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Children’s Perception of Magnitudes of Emotional Expression in Comparison to Number

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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
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Abstract

Numeric magnitudes often bias how adults and children organize information spatially. Specifically, studies have found consistent results that numerical information is mentally organized in left-to-right orientation like a “number line” and this orientation is applied to magnitudes of various types of stimuli: Arabic numbers, physical size, and duration of time. Most recently, studies have found that magnitudes of emotion in facial expressions are also organized in this left-to-right orientation in adults. In the current study, we investigated the existence of this left-to-right organization of degrees of emotional expression in children ages 3.5 - 6.5 years. Results suggest that children across this age range organize numerical magnitude from left-to-right, but only girls appeared to have marginal left-to-right organization of emotional expression. These findings suggest that spatial organization of numerical magnitude emerges early in development, but that there may be variation with respect to organization of emotional magnitude. The current study points to a possible gender difference concerning the mental representation of emotion that deserves further investigation.

Introduction

Children learn to use the term "more" at a relatively young age. Statements such as "More cookies!" or "I want more playtime!" become commonplace by the time a child learns to verbally communicate (Weiner, 1974). But at what point do humans actually truly understand this concept of relative quantity? Moreover, how do we mentally organize differences in quantity (i.e., magnitude)? In the process of investigating the development of these learning milestones, researchers have proposed the existence of a *generalized magnitude system* (Lourenco & Longo, 2010). In short, magnitude information of different types (e.g., number, physical size, and duration) is processed mentally in a common code. Magnitude as a relative "more than" or "less than" value is extracted from a variety of stimuli and represented abstractly in the mind.

Number

Converging behavioral evidence suggests that numerical representations are organized from left ("less than") to right ("more than") in space like numbers on a mental ruler. When presented with stimuli that vary in numerical magnitude (e.g., Arabic numerals), humans have a bias towards organizing the smaller numbers on the left side of mental space and the larger numbers on the right. In one study, Dehaene, Bossini, and Giraux (1993) found that parity (i.e., odd or even) judgments were faster when Western adults responded to smaller numbers (e.g., 1 and 2) on the left side of space and to larger numbers (e.g., 8 and 9) on the right, the so-called *SNARC* (Spatial-Numerical Association of Response Codes) effect. It has also been shown that people randomly generate smaller numbers when facing leftward and larger numbers when facing rightward (Loetscher, Schwarz, Schubiger, & Brugger, 2008). These findings suggest that numbers are mentally organized in increasing left-to-right orientation, similar to a ruler or numbers on a computer keyboard.

There is some debate as to the origin of this left-to-right mental orientation. If its development is based on experience, contact with certain stimuli that organize information from left to right might be a contributing factor. For example, exposure to reading from left to right, physical objects such as rulers or keyboards depicting numbers from left to right, and explicit counting from left to right may be at the root of this phenomenon. The experience-based development of left-to-right orientation hypothesis is supported in research done by Zebian (2005). In this study, adult Arabic monoliterates, English monoliterates, Arabic/English biliterates, and Arabic illiterates were asked to make same/different judgments of two Arabic numerals (e.g., 1 2) with one presented on the left side of the screen and the other presented on the right side of the screen. They found that adults who read Arabic (which is read from right to left) were faster and more accurate in their responses when the larger numbers were on the left side and the smaller numbers on the right side, suggesting a right-to-left organization of number (the reverse of that seen in Western culture).

These results suggest that the directionality of the mental number line may be related to the directionality of one's reading and writing systems. Thus, this left-to-right orientation may not emerge in children until their daily life activities are expanded to those of an academic nature (i.e., reading and writing). In accordance with Zebian's research, a previous study found a reliable "mental number line" only in elementary school children from 4th grade onward, suggesting perhaps that prolonged experience with reading is essential (Berch, Foley, Hill, & Ryan, 1999). More specifically, children in grades 2-4, 6, and 8 were asked to make parity judgments as in the case of Dehaene et al. (1993). With these judgments, only children from about 4th grade onward showed evidence of left-to-right orientation of number, performing more accurately and faster on the odd/even judgment task when smaller digits were on the left side of space and larger digits on the right side of space. However, it is possible that Berch and colleagues used a paradigm designed for adults that was not adjusted for the mental capacities of the younger participant sample. Children in grades 2-3 may not have a firm grasp of parity assignment and may not even understand what the terms "odd" and "even" refer to when applied to number. Yet, by the ages of 7 and 8, children have already begun reading from left-to-right, using rulers, studying basic addition/subtraction, and have been exposed to copious amounts of other cultural stimuli that arrange magnitudes from left to right. Therefore, younger children may also have a left-to-right orientation of number.

Limitations of the original study by Berch and colleagues have been addressed in more recent research and results have suggested the existence of a "mental number line" in children as young as 3.5 (Lourenco, Fernandez, & Addy, in prep; Opfer, Thompson, & Furlong, [2010]). For example, Opfer et al. (2010) showed left-to-right organization of number in 4-year-olds on a task that did not require knowledge of specific number concepts such as parity, thus adjusted for the mental capacities of the age group. In their task, they presented participants in the first condition with one box on the left of the child and one on the right of the child, each with seven compartments. The experimenter revealed a hidden object in one of the compartments of the left box while verbally numbering each compartment from left to right. The participants then had to find a similar object in the right box while receiving the same verbal numbering. In the second condition, children had to complete the same task with right-to-left verbal numbering. That is, the experimenter delineated the location of the hidden object by numbering each compartment from right to left. The researchers hypothesized that if children expect numbers to be organized from left-to-right, they will find the object more quickly and accurately in the first condition where the hidden object's location was specified via left-to-right verbal number delineation. As hypothesized, they found that children in the left-to-right condition performed more accurately and quickly than the children in the right-to-left condition. Thus, it seems even pre-literate children organize numerical information from left to right. Additionally, Opfer et al. suggest that the reason for the early development of this left-to-right organization may be due to repeatedly engaging in the physical action of counting from left-to-right.

More recently, Lourenco and colleagues (in preparation) created another age-appropriate task that tested the left-to-right orientation of non-symbolic number (e.g., arrays of objects) rather than of symbolic number (i.e., Arabic numerals). The task was modeled after the study of Loetscher et al. (2008) described above. Rather than having the participants produce random numbers, children were simply asked to choose a certain quantity when turning their heads either left or right. In this study, researchers presented children with two identical stuffed animals. One animal was placed on the participant's left side and the other animal was placed on the participant's right side. Participants were then presented with three pictures of a certain shape (circles, squares, or triangles) that increased in numerical magnitude (e.g., 2 circles, 4 circles, and 8 circles) (placed in front of the stuffed animal in either increasing or decreasing order). The participant was then asked to select which picture he or she wanted to give to the stuffed animal. In this way, participants were required to map numerical magnitude to the left and right side, and in doing so, naturally turned their heads rightward or leftward as in the case of Loetscher et al. (2008) to make a decision. Lourenco et al. found that children as young as 3.5 years of age choose smaller quantities for the stuffed animal positioned to their left and larger quantities for the stuffed animal to their right, indicating a left-to-right mental organization of number.

