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Bari Schwartz 4/13/2012

Size Matters. Does Number? Magnitude Perception and Dominance Judgments.

by

Bari Schwartz

Stella Lourenco
Adviser

Psychology Department

Stella Lourenco

Adviser

Phillipe Rochat

Committee Member

Melvin Konner

Committee Member

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An abstract of
a thesis submitted to the Faculty of Emory College of Arts and Sciences
of Emory University in partial fulfillment
of the requirements of the degree of
Bachelor of Arts with Honors

Psychology Department

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Abstract

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Social animals develop social structures so they can organize their environment. Following these structures, animals must make decisions based on dominance. Those who are more dominant have priority access to desirable objects such as food and mates. Previous research suggests that human infants and other non-human animals are able to use certain information, such as physical size and number, to determine dominance. The current study examined how 3-year-olds, 5-year-olds, and adults used physical size and numerical information to determine which of two groups was dominant. When presented alone, 3-year-olds and adults were able to use number and physical size to make dominance judgments. When pitted against each other, these participants showed a preference for physical size, at least when the groups consisted of relatively few individuals. Five-year-olds, however, focused on number to make dominance judgments. These results suggest that there is an early basis for the ability to use magnitude information to represent dominance and that learning may affect the relative saliency of magnitudes when judging dominance.

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Acknowledgements

This thesis would not have been possible without the help of a handful of people. I would like to thank my advisor, Dr. Lourenco, for helping me throughout this taxing time. Her guidance, support, and encouragement enabled me to succeed with this thesis.

I owe my deepest gratitude to Justin Bonny, a current PhD student at Emory University, for making himself available to help and support me in a multitude of ways, despite his very busy schedule.

I would like to thank our lab coordinator, Edmund Fernandez, for keeping me calm during times of stress and providing me with help and support. Thank you to Chi Ngai Cheung, and all of the research assistants and fellow honors students in the Spatial Cognition Lab for all your support and helpful comments.

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Introduction

Humans, and other animals that live in social worlds, regularly make decisions about others and how to act towards them. Among the most crucial are decisions about dominance. The ability to judge one's capability to compete with another is evolutionary and behaviorally more advantageous than to always engage in fight without carrying out such assessments (Hawley, 1999). If someone picks a fight with you, you must decide whether you would be strong enough to fight or if you should back away – the critical fight or flight response. This is also the case in groups. A group must decide whether or not they would be strong enough to dominate over another group. But how do animals, human or non-human, make such decisions? One broad type of information that is generally helpful is magnitude. Magnitude is a mental representation of quantitative information, which can be countable (discrete, e.g., number) or uncountable (continuous, e.g., spatial extent) (Gallistel & Gelman, 2000; Walsh, 2003). Is the person trying to pick a fight with you larger than you? Does he/she have a group of friends to back him/her up? These are the types of questions we plan to address in the present study.

Dominance in Non-human Animals

Many times, social interactions based upon dominance serve important functions governing the lives of social animals, influencing the way in which they live and behave (Rowell, 1974). Examples include influencing who gets access to food, mates, and dominance statuses in hierarchies. Because dominance plays such an important part in who obtains resources, and how such resources are obtained, dominance is generally defined in terms of who has priority access to desirable objects (Rowell, 1974). An individual, or a group, who is more dominant will have priority access to, for example, food.

Non-human animals have been found to use different types of cues to determine dominance. Using controlled animal experiments as well as naturalistic field observations, research suggests that physical size and number are important cues when determining dominance among animals (McComb, Packer, & Pusey, 1994; Waal, 1982; Wilson, Hauser, & Wrangham, 2001). Previous studies, which have examined social competitions between single individuals, have found that individuals usually avoid serious competitions when their opponents are visibly larger or stronger than themselves (Clutton-Brock et al., 1979; Davies & Halliday, 1978; Robertson, 1986; Robinson, 1985; Rosenberg & Enquist, 1991). Additionally, some animals actively attempt to alter their physical size to convey dominance. Chimpanzees make their bodies look deceptively larger and heavier than a conspecific's by standing up straight and making their hair stand up during a confrontation (Waal, 1982), while clownfish actually become anatomically physically larger when they move up a social hierarchy in order to portray and maintain dominance (Buston, 2003). Another example that shows the importance of physical size is a study by Pereira (1995), which examined sexual dimorphism and its effect on dominance. In this study, Pereira compared size-dimorphic baboons with non-dimorphic macaques and found that there is more male dominance in the size-dimorphic baboon society. Because of the size-dimorphism, adult male baboons are so much larger than the adult females that they seem unbeatable, and thus the females may allow the males to dominate. Taken together, these examples show that physical size information is important in perceiving dominance among non-human animals.

In addition to physical size, there have also been experimental studies that suggest that animals can make use of numerical information in dominance situations. Unlike competitions among individuals, group dominance relies on contrasts in properties of sets, such as number.

Evidence of animals using number to determine group dominance comes from research using playback experimental approaches with lions and chimpanzees (McComb et al., 1994; Wilson et al., 2001). The playback approach consists of simulating an intruding attack by playing the calls of strangers of the same species. By varying the number of animals in the intruding call and by varying the number of animals in the groups being studied, experimenters were able to determine that lions and chimpanzees relied on number in assessing competition. More specifically, defending animals were less likely to approach the playbacks if the intruding call out-numbered those in the defending group (see also Wilson et al., 2001). Thus, these groups were able to use estimates of the number of individuals both in their own group and those of the intruding group. McComb et al. were the first to show that in social conflicts, groups assess dominance on the basis of relative group size. In these studies, however, it is not possible to dissociate number and overall physical size of the group. In other words, rather than differences in number per se, these effects could be due to spatial cues (e.g., physical size of group members) or even auditory cues (e.g., louder calls).

Dominance in Humans

We know from previous literature that social animals, including human adults, develop dominance hierarchies that offer more dominant animals access to desirable resources (e.g., food, mates, territory, etc.). It is believed that this hierarchical structure is universal among social animals, including humans (Thomsen, Frankenhuis, Ingold-Smith, & Carey, 2011). Even human toddlers are known to develop dominance hierarchies that are similar to those of animals (McGrew, 1972; Sluckin & Smith, 1977). Moreover, it has been noted that certain cues, such as body size, appear to be universal among species in determining dominance (Thomsen et al., 2011). Human adults make dominance decisions every day, but where does the development of this ability begin and what impacts its development?

