals than from less dominant
ones. Children’s learning preference could also stem from an evaluation of individuals’
competence. That is, like adults (Anderson & Kilduff, 2009), young children may associate dominance with competence (even if no direct evidence of competence is observed), and that evaluation drives children’s learning decisions. In addition, it is possible that dominance and competence may influence children’s preferences independently. Consequently, researchers should attempt to disentangle these possibilities by examining the specific contexts in which dominance and competence may influence children’s learning decisions. Whether children’s (and chimps’) preference to learn from dominant individuals includes an evaluative component remains a question, but the aforementioned results suggest that both non-human and human primates are predisposed to learn from dominant or prevailing individuals.

When the status of an individual is not clear, children may choose to learn from an individual that receives greater attention from members of their ingroup (Chudek, Heller, Birch & Henrich, 2012). For example, in a study conducted by Chudek and colleagues, 3-4 year olds were shown two models performing similar tasks (e.g., food choice or artifact usage). One model was being watched by two bystanders, while the other model did not receive any attention. Children were more likely to endorse the model that had been watched by bystanders. According to the culture-gene co-evolutionary theory, such preferential attention is considered to indicate a prestige bias, which should serve as a cue that such individuals that are more knowledgeable. This suggests that young children may also be able to identify prestigious individuals and prefer to learn from them. However, many open questions remain about the origins and development of prestige recognition, and whether children recognize and respond to these forms of status in a similar manner as adults. Furthermore, it is unclear how cultural factors (e.g., whether the hierarchy was established through a dominance or prestige) influences acceptance of and/or preferences for leadership styles and intergroup behavior. Future work should explore whether
children reason about and make inferences about the strategies that individuals use to obtain greater status, and how this may vary across development and cultures.

5.3 Concluding Remarks

Together, the work discussed in this dissertation provides a better understanding of infants’ representation of social hierarchies, primarily through reasoning about social dominance relationships. In addition, these results suggest that the cognitive mechanisms used by nonhuman primates and humans to detect and track social dominance relations may share common roots. However, given the preliminary nature of this work, researchers should investigate the developmental trajectory of reasoning about social dominance across the lifespan and consider how culture and experience may influence perceptions of status over time. There are also important implications of this work to consider. Though social hierarchies may have evolved to reduce conflict and promote within group-cohesion, social stratification inherently perpetuates and reinforces inequality. By exploring the foundations of social status reasoning from infancy and continuing to study how it is shaped across development and cultures, we can better understand the roots of inequality and the psychological processes that may serve to perpetuate inequality.
Figure 2.1 Example of the numerically larger group and numerically smaller group
Figure 2.2 Example of one agent from each group coming into conflict
Figure 2.3 Mean looking time to the unexpected outcome trial compared with the expected outcome trial for 9-12 month old infants. Error bars denote SE of the mean.
Figure 2.4 Mean looking time to the unexpected outcome trial compared with the expected outcome trial for 6-9 month old infants. Error bars denote SE of the mean.
Figure 2.5 Example of one agent from the numerically larger group being obstructed by a barrier.
Table 2.1 Infants' mean looking time to trial 1 and 2 in Study 2

<table>
<thead>
<tr>
<th>Trial #</th>
<th>Trial Type</th>
<th>Mean Looking Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Unexpected Outcome</td>
<td>11.11</td>
</tr>
<tr>
<td>1</td>
<td>Expected Outcome</td>
<td>5.79</td>
</tr>
<tr>
<td>2</td>
<td>Unexpected Outcome</td>
<td>8.34</td>
</tr>
<tr>
<td>2</td>
<td>Expected Outcome</td>
<td>5.92</td>
</tr>
</tbody>
</table>
Table 2.2 Infants’ Mean Looking time to Trial 1 and 2 in Study 3

<table>
<thead>
<tr>
<th>Trial #</th>
<th>Trial Type</th>
<th>Mean Looking Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Agent from larger group retreats</td>
<td>9.2</td>
</tr>
<tr>
<td>1</td>
<td>Agent from smaller group retreats</td>
<td>8.51</td>
</tr>
<tr>
<td>2</td>
<td>Agent from larger group retreats</td>
<td>11.86</td>
</tr>
<tr>
<td>2</td>
<td>Agent from smaller group retreats</td>
<td>11.89</td>
</tr>
</tbody>
</table>
Figure 3.1 Raw mean looking times to the outcome of the test trials in Study 4, 5 and 6 \((n = 36, 2 (n = 60),\) and \(3 (n = 88)\). Error bars represent SEM, and an asterisk denotes a significant difference between the two events \((p < .005)\).
Figure 4.1 Mean looking time to Unexpected Outcome trial (allies unable to witness conflict) compared with the Expected Outcome trial (allies able to witness conflict) for 9-12 month old infants. Error bars denote SE of the mean.
Figure 4.2 Mean looking time to trial depicting smaller group winning (allies unable to witness conflict) compared to trial depicting larger group winning (allies unable to witness conflict) for 9-12 month old infants.