Generalized Magnitude Representation

Other studies suggest that the left-to-right mental organization of magnitude may not be limited to just number. In short, humans automatically extract numerical information or magnitude more generally from a variety of stimuli (e.g., duration of time), not just number, and organize it spatially. Mental space may be used to extract the abstract relational ideas of "more" and "less" regardless of the form in which they are presented (Lourenco & Longo, in press). Research with temporal information has found that duration is underestimated for left-side stimuli and overestimated for right-side stimuli (Vicario et al., 2008), and people are faster to respond to shorter durations with their left hands and to longer durations with their right hands (Vallesi, Binns & Shallice, 2008), suggesting left-to-right organization of increasing duration values. These findings beg the question as to whether other types of magnitudes are organized in the same way. The current study investigates the left-to-right organization of emotion in facial expressions.

Emotional expression is not as clearly defined as number in terms of "more" versus "less". In fact, many consider displays of emotion to be a more categorical variable (i.e. "happy" versus "sad") (Ekman, 1992). Relatively few studies have analyzed emotional expression in faces as a magnitude; that is, the degree of emotional expression. However, in one of those, researchers examined whether emotion degrees (or magnitudes) in facial expression within a category (i.e. "less" versus "more" happy; "less" versus "more" angry) might be mentally organized from left to right, like number (Holmes & Lourenco, in review). Even though magnitude of emotion within a category is not prototypically related to number such as duration of time, it may still be organized spatially in the mind. To test this, Holmes and Lourenco modeled their study after that of Dehaene et al. (1993), using facial expressions that ranged in degree of happiness and angriness. University undergraduates were asked to make male/female judgments rather than odd/even judgments. They found that participants responded increasingly faster on the right side of space as degree of happiness/anger increased, illustrating a left-to-right organization of degree of emotional expression. The researchers argued that this "emotion line" may borrow from the cognitive resources used in organizing numerical magnitudes. In the current study, I extend this work to children in order to pinpoint when and how such an "emotion line" begins to develop.

Evidence consistent with an association of emotional expression and the processing of magnitude comes from a recent study by Gil, Niedenthal, and Droit-Volet (2007). In this study, children were asked to estimate the duration of time of the presentation of several faces. They found that when children aged 3, 5, and 8 years were asked to estimate the presentation duration of an angry face (versus a neutral face) they overestimated duration for the angry face in comparison to the neutral face's estimate in all age groups. The authors argued that this overestimation of time for angry facial expressions was due to an inherent wiring that adapts humans and animals to accelerate the perception of time passing when anger is perceived. However, another possibility is that their results are confounded with perception of magnitude that is not unique to angry expressions alone. Children in their study could have paired longer duration with the face that had more expression due to a more general representation of more vs. less. Indeed, such cross-dimensional effects have been reported for several pairings of magnitude; for example, people are faster to judge which number is semantically larger when physical size is congruent (e.g., 2 7) vs. incongruent (e.g., 2 7) (Henik & Tzelgog, 1982). As in the case of this size congruity effect, the two dimensions of emotional intensity and temporal duration may become confused. The extraction of magnitude information from the angry faces may have influenced the perception of the magnitude of duration.

Current Study

We investigated whether happiness, as displayed in facial expression, is mentally organized in left-to-right orientation in comparison to number. Furthermore, we analyzed specific factors to advance our understanding of how and when a *generalized magnitude system* develops in children. Participants completed the same task as Lourenco at al. (in prep) with added face stimuli from the happy face trials in Holmes and Lourenco (in review). We hope to extend the findings in Lourenco and Holmes (in review) to a child population to begin to pinpoint when and how the "emotion line" begins to develop. We expected to find a left-to-right orientation of number in all children, but perhaps later-developing effects for emotional expression since there exists no cultural support for left-to-right orientation of emotional expression (i.e., we do not line up people in order of their degree of facial expression). Building off of Holmes and Lourenco (in review)'s theory that the organization of emotion magnitudes may borrow from the cognitive resources used in the organization of number, we expected that the left-to-right organization of number would be associated with the left-to-right organization of emotion (i.e., the more strongly left-to-right oriented with number a person is, the stronger left-to-right oriented with emotion she will be). Additionally, we hypothesized that certain variables such as age and cardinality (i.e., number knowledge) would be associated with a stronger left-to-right organization of number and perhaps even the organization of emotion (since emotion organization may borrow from number). With the findings of this study, we hope to gain a better understanding of the nature of magnitude representation, specifically how is comes to be spatially organized in the mind.

Method

Participants

Participants included 42 children (3.5- to 6.5-year-olds). One participant was dropped due to not meeting the age requirement. The remaining 41 participants (20 females: M_{months}=57.65, *SD*=8.76; 21 males: *M*=59.35, *SD*=9.57) were tested at the Spatial Cognition Lab of Emory University's Child Study Center (32) and at The Clifton Schools of Atlanta (9). The experiment took place on the floor of an enclosed room at both locations. At the Child Study Center, parents were permitted to observe from a seat positioned in the corner. Parents provided informed consent and demographic information before their child's participation. Participants were identified as 56.1% "Caucasian", 9.8% "Hispanic/Spanish/Latino", 17.1% "Black/African American", 14.6% "Two or more races", and 2.4% "Other". All children participated in a task to assess handedness; 78% of participants were right-handed. After completing all tasks, participants were compensated with a small gift. All procedures were approved by the Institutional Review Board (IRB) at Emory University.

Stimuli

Number stimuli were shapes (i.e., circles, squares, or triangles) presented on 13.5 cm by 10.5 cm note cards on a white background. Each array depicted three distinct quantities (circles=2, 4, 8; squares=3, 6, 12; triangles =5, 10, 20) (See *Table 1* for shape areas and perimeters and *Figure 1* for example array). Face stimuli (area=8.33 cm^2), also presented centrally on the same note cards with a white background, were from the NimStim Face Stimulus Set (Tottenham et al., 2009; see *Figure 2*). Images of six models (three male) each depicting three distinct expressions (which we labeled *happy*, *very happy*, and *extremely happy*) were selected based on validity scores for a total of 18 full color images. The *neutral* face from the original set (used by Holmes & Lourenco) was removed in order to more closely match the number trials. In addition, there is a question as to whether the neutral face would be considered part of the "happy" continuum of emotional facial expressions.

Procedure

Modeled after Lourenco et al. (in prep), the participants were introduced to stuffed animals and told that they would be playing a game with pictures. The stuffed animals were then placed to the left and right side of each child. Before the trials began, the experimenter moved one of the stuffed animals away from the participant so that he or she would remain focused on one of the sides. The participant was then presented with three picture sets of a certain shape (circles, squares, or triangles) that increased in number (i.e., 2, 4, 8 or 3, 6, 9 or 5, 10, 20 respectively) with each picture. The pictures were placed in either increasing or decreasing order between the stuffed animal and the participant. The participant was then asked to select which picture he or she would like to give to the stuffed animal (i.e., "Which picture does the panda want to play with?"). In this way, the participant naturally turned his or her head rightward or leftward as in the case of Loetscher, Schwarz, Schubiger, and Brugger (2008) to make a decision (see *Figure 3* for a diagram of this layout). The same procedure was repeated with the stuffed animal on the other side. The entire process repeated until all 6 trials of each picture set (a total of 12 trials so that all stimuli are presented on both the right and left sides) were completed.