Research showing that non-human animals use magnitude cues to make judgments of dominance suggests that this ability may be present early in human development, perhaps even innate (Thomsen et al., 2011). To examine this possibility, Thomsen and colleagues recently conducted an experiment in which infants (8 to 13-month-olds) were presented with a visual attention paradigm where dominance was conveyed using physical size in a simple interaction. The stimuli consisted of animations of two blocks of different sizes with smiley faces beginning on opposite sides of the screen and moving towards the middle. As they both reached the middle, they blocked each other's paths and bumped into each other. They then backed up and re-approached. This interaction illustrated a competition; that is, each character wanted to reach the other side but only one would be able to. The experimenters showed the infants expected trials and unexpected trials, and measured infants' looking times. In the expected trial, the smaller block moved out of the way for the larger one, whereas in the unexpected trial, the larger block moved out of the way. These infants showed greater looking time towards the unexpected trials, and thus Thomsen et al. (2011) concluded that these infants used the size of the blocks to predict which character would win the competition. Infants expected the small block to move out of the way so that the large one could continue in its path.

If these dominance relationships are apparent in most, if not all, social settings and species, it would make sense that there would be an innate aspect to, or an early development of, the ability to use information to represent dominance. Young individuals should possess this ability so that they could act appropriately in social situations (Thomsen et al., 2011). The study by Thomsen and collegues was the first step in examining the use of magnitude information to make dominance judgments in humans. Further research is needed to better investigate the use of physical size and other sources of dominance, such as the number of individuals in a group. It is also important to investigate how the ability to use magnitude information in dominance judgments develops over time. Is there continuity, or do judgments vary discontinuously over development?

Magnitude Discrimination

We know from previous studies that humans and other animals are sensitive to differences in number and physical size in non-social contexts. Non-human animals and humans across development are capable of discriminating stimuli based on these cues (*non-human animals:* Meck & Church, 1983; Rumbaugh, Savage-Rumbaugh, & Hegel, 1987; Tudusciuc & Nieder, 2009; *infants:* Clearfield & Mix, 1999; Feigenson, Carey, & Spelke, 2002; Starkey, 1980; Xu & Spelke, 2000; *children:* Droit-Volet, Clèment, & Fayol, 2008; Huntley-Fenner & Cannon, 2000; Rousselle, & Noel, 2008; *adults*: Buckley & Gillman, 1974; Droit-Volet, Clèment, & Fayol, 2008). The ability to discriminate magnitudes has been tested with different magnitudes, ranging from physical size and number to loudness and pitch. Additionally, the ability to discriminate magnitudes has been tested using a variety of different paradigms (e.g., habituation/dishabituation, comparison tasks, and ordering tasks). Across different magnitudes, paradigms, and ages, there is evidence for magnitude sensitivity. However, these paradigms tend to rely on non-social tasks. Researchers have investigated the ability to discriminate magnitudes (e.g., two versus four circles, or large versus small circles) rather than how they are used for socially-based judgments.

Since we have evidence that individuals can discriminate more versus less in a non-social setting, we can now examine whether they can use numerical information and physical size in a social setting to make dominance judgments. In addition, previous research studying dominance judgments with humans has focused only on individuals, whereas the current study examines dominance judgments with groups of individuals. For example, do we assess which group is more or less, or stronger or weaker, in order to determine who would win? Although we have some evidence from animal and infant studies to suggest that this assessment would be appropriate (McComb et al., 1994; Thomsen et al, 2011; Wilson et al., 2001), it still remains unknown if humans can, and will, use numerical and physical size information to make these social judgments and whether or not the use of this information applied to groups will follow similar patterns as when applied to individuals. What also remains unknown is how we negotiate more complex situations where multiple cues are present, and how our ability to make dominance judgments changes over our lifespan. Is this ability present early in life or does it emerge much later? Do learning and life experiences affect the ability to assess dominance? These are some of the questions we aim to investigate.

The Current Study

The goal of the current experiment was to expand and elaborate on the infant study by Thomsen et al. (2011) in a number of important ways. The first was the inclusion of verbal children (and adults) instead of preverbal infants, as used in Thomsen and colleagues. We examined 3- and 5-year-olds, as well as college undergraduates, who were asked to make explicit judgments of which group would win a competition, rather than having to rely on discrimination using looking times. Since Thomsen et al. based their conclusions on infants' looking times, it is difficult to infer that they made actual dominance judgments, rather than just noticing perceptual differences. It thus remains unknown how young children make judgments of dominance. Because we studied verbal children, we were able to obtain an explicit choice. Also, because our participants were older than the preverbal infants used in Thomsen et al. we were able to use different, and slightly more complex scenarios than they were able to use. Moreover, these children have had more experiences in social situations and thus might have a more developed and complex concept of dominance than infants would. By collecting data from three different age groups we were able to compare results and gain insight into when the ability to use magnitude information to make dominance judgments arises and how it might develop.

Another way in which we extended the Thomsen et al (2011) study was by asking whether number served as an effective cue like physical size. There are many magnitudes available in real life that humans, as well as non-human species, perceive. An obvious one is number, already discussed above. Previous studies with lions and chimpanzees (McComb et al., 1994; Wilson et al., 2001) have shown that in competitions among social groups numerical information plays an important role in dominance judgments. This is because there is strength in numbers, not only physical size. Besides examining the effect of physical size on the perception of dominance, we also looked at the effect of number. We examined competitions between groups of characters, rather than single individuals. Further, these groups did not just bump into each other, but they competed for a desirable object, since dominance is many times characterized in this way (Rowell, 1974). We also included several trials, using slightly different scenarios by using different desirable objects and different physical sizes and numbers of individuals. We looked at how children, and adults, used each magnitude independently. Moreover, and critically, we also pitted them against each other to determine which cue would be preferentially used when both are available. These manipulations have not been systematically examined in previous studies and are thus a way in which we to sought to expand on the current literature.

Hypotheses and goals. In this experiment, participants were presented with a social competition task (SCT), which consisted of two groups of characters competing for a desirable object such as a birthday cake or set of stickers. Across three conditions, we assessed the extent to which participants used physical size and numerical information to choose a winner, even when pitted against each other.

Based on discrimination studies mentioned previously and the Thomsen et al. (2011) study, we predicted that in the Size condition, individuals would choose the group with the larger individuals to win the competition. In the Number condition, we predicted that individuals would choose in terms of the greater number of individuals. We predicted this because previous studies that have been mentioned have concluded that infants and children are able to discriminate between physical sizes, determining which of two choices is more or less. However, since other experiments have not tested number in this context, this is an important extension. Lastly, both number and physical size are salient magnitude cues. When pitted against each other in the Conflict condition there are two likely scenarios. If physical size is the more important, or preferential, cue then participants should base their decisions on the physical size of the characters. On the other hand, if number is the more important, or preferential, cue then participants should choose based on the number of characters in the groups.

Methods

Participants

A final sample of 30 3-year-olds (16 female; M = 40.76 months, SD = 3.48) and 30 5-year-olds (16 female; M = 64.56, SD = 3.14) participated in this study. An additional two 3-year-olds were excluded from statistical analyses because of side biases during the task. Children were recruited from Atlanta and were tested individually in a laboratory. Participants were given a small gift as a thank you for participating. A total of 30 undergraduates (21 female; *M* = 19.73 years, *SD* = .96) also participated. Undergraduates were recruited from introductory psychology classes at a southeast university and received course credit for participating. After the experiment was completed, the experimenter explained the premise and purpose of our study and allowed participants or parents to ask questions.