Individual data points are depicted. Error bars denote SE of the mean.
References


Casstevens, R. (2007). jHab: Java habituation software (version 1.0. 2)[computer software]. Chevy Chase, MD.


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children’s selective trust in dominant agents.


Appendices

Appendix A Additional Data Analyses (Study 4-6)

Study 4 Results (Raw data)

An ANOVA was run with a difference score (calculated from infants’ looking times to the Unexpected and Expected outcomes) entered as the dependent variable, and entered two between subjects factors: trial order (Expected Outcome trial first vs. Unexpected Outcome trial first) and gender. No main effect of trial order was found (F1, 35 = 0.45, p = .51). In addition, no main effect of gender (F1, 35 = 0.41, p = .53) or interaction between trial order and gender (F1, 35= 0.08, p = .78) was observed. To rule out the possibility of age differences, we ran the same analysis and entered age as a covariate. We found no significant differences due to age (F1,35 = 0.92, p = .34).

As predicted, a paired-samples t test revealed that 17-19 month olds looked significantly longer to the Unexpected Outcome trial, in which an intervening agent helped an outgroup member (M = 15.97 s, SD = 8.00), compared with the Expected Outcome trial, in which an intervening agent helped an ingroup member (M = 12.24 s, SD = 8.74), 95% CI [0.49, 6.98], t(35) = 2.34, p = .025, d = 0.45.

Study 5 Results (Raw data)

An ANOVA was run with a difference score (calculated from infants’ looking times to the Unexpected and Expected Outcomes) entered as the dependent variable, and entered two between subjects factors: trial order (Expected Outcome trial first vs. Unexpected Outcome trial first) and gender. As with Study 1, no main effect of trial order was found (F1, 59 = 0.29, p = .59). In addition, no main effect of gender (F1, 59 = 0.067, p = .80) or interaction between trial order and gender (F1, 59 = 0.076, p = .78) was observed. To rule out the possibility of age
differences, we ran the same analysis and entered age as a covariate. We found no significant differences due to age (F1,59 = 0.22, p = .64).

A paired-samples t test comparing the mean looking times to each trial type revealed that 9-13-month-olds looked longer significantly longer to the Unexpected Outcome trial, in which the intervening agent helped an outgroup member (M = 13.21 s, SD = 7.05) compared with the expected outcome trial, in which the intervening agent helped their ingroup member (M = 10.84 s, SD = 8.00), 95% CI [0.12, 4.62], t(59) = 2.11, p = .039, d = 0.31.

**Study 6 Results (Raw data)**

An ANOVA was run with a difference score (calculated from infants’ looking times to the Unexpected and Expected Outcomes) entered as the dependent variable, and entered two between subjects factors: trial order (Expected Outcome trial first vs. Unexpected Outcome trial first) and gender. No main effect of trial order was found (F1, 87 = 0.91, p = .34). In addition, no main effect of gender (F1, 87 = 0.41, p = .52) or interaction between trial order and gender (F1, 87 = 0.079, p = .78) was observed. To rule out the possibility of age differences, we ran the same analysis and entered age as a covariate. We found no significant differences due to age (F1,87 = 0.55, p = .46).

A paired-samples t test comparing the mean looking times to each trial type revealed that 9-20-month-olds looked significantly longer to the Unexpected Outcome trial in which the intervening agent helped an outgroup member (ie. two different colored agents collided), (M = 11.60 s, SD = 7.21) compared with the expected outcome trial, in which an intervening agent helped their own group member (ie. two same colored agents collided) (M = 9.17 s, SD = 6.39), 95% CI [1.20, 3.65], t(87) = 3.92, p <.001, d = 0.36.
Appendix B  Additional Data Analyses (Study 7 & 8)

Study 7 Results (Log Transformed data)
Looking times from each test trial were first log-transformed and subsequent analyses were conducted on the log-transformed data (see Csibra, Hernik, Mascaro, Tatone & Lengyel, 2016). We ran an ANOVA with a difference score entered as the dependent variable, and entered two between subjects factors: trial order (expected outcome trial first vs. unexpected outcome trial first) and gender. No main effect of trial order was found (F_{1,47} = 1.24, p = .27). In addition, no main effect of gender (F_{1,47} = 0.005, p = .95) or interaction between trial order and gender (F_{1,47} = 0.053, p = .82) was observed. To rule out the possibility of age differences, we ran the same analysis and entered age as a covariate. We found no significant differences due to age (F_{1,47} = 0.17, p = .68).

Study 8 Results (Log Transformed data)
Looking times from each test trial were first log-transformed and subsequent analyses were conducted on the log-transformed data (see Csibra, Hernik, Mascaro, Tatone & Lengyel, 2016). We ran an ANOVA with a difference score entered as the dependent variable, and entered two between subjects factors: trial order and gender. No main effect of trial order was found (F_{1,47} = 2.15, p = .15). In addition, no main effect of gender (F_{1,47} = 0.11, p = .74) or interaction between trial order and gender (F_{1,47} = 0.032, p = .86) was observed. To rule out the possibility of age differences, we ran the same analysis and entered age as a covariate. We found no significant differences due to age (F_{1,47} = 1.20, p = .28).