Once the number stimuli trials were finished, the same basic procedure with the stuffed animals was employed with face stimuli. The experimenter presented one of the stuffed animals with three pictures of the same face ranging in degree of happiness (i.e., *happy*, *very happy,* and *extremely happy).* Then the participant was asked to choose which picture the stuffed animal would like to play with (i.e., "Who does the panda want to play with?"). Again, this was repeated until all 6 trials of different faces were completed (a total of 12 for both right and left sides). Twenty-three participants received the number task first and the remaining participants received the face task first.

The second task that the participants completed was the "Give-A-Number" task (Wynn, 1992) to assess participants' understanding of cardinality (i.e., number knowledge). The experimenter took one of the stuffed animals from the previous task and paired it with a box of blocks. The experimenter then asked the child to give the stuffed animal a certain number of blocks. Participants must understand the verbal label for a number (e.g., "two") and connect it to its conceptual meaning (e.g., two blocks). In the task, the participant was asked to give the stuffed animal two blocks and that number increased until either he or she gave the incorrect amount of blocks for two sequential numbers or reached the maximum number of 16.

Lastly, in order to assess whether children could accurately discriminate quantitative differences in the face stimuli used in our task, the experimenter administered a computer task using the E-Prime program (Psychology Tools Inc). The participant sat in front of a computer screen (39.6 by 19.1 cm). Once there, pictures of the faces from the NimStim Face Stimuli Set used in the Face task (described above) were presented in pairs of two (the same face with two different degrees of happiness) in a randomly generated order until all possible combinations of happiness degrees within each face model were presented (i.e., *happy* and *very happy*, *happy* and *extremely happy*, and *very happy* and *extremely happy*). The participant was asked to point to the happier face (i.e., "This is Nate. We saw him earlier. He's happy in both of these pictures, but where is he MORE happy?").

Results

When scoring the participants' choices from the sharing tasks, the number trials were assigned both absolute values (e.g. arrays of "2", "4", "8" assigned "2", "4" and "8" respectively) and rank values ("1", "2", "3", respectively). In the face trials, the degrees of happiness were assigned rank numerical scores, since facial expressions carry no corresponding absolute values. The *happy* face was given a numerical score of "1", the *very happy* face a score of "2", and *extremely happy* face a score of "3." To assess the existence of a left-to-right orientation of both number and facial expression, we examined the average right side score compared to the average left side score and calculated the difference for each participant. Therefore, if a participant has a left-to-right organization, they will have a higher average score for right-side choices and a lower average score for the left-side choices resulting in a positive difference score. To further understand the organization of different types of magnitude in this sample we looked at the number stimuli and face stimuli scores separately.

Number task

For the number task, the difference between the average right side choices and the average left side choices with both actual scores (e.g. circles: "2", "4", "8") and rank scores ("1", "2", "3") were compared using a one-sample t-test. As in Lourenco et al., the average difference compared to zero (which indicates no spatial organization) was M=1.27, SD= 2.63, which was statistically above chance responding [$t(40) = 3.11$, $p = .003$]. Therefore, left side choices are significantly lower than the right side choices, which suggest a reliable left-to-right orientation of number. The same results were obtained using rank scores. The average difference was statistically greater than zero (*M*=.27, *SD*= .54); $t(40) = 3.16$, $p = .003$, reflecting a significantly reliable left-to-right orientation of number in rank values as well (see *Figure 4*). To test whether the layout of sheets (between-subjects: ascending vs. descending order), the starting position of the stuffed animal (between-subjects: left vs. right), or the order of stimulus presentation (between-subjects: number vs. face trials first) had any effects or interactions with our findings, we ran a between-subjects 2 x 2 x 2 ANOVA. There were no statistically significant main effects or interactions for layout of sheets [$F(1, 39) = .675$, MSE = .184 $p < .4$], starting position of the animal [$F(1, 39)=3.631$, MSE=.989 $p < .07$], or the order of stimuli presentation [$F(1, 39)=2.298$, MSE=.626 $p < .1$]. Thus, as predicted and displayed in previous research, our results confirm that from early in development, children represent number in left-to-right orientation.

Face task

As in the Number task, difference scores were computed for the face trials. As noted above, only rank scores were possible for face trials; thus, each degree of happiness was assigned a rank score ("1", "2", "3"). Difference scores were computed by subtracting average left-side choices from average right-side choices and were compared in a one-sample t test. The average difference was not statistically greater than zero (*M*=.07, *SD*= .79); $t(40) = .589$, $p = .559$, indicating that the mean difference between right and left choices was not significantly above chance responding. Therefore, left side choices are not significantly lower than the right side choices, which suggest no consistent orientation of emotional expression. Again, to see if the layout of sheets (between subjects: ascending and descending order), the starting position of the stuffed animal (between subjects: left and right), or the order of stimuli presentation (between subjects: shapes first versus faces first) had any effects or interactions with our findings, we ran a between-subjects 2 x 2 x 2 ANOVA between the variables. There were no statistically significant main effects or interactions for layout of sheets [$F(1, 39)=1.863$, MSE=1.260 $p < .182$], starting position of the animal [$F(1, 39)=.526$, MSE=.356 $p < .473$], or the order of stimuli presentation [$F(1, 39)=1.588$, MSE=1.074 $p < .216$].

Gender analyses

Despite a nonsignificant effect for gender in the face task [$F(1, 39)=1.281$, MSE=.804 $p < .265$], an abundance of research suggesting gender differences in face processing and emotion recognition (LoBoe & DeLoache, 2009; McBain, Norton, & Chen, 2009) motivated us to separate the difference scores by gender. Subsequently, analyses of the difference scores on the Face task for girls [M=.22, SD= .55; $t(18) = 1.773$, $p = .092$)] and boys [(M=-.06, SD= .97); $t(19) = -.300$, $p = .767$)] indicated that there may be some dissimilarity (see *Figure 5*). This analysis suggests a marginally significant effect for girls. More specifically, girls might tend to organize degrees of happiness from left-to-right, as is the case for number. In contrast, there was no reliable effect for boys.

This possible gender difference on the Face task, prompted us to look more closely at the Number task to see whether gender difference existed there as well. In a closer analysis of the Number task, boys' average difference between left and right was significantly above chance responding [(M=.27, SD= .39); $t(20) = 3.179$, $p = .005$] whereas girls' average difference score was only marginally above chance and also more variable. [(M=.27, SD= .68); $t(19) = 1.752$, $p = .096$]. Additionally, we split results by gender to explore these possible gender differences in the organization of degrees of emotion in the follow-up analyses listed below.