Stimuli and Design

In this experiment, we aimed to examine the variables of magnitude and range (a larger versus smaller number of characters per group) within and across child (3-year-olds and 5-year-olds) and adult samples. Participants were presented with our SCT, which consisted of two groups of characters competing for a desirable object, either a birthday cake, a jar of cookies, stickers, or the game Candy Land. The characters used were two-dimensional squares with faces (see Figure 1). Following Thomsen et al., we used shapes as characters in order to eliminate the use of previous information about the social identities of different animals and humans, arguably providing a cleaner measure of intuitions when making social judgments. Each participant was presented with all three conditions: Number, Size, and Conflict.

In the Number condition, children were presented with two groups of characters, which differed in the number of characters per group. Each member in these groups was the same size as the rest of the members of said group, such that individual size could not be used for assessing dominance (see Figure 1).

In the Size condition, children were presented with two groups of characters, which differed in the physical size of the individuals, but were consistent in number (see Figure 1). Between the two groups, number was equated, but groups differed in size by a 2:1 ratio. In other words, number could not be used to determine dominance; the only cue available was bigger versus smaller characters. Refer to Table 1 for exact dimensions.

In the Conflict condition, participants were presented with two groups of characters that differed in both physical size and number. Unlike the other two conditions, physical size and number were pitted against each other. That is, the group with the greater number had individuals that were smaller in physical size than the group with the lower number of individuals. The conflict trials had two types that included a variation in spatial information. Sometimes the elements in each group were all the same physical size and other times they varied (Figure 1). We included these two variations in order to make the task more realistic. In the real world, a group of individuals would most likely not be the exact same size, so varying the size of elements per group made the task more ecologically valid. These two variations also served as a control. We wanted to make sure that individuals were not focusing on the single largest element in the group, but, rather, the group as a whole.

Each condition contained two ranges of numbers. The small range trials consisted of 2 or 4 characters per group and the larger range trials consisted of 5 or 10 characters per group. This manipulation was included in order to determine whether or not number and physical size information was used differently based on a small or large set of elements.

All participants (children and adults) received 8 trials in each condition for a total of 24 trials. Across trials, number, range, and position of the larger group were counterbalanced. Trials were presented in a randomized order.

Task and Procedure

In the child version, there were animations (created in Adobe Flash software on a 1200 x 900 pixel, 31.75cm x 23.81cm, computer screen), which began with one group of characters in the top left corner and a second group of characters in the top right corner. The desirable object (e.g., birthday cake) was centered at the bottom of the screen (see Figure 1). The characters remained stationary for 4 s at the top of the screen before moving slowly in a diagonal direction towards the desirable object (which remained stationary throughout). Once the characters reached the desired object, the groups moved up and down, with the same timing but in opposite directions, and then paused. Following the animation, the groups' initial positions were shown and participants were asked to make a selection of which group they thought would win. Refer to Figure 2 for animation timing.

Children were tested individually with the experimenter who, before beginning, briefly explained that they were going to play a fun game where they would watch videos and would have to pay close attention. During each trial, the experimenter said, "In each animation, characters will be competing for [object]. Look how [yummy/fun] it is! Everyone loves [object] and everyone wants to get it." When the groups and object appeared on the screen, the experimenter pointed to one group and said, "This group wants the [object]," and then pointed to the second group and said "And this group wants the [object]. But only one group gets to [eat/play] with the [object]." Children then watched the video of the groups moving towards the object of desire. After the animation, a screenshot of both groups and the object remained on the screen. At this point, the experimenter asked the participant, "Which group of characters won and got to [eat/play] with the [object]?" The experimenter recorded the participant's answer and started the next trial.

The task was modified slightly for adult participants. The main difference was that there was no animation. Adults saw the initial screenshot with two groups of characters at the top and the desirable object centered at the bottom of the screen. They sat at a computer alone and read instructions informing them that they would view screenshots of animations that had been given to children. They were told that they would have to respond with which group they thought (not what the children thought) would win, as well as the odds at which the group would win. The task was created using a computer program called E-Prime (PST, Inc.), which recorded the participant's choice, reaction time, and likelihood judgment.

Results

Scoring for Social Competition Task

Responses were scored as either a number judgment or a size judgment. In the Size condition, if participants made their judgment in line with the physical size information they received a score of 1; if they did not, then they received a score of 0. In the Number condition, if participants made their choice in line with the numerical information they received a score of 1; if they did not, then they received a score of 0. Scores were averaged for each condition (Size, Number), which gave us a proportion of time choice was made in terms of target information (.50 = chance). Average scores above .50 for the Size and Number conditions meant significant use of physical size information and number, respectively.

In the Conflict condition, where number and physical size conflicted, participants received a score of 0 if they chose on the basis of number and received a score of 1 if they chose on the basis of size. In the Conflict condition, if the average score was significantly below .50 that meant that the participant chose significantly based on numerical information, whereas if the score was significantly above .50 it meant that choice was based on size information.

Analyses of Children's Responses

We used a 3 (magnitude: size, number, conflict; within-subjects) by 2 (range: small, large; within-subjects) by 2 (age group: 3-years, 5-years; between-subjects) mixed Analysis of

Variance (ANOVA) to examine any differences in choice proportion. Because sphericity was violated for magnitude and the interaction (p < .001, p = .008) we used the Greenhouse-Geisser correction. We observed a significant main effect for magnitude, $F(1.651, 95.738) = 15.33$, p < .001, $\eta_p^2 = .209$, and a significant interaction between magnitude and age group, $F(1.651, 95.738) = 3.97$, $p < .029$, $\eta_p^2 = .064$ (Figure 3). Follow-up comparisons indicated that the interaction was driven by a significant difference between age groups in the Conflict condition where 5-year-olds chose the group that was larger in number significantly more than 3-year-olds, $t(58) = 3.96$, $p < .001$ (all other ps > .2).

Comparisons to chance revealed that both 3-year-olds (M = .63, SD = .23), $t(29) = 3.04$, p = .005, and 5-year-olds (M = .63, SD = .32), $t(29) = 2.17$, p = .038, chose in terms of greater number for the Number condition. For the Size condition, 3-year-olds (M = .65, SD = .26) chose in terms of larger size, $t(29) = 3.19$, p = .003. In contrast, 5-year-olds (M = .57, SD = .25) choices did not differ from chance, $t(29) = 1.58$, p = .125 (Figure 3), suggesting that they selected randomly. Furthermore, in the Conflict condition, 3-year-olds (M = .53, SD = .24) did not differ significantly from chance, $t(29) = .70$, p = .491, suggesting no preference for size or number. In contrast, 5-year-olds (M = .29, SD = .24) significantly chose in favor of numerical information, $t(29) = -4.77$, $p < .001$ (Figure 3).

Analyses of Adult's Responses

We used three 3 (magnitude: size, number, conflict; within-subjects) by 2 (range: small, large; within-subjects) repeated-measures ANOVAs to examine any differences in choice proportion, reaction time, and odds within the adults age group.

Choice proportion. Because sphericity was violated for magnitude and the interaction (p < .001, p = .007) we used the Greenhouse-Geisser correction. We observed significant main effects for magnitude, $F(1.319, 38.265) = 43.86$, $p < .001$, $\eta_p^2 = .602$, and range, $F(1, 29) = 12.14$, $p = .002$, $\eta_p^2 = .295$, as well as a significant interaction between magnitude and range, $F(1.421, 41.210) = 15.06$, $p < .001$, $\eta_p^2 = .342$ (see Figure 4). This interaction was driven by the difference in range for the Conflict condition such that participants were more likely to base their responses on size in the small range group ($M = .73$, $SD = .34$) compared to the large range ($M = .43$, $SD = .37$), $t(29) = 4.59$, $p < .001$. No difference in range was observed for Number and Size conditions (*p*s > .6). Post hoc tests comparing Number and Size conditions showed that participants chose in terms of the target information more consistently in the Number condition than in the Size condition, $p = .018$ (LSD multiple comparisons). This suggested that numerical information was an important additional cue in this condition. As expected, participants chose in terms of target information in the Number and Size conditions, significantly above chance regardless of range (*ps* < .001). However, in the Conflict condition, participants chose in terms of greater size, significantly above chance, for the small range ($M = .73$, $SD = .34$), $t(29) = 3.66$, $p = .001$, but not significantly different from chance for the large range ($M = .43$, $SD = .37$), $t(29) = -1.00$, $p = .326$ (see Figure 4). This suggests that in the Conflict condition numerical information was more influential in the large range.

Reaction time and odds. Both reaction time and odds data revealed a similar pattern of results as choice proportion. Using a similar repeated-measures ANOVA with reaction times as the dependent variable, we observed significant main effects of magnitude, $F(1.516, 43.977) = 11.997$, $p < .001$, $\eta_p^2 = .293$ (Greenhouse-Geisser correction), and range, $F(1, 29) = 5.71$, $p = .024$, $\eta_p^2 = .165$. The main effect of magnitude was driven by reaction times being significantly slower in the Conflict condition as compared to the Number and Size conditions (*p*s < .004, LSD multiple comparisons). Furthermore, by using a similar repeated-measures ANOVA with odds, we observed a significant main effect for magnitude, $F(1.449, 40.567) = 42.17$, $p < .001$, $\eta_p^2 = .601$ (Greenhouse-Geisser correction), and a significant interaction between magnitude and range, $F(2, 56) = 6.74$, $p < .002$, $\eta_p^2 = .194$. For the main effect of magnitude, odds given for the Number condition was higher than both Size and Conflict conditions, and the odds given for the Size condition was higher than Conflict, *ps* < .001 (LSD multiple comparisons). The interaction was driven by the difference in range for the Conflict condition such that participants were more likely to give higher odds in the small range group compared to the large range, $t(28) = 3.55$, $p = .001$.

General results

In order to examine the development of the use of these magnitude cues, we performed a mixed ANOVA using all three age groups. There was a significant main effect for magnitude, $F(2, 174) = 42.19$, $p < .001$, $\eta_p^2 = .327$, a significant interaction between magnitude and age, $F(4, 174) = 4.07$, $p = .004$, $\eta_p^2 = .086$, a significant main effect for range, $F(1, 87) = 10.14$, $p = .002$, $\eta_p^2 = .104$, and a significant interaction between magnitude and range, $F(1, 174) = 10.09$, $p < .001$, $\eta_p^2 = .104$. Post hoc comparisons using the LSD multiple comparisons indicated that in the Number and Size conditions the adults were significantly different from both the 3- and 5-year-olds, *ps* < .001, in that adults were more consistent in making their choices based on the target cues (number and size information, respectively) (Figure 5). These comparisons also revealed that in the Conflict condition, the 5-year-olds were significantly different from the 3-year-olds and adults, *p*s < .002, in that 3-year-olds and adults selected the larger individuals to win whereas the 5-year-olds selected the group with more individuals (Figure 5). The magnitude by range interaction was driven by the difference in choice made in the small range trials compared to the large range trials in the Conflict condition, $t(89) = 4.39$, $p < .001$ (Figure 5). In the Conflict condition, collapsed over all ages, numerical information played more of an influential role in choice for the large range trials as compared to the small range trials. In terms of comparisons to chance, individuals in the large range trials made their choices significantly in terms of number, $t(89) = -3.30$, $p = .001$, selecting the group with more individuals. In the small range trials, however, individuals chose at chance, $t(89) = 1.31$, $p = .193$, suggesting that their choices were not consistently based on one magnitude or the other.

Discussion

Three-year-olds and Adults

Taken together, the data from all three age groups suggest an interesting story. First, the data from the 3-year-olds looked remarkably like the data from the adults, except for lower consistency. The data from both the 3-year-olds and adults are consistent with previous literature suggesting that when presented alone, individuals can use number and physical size information to make dominance judgments (i.e., who wins in a competition). The following are real world examples that show the applications of numerical and physical size information in dominance situations. In the first instance, imagine a group of two men fighting a group of four. If all of the men are relatively the same size and strength, one would expect the group with more men to be more dominant and win because of the greater number of people. On the other hand, imagine a group of five men, who go to the gym and work out (large in height and muscular), fighting a group of five men who do not go to the gym and thus are frailer. One would expect that the stronger men, who are larger in physical size, would be more dominant and win.

The results obtained with 3-year-olds and adults in the Conflict condition suggested that when number and physical size were pitted against each other, individuals expressed flexible judgments based on range (small versus large number of individuals per group). With the small number range, physical size was the preferred cue when they made dominance judgments. For the large range trials, however, performance was at chance, which suggested that even though individuals were not significantly choosing in terms of greater number, numerical information was still playing more of an influential role than we had seen with the small range. As the group became larger in number, individual characteristics (i.e., physical size of individual elements) became less important when participants determined dominance. We would suspect that if our large range trials were greater than 5 and 10 elements (the numbers used in the present study), we might have seen a greater reliance on number in the Conflict condition. As a group gets larger, group information (i.e., number of individuals in the group) becomes more important to focus on.