Follow-up Analyses

In order to address our supplement hypotheses, we looked into other factors such as the strength of one's left-to-right orientation of number in relation to the left-to-right orientation of faces, participants' age, and number knowledge (i.e., cardinality, as assessed by the "Give a Number" task) and we split them by gender. Lastly, to further investigate the emerging gender difference concerning the left-to-right organization of emotion, we analyzed participants' accuracy of discriminating between degrees of happiness (as assessed by the discrimination task described above).

In order to assess whether left-to-right orientation (i.e., a positive difference score) of number is at all associated with left-to-right orientation (i.e., a positive difference score) of face stimuli, we ran Pearson correlations across both tasks for boys [$r(19)=-.048$, $p = .836$] and girls [$r(18)=.139$, $p =.558$]. These results suggest that left-to-right orientation of number is not associated with left-to-right orientation of emotional expression in either gender. Thus, if one is left-to-right oriented for number, it does not appear to influence organization of emotional expression.

Similarly, we ran Pearson correlations to see if the age of the participant was related to either the number stimuli left-to-right orientation or the face stimuli left-to-right orientation. In boys, the results suggest that age is positively correlated with the left-to-right orientation of number [$r(19)=.494$, $p < .023$], but not faces [$r(19)=-.231$, $p < .314$]. This indicates that as boys get older, they become more left-to-right oriented with number but not with degrees of emotional expression in faces. Interestingly, in girls, the results suggest that there is no correlation between age and left-to-right orientation of magnitudes for either number [$r(18)=-.209$, $p < .377$], or emotional expression [$r(18)=-.145$, $p < .541$]. We also ran Pearson correlations to see whether number knowledge was associated with number left-to-right orientation or emotion left-to-right orientation. In boys, the results suggest that number knowledge is leaning towards a significant correlation with the left-to-right orientation of number [$r(19)=.352$, $p < .118$] but not with emotion[$r(19)=-.271$, $p < .234$]. Thus, a higher number knowledge score was associated with a stronger left-to-right organization of number but not emotion. Conversely, the girls' results suggest that number knowledge is not correlated with left-to-right orientation of number [$r(18)=-.176$, $p < .457$]. However, girls have a marginally significant negative correlation between number knowledge and left-to-right orientation of emotion [$r(18)=-.409$, $p < .073$], suggesting that the more left-to-right oriented they are with the faces, the poorer they perform on the number knowledge task.

Lastly, we analyzed children's responses on our discrimination task, in which they were asked explicitly to judge which of two faces depicted greater happiness. As noted above, we included this task to understand how the sample participants perceive the presented degrees of happiness in faces. In a one-way ANOVA, with gender of participants as a between-subjects variable and accuracy as the dependent variable, we found no significant effect of gender, [$F(1, 39)=.331$, MSE=.020 $p < .5$]. This suggests that accuracy on the degree of emotion discrimination task did not differ as a function of gender. In short, one gender was not significantly more accurate than the other (boys: $M=.76$, $SD=.259$; girls: $M=.71$, $SD=.230$). Additionally, according to results of a Pearson correlation between mean accuracy on the discrimination task and left-to-right orientation of happiness in faces, there was no significant association between the two [$r(39)=-.152$, $p < .348$]. This indicates that accuracy on discrimination task is not associated with a higher difference score in faces. Thus, it appears that higher accuracy in discriminating differences in degrees of happiness does not necessarily mean one will have a left-to-right organization of those degrees, regardless of gender.

For an even closer analysis of how participants understand happiness in the faces of others and its application to left-to-right magnitude organization, we looked at the individual response accuracies on certain face pairings. Specifically, in our discrimination task, each model has three pairs (i.e., *happy* face versus *very happy* face; *very happy* face versus *extremely happy* face; *happy* face versus *extremely happy* face; see *Figure 7*) and the accuracy for each pairing across faces may shed light on how children understand differences in quantitative degrees of facial expression. When these faces were used in Holmes and Lourenco's study with adults, a separate group of participants assigned ratings from 1-7 (1="neutral expression", 7= "very emotional expression") to each expression of happiness across the face models (6 models in total). Mean ratings for the three expressions were 3.35 (*happy*), 4.67 (*very happy*), and 5.98 (*extremely happy*), giving us a more psychologically valid measure of the perceived emotional magnitude in each facial expression. Additionally, the differences between the expression ratings indicate a psychological distance between each degree of happiness of approximately 1.3 (i.e., 4.67-3.35=1.32; 5.98-4.67=1.31) (in review).

Interestingly, across the six faces, children in this study were most accurate on the *happy* versus *very happy* pairing (M=4.73, SD=1.48; psychological distance of 1.3) rather than the assumedly easier pairing of *happy* versus *extremely happy* pairing (M=4.39, SD=1.82; psychological distance of 2.6) (see *Figure 6)*. Theoretically, the faces with the greatest psychological distance (i.e., *happy* versus *extremely happy*) should be the easiest to discriminate. Likewise, the pairings of *happy* (3.35) versus *very happy* (4.67) and *very happy* (4.67) versus *extremely happy* (5.98) both have differences of about 1.3 and therefore should be equally difficult to discriminate. However, participants performed least accurately on the *very happy* versus *extremely happy* pairing (*M*=4.05, *SD*=1.76). Paired samples t-tests comparing mean accuracies for the pairings reveal that the pairings with a distance of 1.3 (*happy* versus *very happy*; *very happy* versus *extremely happy*) are not equally difficult. Additionally, the accuracy of the pairing with the largest distance (*happy* versus *extremely happy*) was not significantly different when compared to either of the 1.3 degree of difference pairings. Again, in comparing the *very happy* versus *extremely happy* and the *happy* versus *extremely happy* pairing we found no significant differences in accuracy between the two pairings (see *Table 2* for corresponding statistical values).

In summary, these analyses suggest that participants' accuracy in discriminating degrees of happiness does not follow the predicted pattern. More specifically, the accuracy scores on this discrimination task do not correspond with the psychological distance ratings provided by adults. This suggests that not all children are representing faces along the continuum from less happy to more happy in the same way as adults did in the Holmes & Lourenco study (in review). Therefore, since the children in this sample are viewing the degrees of happiness differently, this may have affected their performance on the task for left-to-right organization of emotion.

Discussion

"More" or "less" observations pervade almost every aspect of life. "Can I get some *more* coffee, please?" "I'll be done with my homework in *less* than two hours." "Doesn't she look *happier* in this picture?" Past research suggests that in order to make these "more" or "less" judgments, individuals convert magnitude information into a common code and organize it spatially in the mind (Lourenco & Longo, in review). Moreover, there is evidence in adults that numerical representations are organized in our minds by increasing magnitude in left-to-right order (Dehaene et al., 1993; Loetscher et al., 2008). Additionally, some research suggests that magnitude code information from less prototypically number-related stimuli (e.g., degrees of happiness) may "borrow" from number's organization and consequently is also oriented spatially in our minds from left-to-right (Holmes & Lourenco, in review). Yet, while past research has indicated that even children as young as 3.5 years organize number in left-to-right orientation (Lourenco et al., in prep), the generalizing of other types of magnitudes into a left-to-right orientation has not been tested in a child population.