Five-year-old Children

We initially thought that the data would follow a linear pattern with age, which made the performance of the 5-year-olds in this study highly unexpected. The 5-year-olds displayed an extreme focus on number such that they preferred to use numerical information in the Conflict condition, and when numerical information was unavailable (Size condition) they responded randomly. Why might 5-year-olds have focused so heavily on number when 3-year-olds showed greater flexibility? At the age of 5, number becomes quite prominent in the lives of children. Parents and teachers are keen on counting with their children and teaching them about symbols for numbers. Math instruction in school and from caregivers has been shown to increase focus and understanding of number in young children (Bisanz, Dunn, & Morrison, 1991; Jordan, Levine, & Huttenlocher, 1994). This focus on math and numbers was expressed in our data. In the Number condition, children were more likely to select the group with more individuals, the target information. However, in the Size condition, where the 3-year-olds and adults chose in terms of larger physical size, the 5-year-olds failed to do so, and chose at chance levels. We would think that they would have been able to use physical size information, but the fact that the 5-year-olds focused on number suggested a reason why they had difficulty with this condition. Moreover, in the Conflict condition, the 5-year-olds significantly favored numerical information and chose the group with the greater number, regardless of range. This was, again, unlike what the 3-year-olds and adults did. Number is heavily emphasized in the environment (e.g., home, school) and thus may have made number so salient that when not informative they failed to use physical size consistently.

In addition, comments that the children made during the task suggested other factors that may have influenced their behavior. We know from previous literature that even young children are capable of discriminating stimuli based on number. However, in our study there were other things that 5-year-olds may have paid more attention to, which may have affected their performance. Five-year-olds made various comments related to sharing and personifying the characters. A focus on the concept of sharing could explain why choice proportion was not as high in the Number condition as we would have thought based on their focus on number. In the Number condition children specifically made comments such as, "they are lesser, they get more stickers," "these have too much, so this one [the lower number] wins, " and "the others won't share because there are too many." One girl even commented, "well they should all share," and initially did not want to make a choice, while another said, "maybe one group should play first, and then the second." Children were able to discriminate which was the group with the greater number, but chose not to apply that information to the task. Many times they chose the group with the lower number because there were fewer individuals to share with. Part of this could be due to 5-year-olds' schooling environment, where social groups might play a larger role in their lives and where there is a heavy focus on learning to share. Adults have social groups too, that are much more complex than those of children, but they are old enough to better understand the task and apply appropriate judgments based off of relative information. The need to share in a social context may have affected 5-year-olds' responses. While studying the development of egalitarianism in children ages 3 to 7-years-old, Fehr, Bernhard & Rockenbach (2008) found that sharing behavior increased with age. The increase in willingness to share from 3 to 5 years of age could explain why the 5-year-olds in the current study commented on sharing the desirable objects more than the 3-year-olds and thus affected the results.

Furthermore, Fehr et al. (2008) also discussed the influence of parochialism (i.e., preference for one's own social group) on behavior. They tested whether or not the partner in the games was part of the participants' social group and found that children were more pro-social, more willing to share, and less envious of individuals in their own social group than outsiders. They also found that these effects generally became stronger with age. In the current study, 5-year-olds commented that the characters of larger physical size were the parents and the smaller ones were the children ("the babies like to eat cookies," and "they win because they are the kids not the grown-ups,"). They were able to discriminate which was larger, yet many times chose the smaller ones ("the children") to win. Perhaps the 5-year-olds were showing parochialism towards the smaller individuals, more so than the 3-year-olds, and thus affected their ability to choose the group larger in physical size in the Size condition.

It is important to note that in the real world many other cues can be important when determining dominance. For instance, social context is important, as well as skills or personalities. Imagine an average sized man, let us call him Man-A, enters a fight with another man, Man-B, who is about the same size. However, Man-B is a black-belt karate star. If both men are the same physical size and it is one versus one, who would win? The man trained in karate would probably be more dominant in this physical fight. What if Man-A was a Harvard graduate and Man-B never finished high school, and they both sat down to take an achievement test, who would be dominant? In this context, Man-A would be dominant. There are many different ways to be dominant in the real world. An interesting and important area for future research would be to examine what other cues are important in assessing dominance and how they vary over different contexts.

Learning How to Represent Dominance

An important question to address is what aspects of dominance could be innate versus learned. It has been previously suggested that humans possess an innate sense of magnitude (i.e., the ability to understand, approximate, and make judgments of various quantities; Dehaene, Dehaene-Lambertz, & Cohen, 1998; Feigenson, Dehaene, & Spelke, 2004). Is the ability to use this sense of magnitude to make dominance judgments innate or learned? Based on the previous study by Thomsen et al. (2011) and the current study, I propose that the ability to use magnitude information to represent dominance is learned, but learned at a very early age.

Thomsen et al. (2011) tested dominance perception in infants and found that the ability to make dominance judgments based on magnitude information increased with age. In their study, the 8-month-old infants did not use physical size information to predict dominance; however, no one would argue that these 8-month-olds were not able to discriminate between the small and large blocks. There have been studies that show that even newborns can detect differences in magnitude (Izard, Sann, Spelke & Streri, 2009). It seems as though they just have not learned to incorporate magnitude information in dominance judgments yet. As the infants' ages increased, the ability to make dominance judgments based on magnitude discriminations increased, such that the 9-month-olds showed trending results, the 10-month-olds showed significant results, and the 12- and 13-month-olds showed even stronger significance. This increase with age suggested that a learned aspect exists. This idea was extended in the current study.

The data from the current study suggested that by 3 years of age, children have almost identical dominance judgments as adults. The adults were certainly more consistent in their judgments and this reflects their greater amount of experiences and learning. Further, in the Conflict condition, the 3-year-olds and the adults also expressed similar range sensitivity (chose in terms of physical size for the small range and at chance for the large range). In the 3-year-olds this pattern was trending, but as one became older, this sensitivity became more significant, as was shown by the adults. This increase in significance provides evidence to support that incorporating magnitude information in dominance is learned.

Interestingly, the 5-year-old data did not show a linear progression with increased consistency from 3-years to adults. Instead they showed evidence that learning and life experiences continued to be influential in applying magnitude discriminations to dominance judgments. The body of experience that the adults have had allowed them to flexibly attend to relevant information and apply what was appropriate to our specific task. The 5-year-olds did not have this flexibility. In the 5-year-olds' home and school environments number is important, and this focus may have skewed their focus on magnitude and thus their dominance judgments. Overall, I do not think that using magnitudes, such as physical size and number, to represent dominance is innate. The ability to discriminate magnitudes may be innate, and at a very young age learning how to apply it to dominance occurs and continues to occur throughout life.

Summary

In summary, the 3-year-olds and adults performed similarly by choosing in terms of target information for the Size and Number conditions (adults more accurately). In addition, in the Conflict condition, the 3-year-olds and adults performed similarly by choosing in terms of physical size for the small range trials and at chance for the large. The 5-year-olds are a different story. Educational and social learning that the 5-year-olds are experiencing in their lives seem to play an important role when performing our task (i.e. their hyper-focus on number). The 5-year-olds may be able to judge dominance on the basis of physical size but at least in our task, academic and social learning affects their task performance. Future research should investigate the effect of larger range trials, what is occurring in the 5-year-olds, and other cues or individual differences that are important in determining dominance.

Table 1

Stimuli Dimensions

Magnitude	Range	Number of blocks	Cumulative area (cm^2)
Number Trial 1	Small	2 vs 4	6.15 vs 12.29
Number Trial 2	Small	2 vs 4	1.54 vs 3.07
Number Trial 3	Large	5 vs 10	4.57 vs 9.14
Number Trial 4	Large	5 vs 10	1.14 vs 2.29
Size Trial 1	Small	2 vs 2	6.15 vs 3.10
Size Trial 2	Small	4 vs 4	6.18 vs 3.07
Size Trial 3	Large	5 vs 5	4.58 vs 2.35
Size Trial 4	Large	10 vs 10	2.29 vs 4.70
Conflict Trial 1	Small	2 vs 4	6.15 vs 3.07
Conflict Trial 2	Large	5 vs 10	4.57 vs 2.29
Conflict Trial 3	Small	2 vs 4	6.15 vs 3.07
Conflict Trial 4	Large	5 vs 10	4.57 vs 2.29

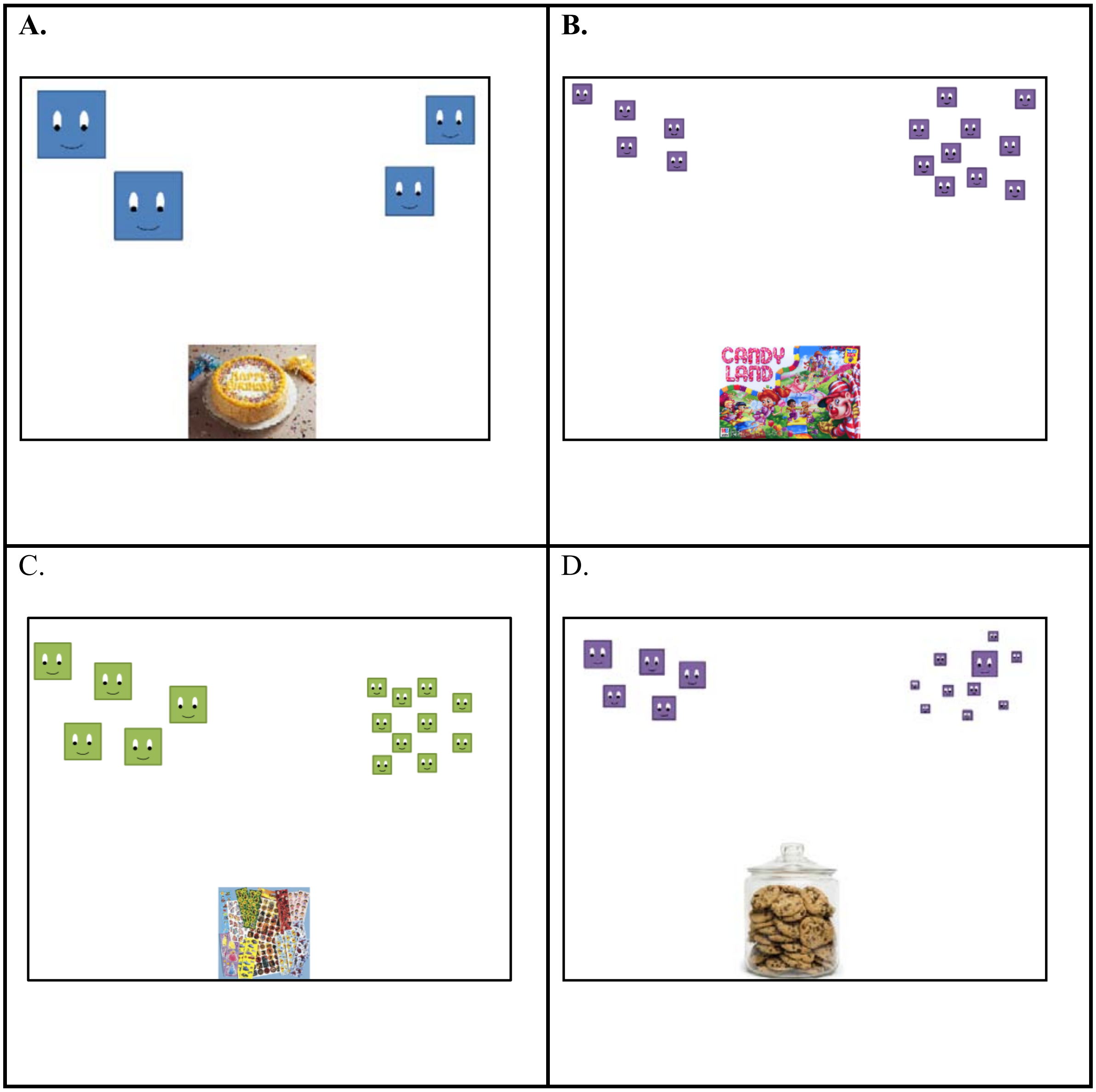

Figure 1 (a-d). Stimuli screenshots: (A) Size Trial 1, small range; (B) Number Trial 3, large range; (C) Conflict Trial 2, large range; (D) Conflict Trial 4, large range.

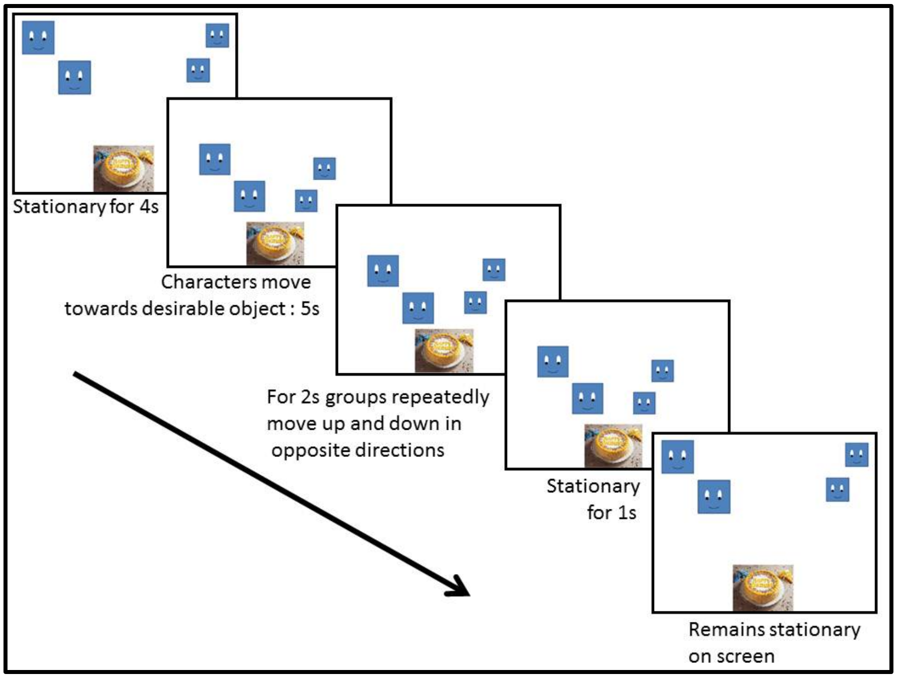

Figure 2. Animation timing. The initial positions of the groups of characters and object remained on screen for 4 s. It took the groups 5 s to move towards the desirable object and then they paused for < .5 s. Then, for 2 s, the groups of objects moved up and down, in opposite directions, and then paused for 1s. Finally, a screen shot of the groups' initial positions was shown and remained on screen until the participant made a choice.