To address this paucity of information regarding how the generalizing of magnitudes develops in children, the primary goal of this research was to test whether the left-to-right organization of number generalizes to other types of magnitudes in a preschooler/early elementary child population. More specifically, do children organize degrees of emotion from left-to-right as they do for number? Additionally, we investigated the possible relationship between number left-to-right organization and emotion left-to-right organization to further our understanding of the hypothesized capacity of magnitudes to "borrow" from number organization. Lastly, we analyzed certain variables that may be associated with left-to-right organization of number (age and number knowledge) to investigate possible factors in the development of left-to-right organization of magnitudes.

Although our work replicated previous studies in showing that pre-literate children organize number from left-to-right, in regards to the generalizing of emotion into a left-to-right orientation, the results are less conclusive. Across genders there was no significant left-to-right organization of emotion. There are several possible reasons for this finding. Perhaps extracting magnitude information is more difficult than number, as Holmes and Lourenco initially hypothesized (in review). While examples of number organization from left-to-right in everyday life are constant (e.g., rulers, keyboards), degrees of emotion are not often lined up in left-to-right order in cultural contexts. For example, less happy people do not orient themselves to the left of happier people. For this reason, it may take much longer to develop a left-to-right organization of emotion. Also, perhaps a slightly older sample would produce more significant results.

In investigating the association of left-to-right organization of number and left-to-right organization of emotion, our results indicated no observable relationship. If the organization of other types of magnitudes "borrows" from our left-to-right organization of number, it is logical to infer that a stronger left-to-right organization of number would be associated with a stronger left-to-right organization of emotion. However, our results suggest no such relationship. These results are consistent with Holmes and Lourenco's reanalysis of data (in review). They found that in adults, despite the presence of left-to-right organization in both number and degrees of emotion, there was no consistent association between the two. This may be due to a unique feature of left-to-right organization of different magnitudes. Perhaps, once an individual reaches a "threshold" level of number left-to-right organization, the ability to organize other types of magnitudes from left-to-right becomes activated. Thus, no matter how far past the "threshold" an individuals' number organization exceeds, the strength of the emotion organization is not affected. Another possibility is that emotion does not borrow from our organization of number and that left-to-right organization may develop independently within each system of magnitudes.

In analyzing the relationship between age and either left-to-right orientation of number or emotion, the only statistically significant finding was concerning boys' age and left-to-right organization of number. At least in this sample, and in this age group, as boys get older, they become more left-to-right oriented with number. It was expected that as children get older they gain more experience with number and therefore become more left-to-right oriented. One reason that girls may not display the same association is they may strengthen more gradually over age and a sample of this size may not have been powerful enough to pick up the more subtle strengthening of left-to-right organization over time. If analyzed in a larger sample and across a larger age range, the girls' left-to-right organization of emotion may show more noticeable developmental increases in strength.

As described above, to further investigate the development of magnitude organization, we examined whether number knowledge was associated with left-to-right orientation of number or of emotional expression. Concerning the left-to-right organization of number, boys have an association with number knowledge that approached statistical significance ($p < .118$). This suggests that the more numbers for which they can connect verbal meaning to conceptual meaning, the more left-to-right oriented they are with respect to number. In our number knowledge task, children must display an explicit understanding of the differences in magnitude of number (e.g., they understand that six blocks in quantitatively more than four blocks). Thus, it is logical that a better understanding of number magnitudes would lead to a stronger left-to-right organization of number. Concerning left-to-right organization of emotion, the only significant finding was that girls had a marginally significant negative correlation between number knowledge and left-to-right orientation of emotion. In short, the more left-to-right oriented they are with emotion, the poorer they performed on the number knowledge task. The reason for this marginal association remains unclear and may in fact be just a random occurrence. Thus, future research should attempt to replicate this finding. One possible explanation it that at this stage in development, children have limited cognitive capacities. Various researchers have proposed that mental resources are allocated to certain operations involved in processing, retaining, and reporting information (Bjorkland & Harnishfeger, 1990). Perhaps at this point in development, female children do not have enough cognitive resources to be simultaneously proficient in certain domains of learning (emotional perception vs. number knowledge). If more cognitive resources are dedicated to organizing emotion more efficiently, the remaining mental resources may be insufficient in improving their counting ability. Thus, the girls who have a stronger tendency to organize degrees of emotion from left-to-right may be using the cognitive space limiting that needed to perform well on the number knowledge task. Yet, this does not explain why the same is not true for the boys in this sample. Clearly, this relationship should be investigated in future research to see if it truly exists.

Possible Gender Difference

While our findings concerning gender as a function of left-to-right organization of emotion are not statistically significant, we would argue that that the girls' scores may be moving towards a marginal left-to-right organization of emotion degrees (p = .092). We propose that these findings imply that girls may develop a left-to-right organization of emotion before boys. Much research suggests that girls are more sensitive and accurate than boys in detecting specific categories of emotion in early stages of life (LoBoe & DeLoache, 2009) and adulthood (McBain, Norton, & Chen, 2009; Montagne et al., 2005). For example, in Montagne and colleagues' study, they presented college-aged adults with video clips of neutral faces gradually morphing into full-blown emotional expressions. The participants were asked to label the emotion (accuracy) at the earliest point in which they perceived it (sensitivity). In short, they not only named an emotion, they pinpointed when the face moved from an emotional intensity of zero to a perceivable magnitude of emotional expression. Of interest to the current study, the researchers found that males needed significantly higher intensities of emotion (particularly with sadness and disgust) in the faces in order to accurately label the presented emotion. With this is mind, perhaps females, even from an earlier stage in life, have a higher sensitivity to the degrees of emotion that allows for a left-to-right organization of those degrees. It is possible this higher sensitivity to degrees of emotion was not observable from the current study's computer discrimination task due to a lack of difficulty. Perhaps the task was too easy and was thus unable to detect subtle variations in participants' degree of emotion differentiation.

Limitations

This study contained some limitations. The discrimination task did not produce the predicted results which were that the children would view the continuum of happiness magnitudes in the same way as adults. Perhaps in future research, researchers could include a face set that has children's rankings of the magnitude of emotion displayed in the face. Also unexpectedly, the discrimination accuracy was not associated with any left-to-right organization of emotion. As mentioned above, this may have been because the discrimination task was not difficult enough and therefore was unable to pick up a subtle relationship between understanding emotional magnitudes and organizing them left-to-right. Additionally, accuracy scores on certain pairings were surprising (i.e. children did not score most accurately on the pairing of *happy* vs. *extremely happy*). Anecdotally, two of the participants mentioned that the *extremely happy* face was "scary" or "looks like he/she is yelling." This may suggest that children do not perceive the *extremely happy* face as falling under the category "happy" and this may have affected their choices for the test of left-to-right organization. Future researchers may want to test whether these limitations are unique to the current study's face stimuli (NimStim Face Set) or also displayed in other commonly used emotional expression face sets. If the latter proves true, it may inform us on how children differ from adults in their processing of intensities of emotion. Additionally, research into whether these abnormal distance effects fade with age would also be informative.

Yet, despite these unexpected distance effects, this research not only replicates previous findings of a left-to-right organization of number in pre-literate children, it also suggests that young girls may organize emotional information from left-to-right. We argue that the generalizing of degrees of emotion into a common code could be at least partially developed in girls by first grade. Despite the less prototypical nature of emotion, it appears that even at a very young age, girls might be extracting magnitude information from faces and mentally aligning it into left-to-right orientation. Further research might benefit from examining this possible gender difference and the factors associated with it (i.e., the negative association in girls between number knowledge and left-to-right organization of emotion). In order to further our knowledge of a *generalized magnitude system* and its applicability to other types of magnitudes, it would be useful to examine left-to-right organization of other emotion categories (e.g., sadness, anger, surprise) and even other stimuli types (e.g., intensity of light, pitch, or loudness).

In conclusion, our research tentatively supports Lourenco and Longo's theory of a *generalized magnitude system* with which we extract magnitude information from a variety of different sources and arrange it spatially in our minds (in review). Mental space in which one can arrange different forms of magnitudes into an adaptable "mental number line," may be a vital component to human's processing of complex information. For example, Lourenco et al.'s study suggests that stronger left-to-right organization of number is associated with higher scores on standardized math tests (in prep). Could the same association be found between left-to-right organization of emotion and a corresponding ability (e.g., social skills)? Future studies may want to include a measurement of children's social skills (e.g., teacher's ratings on a child's interpersonal interactions in the classroom) to examine the relationship between a left-to-right organization of emotion and specific social abilities. While specific outcomes are untested as of yet, the development of this processing tool in children may predict success in both academic and social worlds. Thus, a child's understanding of "more" versus "less" gains new importance and meaning.

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References

Berch, D. B., Foley, E. J., Hill, R. J., & Ryan, P. M. (1999). Extracting parity and magnitude from Arabic numerals: Developmental changes in number processing and mental representation. *Journal of Experimental Child Psychology, 74*, 286-308.

Bjorkland, D. F. & Harnishfeger, K. K. (1990). The resources construct in cognitive development: Diverse sources of evidence and a theory of inefficient inhibition. *Developmental Review, 10,* 48-71.

Dehaene, S., Bossini, S., & Giraux, P. (1993). The mental representation of parity and number magnitude. *Journal of Experimental Psychology*, *122,* 371-396.

Ekman, P. (1992) An argument for basic emotions. *Cognition and Emotion, 6,* 169-200.

Gil, S., Niedenthal, P. M., & Droit-Volet , S. (2007). Anger and time perception in children. *Emotion, 7,* 21119-2225.

Henik, A. & Tzelgog, J. (1982). Is three greater than five: The relation between physical and semantic size in comparison tasks. *Memory & Cognition*, *10,* 389-395.

Holmes, K. J., & Lourenco, S. F. (in review). Common spatial organization of number and emotional expression: The mental magnitude line. *Psychological Science.*

LoBue, V. & DeLoache, J. (2009). On the detection of emotional facial expressions: Are girls really better than boys? *Behavioral and Brain Sciences*, *32*, 397-398.

Loetscher, T., Schwarz, U., Schubiger, M., & Brugger, P. (2008). Head turns bias the brain's internal random generation. *Current Biology, 18,* R60-R62.

Lourenco, S., Fernandez, E., & Addy, D. (in prep).

Lourenco, S. F., & Longo, M. R. (In Press). Origins and development of generalized magnitude representation. In E. Brannon & S. Dehaene (Eds.), *Space, time, and number: The origins of mathematics*. Elsevier Press.

Lourenco, S. F., & Longo, M. R. (2010). General magnitude representation in human infants. *Psychological Science, 21,* 873-881.

McBain, R., Nortion, D., & Chen, Y. (2009). Females excel at basic face perception. *Acta Psychologica,* 168-173.

Montagne, B., Kessels, R. P. C., Frigerio, E., de Haan, E. H. F., & Perrett, D. I. (2005). Sex differences in the perception of affective facial expressions: Do men really lack emotional sensitivity? *Cognitive Processing, 6,* 136-141.

Opfer, J. E., Thompson, C. A., & Furlong, E. E. (2010). Early development of spatial-numeric associations: evidence from spatial and quantitative performance in preschoolers. *Developmental Science, 13,* 761-771.

Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., … Nelson, C. (2009). The NimStim set of facial expressions: Judgments from untrained research participants. *Psychiatry Research, 168,* 242-249.

Vallesi, A., Binns, M. A., & Shallice, T. (2008). An effect of spatial-temporal association of response codes: Understanding the cognitive representations of time. *Cognition, 107,* 501-527.

Vicario, C. M., Pecoraro, P., Turriziani, P., Koch, C., Caltagirone, C., & Oliveri, M. (2008). Relativistic compression and expansion of experiential time in the left and right space. *PLoS ONE, 3,* e1716.

Weiner, S. L. (1974). On the development of more and less. *Journal of Experimental Child Psychology*, *17,* 271-287.

Wynn, K. (1992). Children's acquisition of the number words and the counting system. *Cognitive Psychology*, *24,* 220-251.

Zebian, S. (2005). Linkages between number concepts, spatial thinking, and directionality of writing: The SNARC effect and the reverse SNARC effect in English and Arabic monoliterates, biliterates, and illiterate Arabic speakers. *Journal of Cognition and Culture, 5*, 165-190.

Table 1

Areas (cm^2) and Perimeters (cm) of Number Stimuli

	Cumulative Surface Area	Cumulative Perimeter	Average Area
Blue Circles 1	2.52984	12.68222	1.26492
Blue Circles 2	2.51968	16.99006	0.62992
Blue Circles 3	2.52476	22.41296	0.31496
Red Circles 1	2.55016	12.76096	1.27508
Red Circles 2	5.10032	25.52192	1.27508
Red Circles 3	10.20064	51.04384	1.27508
Blue Squares 1	2.55524	17.4752	0.852424
Blue Squares 2	2.63652	24.1808	0.43942
Blue Squares 3	2.60858	32.4104	0.217678
Red Squares 1	3.21818	19.812	1.07315
Red Squares 2	6.4389	39.624	1.07315
Red Squares 3	12.8778	79.248	1.07315
Blue Triangles 1	2.54254	25.527	0.508508
Blue Triangles 2	2.53746	35.5854	0.253746
Blue Triangles 3	2.57302	49.16424	0.128778
Red Triangles 1	3.175	28.956	0.635
Red Triangles 2	6.35	57.912	0.635
Red Triangles 3	12.7	115.824	0.635

Table 2

Paired Sample T Tests Between Face Pairings' Accuracy

	Happy versus *Very Happy* (Distance=1.3)		*Very Happy* versus *Extremely Happy* (Distance=1.3)		*Happy* versus *Extremely Happy* (Distance=2.6)	
Happy versus *Very Happy* (Distance=1.3)	-	-	*t*	*p*	*t*	*p*
			2.537	.015*	-1.534	.133
Very Happy versus *Extremely Happy* (Distance=1.3)	-	-	-	-	1.594	.119