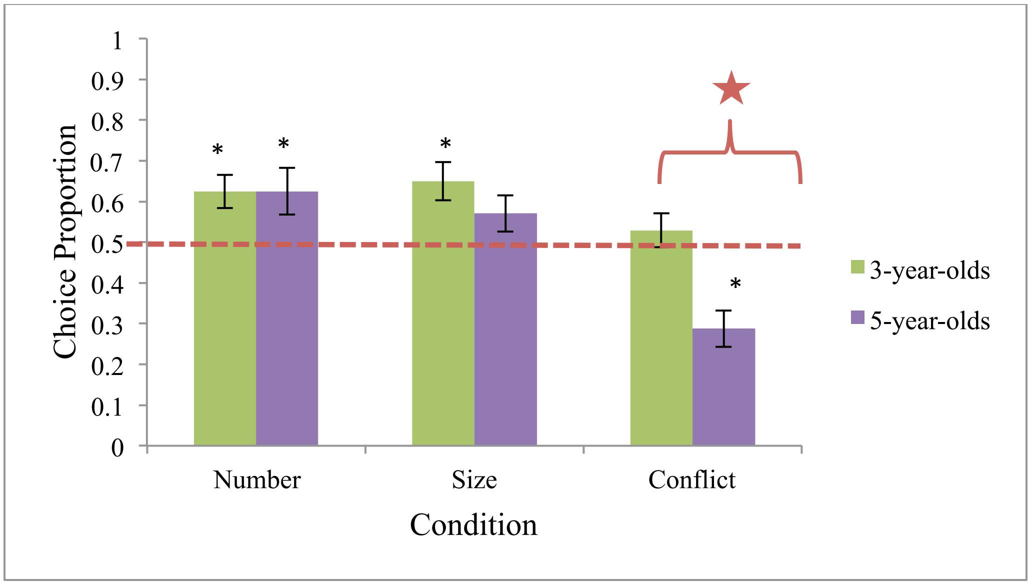

Figure 3. Overall choice proportion for children. Error bars represent ±1 SEM. Asterisks denotes that value is significantly different from chance, *p*s < .05. Because there was no significant interaction with range, magnitude is collapsed over range. The difference between choice proportions in the 3- and 5-year-olds in the Conflict condition drives the magnitude by age interaction (shown by bracket and star).

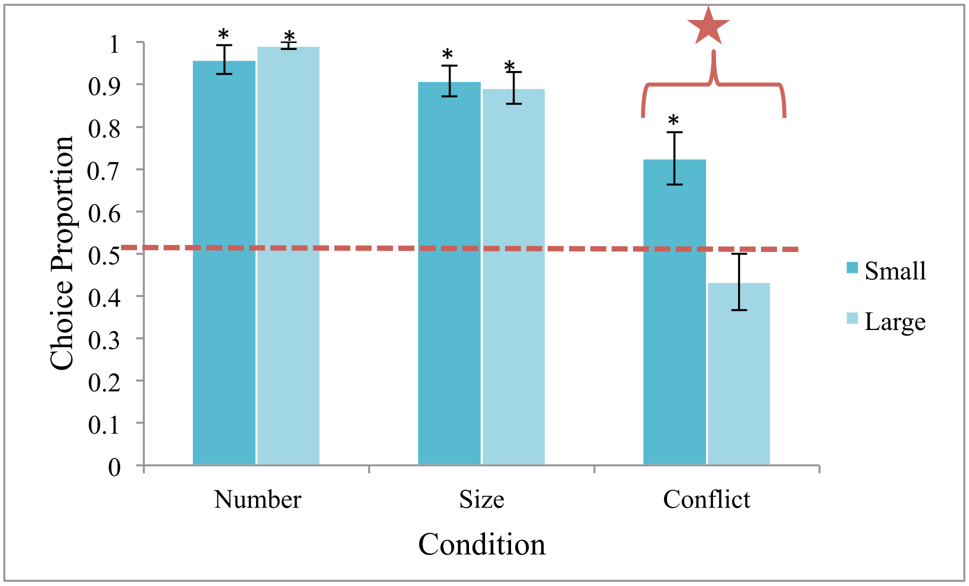

Figure 4. Adult choice proportion broken down by range. Error bars represent ±1 SEM. Asterisks denotes that value is significantly different from chance, *p*s < .05. Here you can see that the magnitude by range interaction is being driven by the significant difference in choice between the small and large range in the conflict condition.

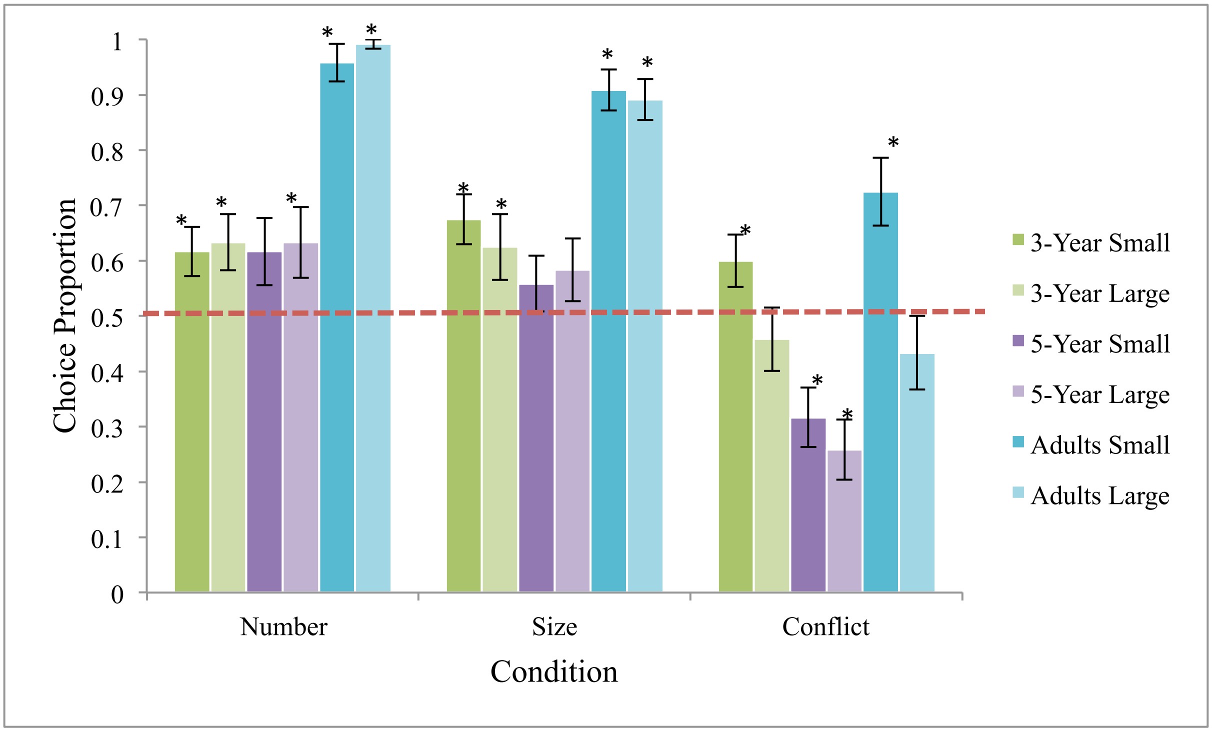

Figure 5. Choice proportion for all ages broken down by range. Error bars represent ±1 SEM. Asterisks denotes that value is significantly different from chance, *p*s < .05. The interaction for magnitude and range was driven by the choices made in the Conflict condition.

References

Bisanz, J., Dunn, M. and Morrison, F.J. (1995). Effects of age and schooling on the acquisition of elementary quantitative skills. *Developmental Psychology, 31(2),* 221-236.

Buckley, P.B. and Gillman, C.B. (1974). Comparison of digits and dot patterns. *Journal of Experimental Psychology, 103(6),* 1131-1136.

Buston, P. (2003). Social hierarchies: size and growth modification in clownfish. *Nature, 424,* 145-146.

Clearfield, M.W. and Mix, K.S. (1999) Number versus contour length in infants' discrimination of small visual sets. *Psychological Science, 10,* 408–411

Clearfield, M.W. and Mix, K.S. (2001). Amount versus number: infant's use of area and contour length to discriminate small sets. *Journal of cognition and development, 2(3),* 243-260.

Dehaene, S., Dehaene-Lambertz, G., and Cohen, L. (1998). Abstract representations of numbers in the animal and human brain. *Trends in Neurosciences, 21,* 355-361.

Droit-Volet, S., Clèment, A., and Fayol, M. (2008). Time, number and length: similarities and differences in discrimination in adults and children. *The Quarterly Journal of Experimental Psychology, 61(12),* 1827.

Fehr, E., Bernhard, H., and Rockenbach, B. (2008). Egalitarianism in young children. *Nature, 454,* 1079-1084.

Feigenson, L., Dehaene, S., and Spelke, E. (2004). Core systems of number. *TRENDS in Cognitive Sciences, 8(7),* 307-314.

Feigenson, L., Spelke, E. and Carey, S. (2002). Infants' discrimination of number vs. continuous extent. *Cognitive Psychology, 44,* 33-66.

Gallistel, C.R. and Gelman, R. (2000). Non-verbal numerical cognition: from reals to integers.

Trends in Cognitive Sciences, 4(2), 59-65.

Hauser, M., Carey, S., Hauser, L. (2000). Spontaneous number representation in semi-free-ranging rhesus monkeys. *Proceedings of the Royal Society, 267,* 829–833.

Huntley-Fenner, G., Cannon, E. (2000). Preschoolers' magnitude comparisons are mediated by a preverbal analog mechanism. *Psychological Science, 11,* 147–152.

Hawley, P.H. (1999). The ontogenesis of dominance: a strategy-based evolutionary perspective. *Developmental Review, 19,* 97-132.

Izard, V., Sann, C., Spelke, E.S., and Streri, A. (2009). Newborn infants perceive abstract numbers. *Proceedings of the National Academy of Sciences of the United States, 106(25),* 10382-10385.

Jordan, N.C, Levine, S.C. and Huttenlocher, J. (1994). Development of calculation abilities in middle- and low-income children after formal instruction in school. *Journal of Applied Developmental Psychology, 15,* 223-240.

McComb, K., Packer, C., and Pusey, A. (1994). Roaring and numerical assessment in contests between groups of female lions, *Panthera leo*. *Animal Behavior, 47,* 379-387.

McGrew, W.C. (1972). *An Ethological Study of Children's Behavior*. Oxford: England.

Meck, W.H. and Church, R.M. (1983). A mode control model of counting and timing processes. *Journal of Experimental Psychology: Animal Behavior Processes, 7,* 18-30.

Mix, K.S., Huttenlocher, J., and Levine, S.C. (2002). Multiple cues for quantification in infancy: is number one of them? *Psychological Bulletin, 128(2),* 278-294.

Rousselle, L. and Noel, M-P. (2008). The development of automatic numerosity processing in preschoolers: evidence for numerosity – perceptual interference. *Developmental Psychology, 44(2),* 544-560.

Rumbaugh, D.M., Savage-Rumbaugh, S., and Hegel, M.T. (1987). Summation in the chimpanzee (Pan troglodytes). *Journal of Experimental Psychology: Animal Behavior Processes, 13(2),* 107-115.

Sluckin, A.M. and Smith, P.K. (1977). Two approaches to the concept of dominance in preschool children. *Child Development, 48(3),* 917-923.

Starkey, P. (1980). Perception of numbers by human infants. *Science, 210(4473),* 1033-1035.

Thomsen, L., Frankenhuis, W. E., Ingold-Smith, M., and Carey, S. (2011). Big and Mighty: Preverbal Infants Mentally Represent Dominance. *Science, 331,* 477.

Tudusciuc, O. and Nieder, A. (2009). Contributions of primate prefrontal posterior parietal cortices to length and numerosity representation. *Journal of Neurophysiology, 101,* 2984-2994.

Waal, F. D. (1982). *Chimpanzee politics.* London: Cape

Walsh, V. (2003). A theory of magnitude: common cortical metrics of time, space and quantity. *TRENDS in Cognitive Sciences, 7(11)*, 483-488.

Wilson, M.L., Hauser, M.D., and Wrangham, R.W. (2001). Does participation in intergroup conflict depend on numerical assessment, range location, or rank for wild chimpanzees? *Animal Behavior, 61,* 1203-1216.

Xu, F., and Spelke, E. (2000). Large number discrimination in 6-month-old infants. *Cognition, 74,* 1-11.