*Indicates significantly different at the .05 level

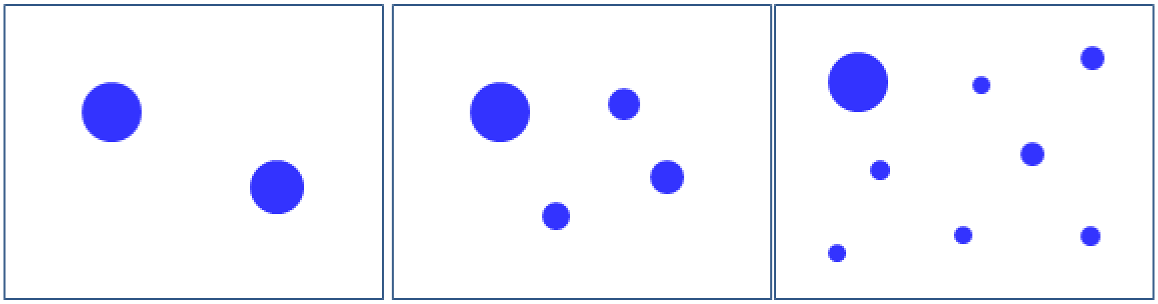

Figure 1. Number Stimuli Array Example. This figure gives an example of the stimuli used in testing the left-to-right organization of number.

Happy *Very Happy* *Extremely Happy*

Figure 2. NimStim Face Set Example. This figure gives a sample face set used in the testing of left-to-right organization of happiness.

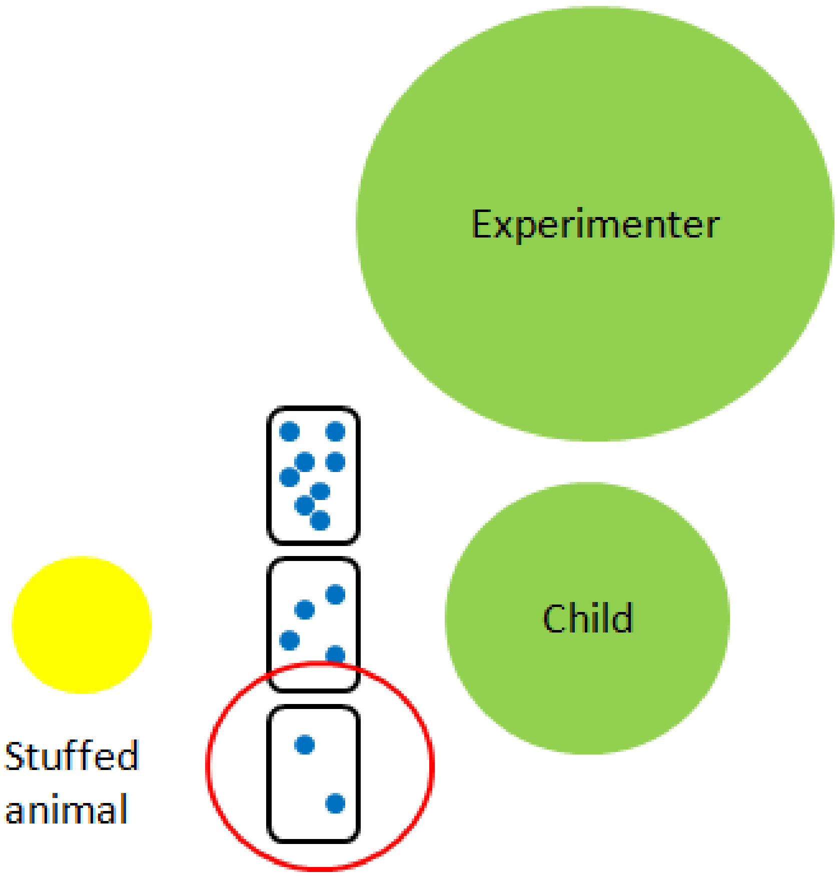

Figure 3. Procedure Setup. This figure illustrates the general set up of the experiment. The child faces the experimenter and must turn his head towards the stuffed animal to choose a quantity. We expect that they will choose smaller quantities on average when choosing for the left stuffed animal.

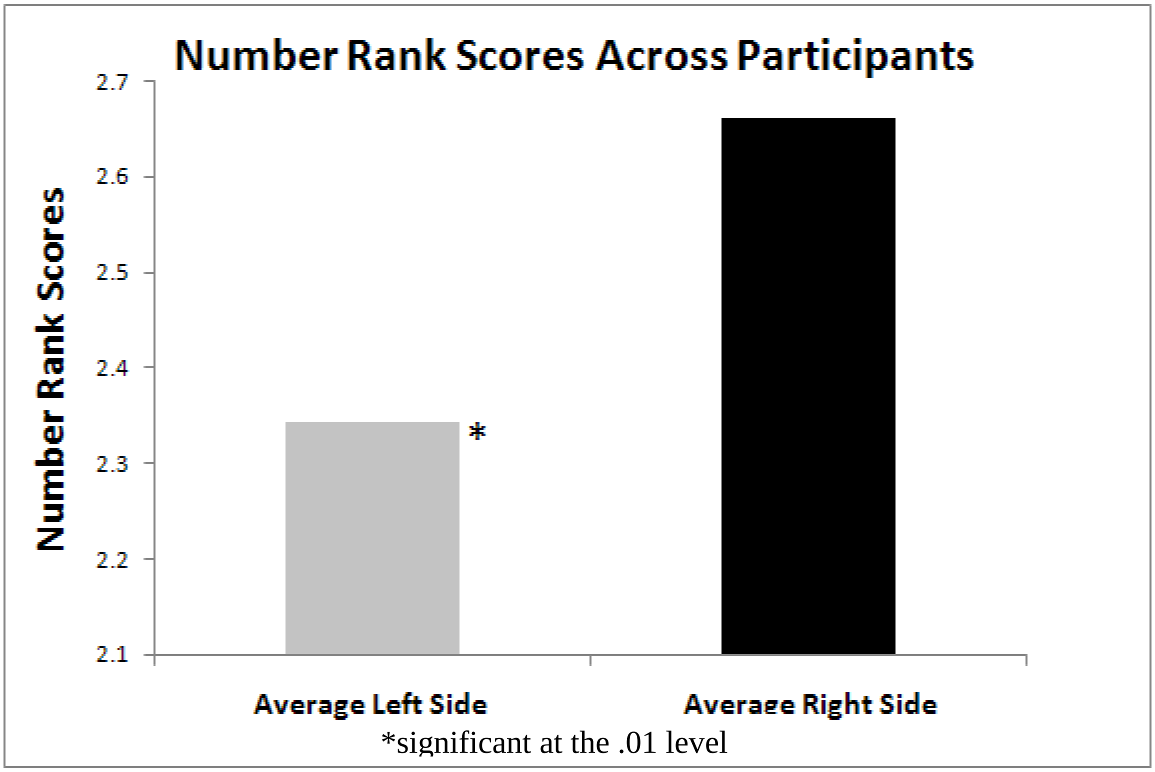

Figure 4. Children have Left-to-Right Organization of Number. This figure illustrates that average left-side choices are significantly lower than average right-side choices with number stimuli, thus number is left-to-right oriented in this sample [(*M*=.27, *SD*= .54); *t*(40) = 3.16, *p* = .003].

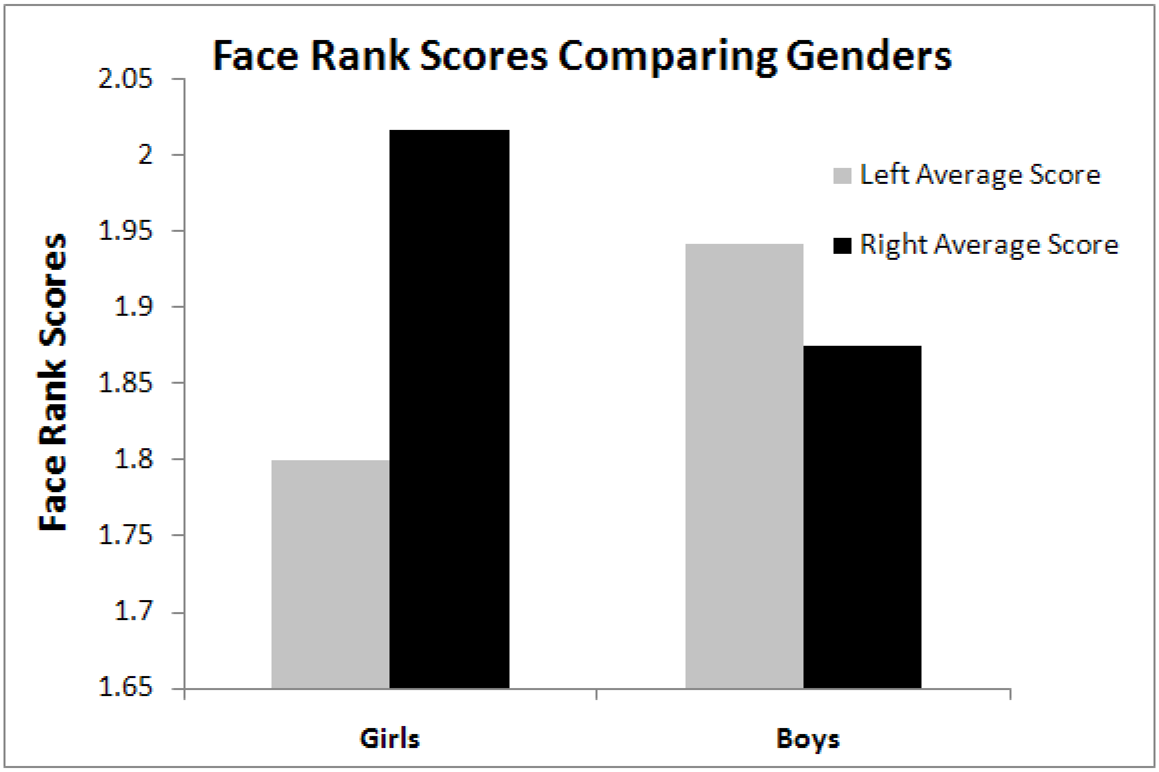

Figure 5. Girls Display Some Left-to-Right Organization of Emotion. Females differences between left-side choices and right-side choices for degrees of happiness: [(*M*=.22, *SD*= .55); *t*(18) = 1.773, *p* = .092] and males: [(*M*=-.06, *SD*= .97); *t*(19) = -.300, *p* = .767].

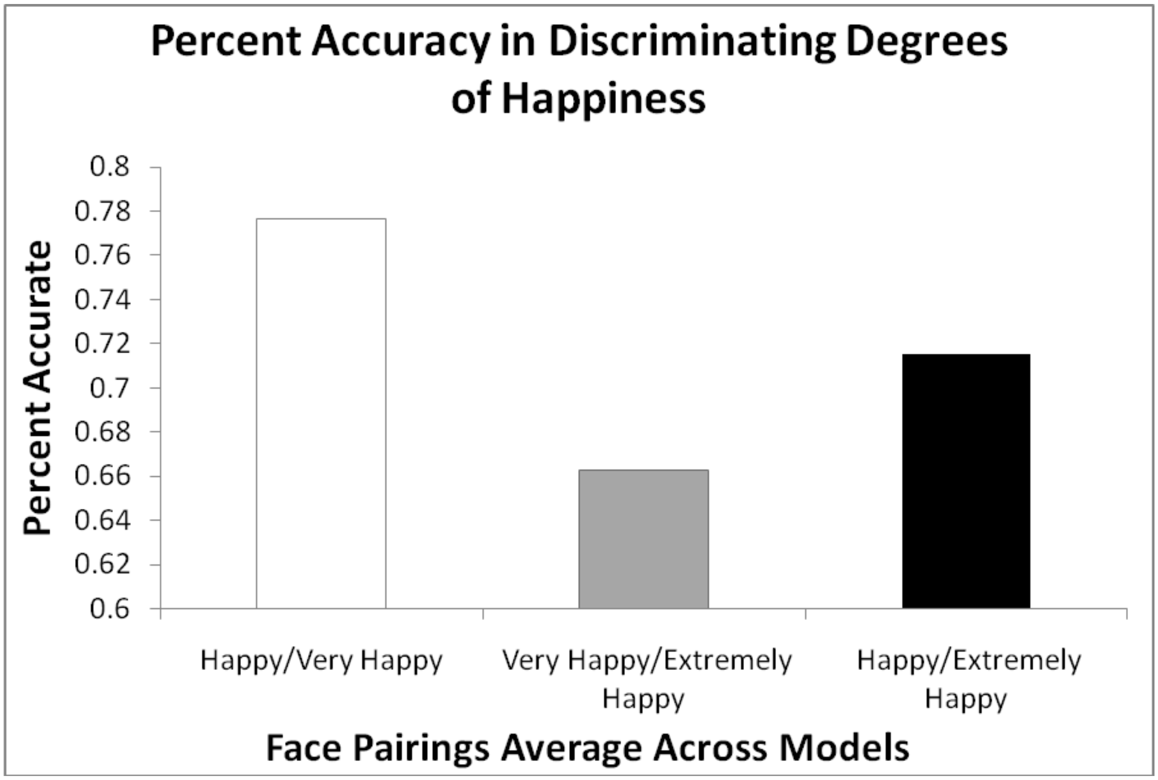

Figure 6. Discrimination Task Results. This figure displays how participants were most accurate at discriminating Happy from Very Happy and least accurate at discriminating Very Happy from Extremely Happy.

Figure 7. Pairings in Happiness Discrimination Task. This figure demonstrates the three possible pairings (one pairing per row) employed to test participants’ magnitude of emotion discrimination ability.