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# A Developmental Neuroscience Study of Moral Decision Making Regarding Resource Allocation

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Distinguishing between equity and equality is essential when making social and moral decisions, yet the related neurodevelopmental processes are unknown. Evaluations of contextually based third-party distributions incorporating recipient need and resource importance were examined in children and adolescents ($N$ = 82; 8–16 years). Spatiotemporal neurodynamic responses show distinct developmental profiles to viewing such distributions. Event-related potentials (ERPs) differentially predicted real-life behaviors based on age, where older children's (8–10 years) evaluations were related to a fairly rapid, automatic ERP component (early posterior negativity), whereas adolescent and preadolescent (11–16 years) evaluations, first-person allocations, and prosocial behaviors were predicted by later, cognitively controlled ERP components (P3 and late positive potential). Together, these results reveal age-related changes regarding the neural responses that correspond to distributive justice decisions.

Overcoming personal self-interest to benefit others through helping, sharing, and distributing resources has evolved in humans to an extent unseen in other species and has led to greater reciprocity, justice, and equity across cultures (Tomasello & Vaish, 2013). Natural selection has promoted the cognitive architecture to support these abilities to facilitate cooperation with and sensitivity to the needs of others (Platt, Seyfarth, & Cheney, 2016). Hence, decision making in social contexts plays a pivotal role in regulating and facilitating prosociality and moral behavior. An extant body of research has closely examined children's distributive justice and sharing behaviors from very early childhood through late adolescence, revealing the ontogenetic trajectory of resource allocation decisions. Taken together, the findings from these studies have revealed a general age-related pattern of resource allocation understanding. In most distributive justice contexts, young children (3–6 years of age) display egalitarian orientations, desiring to divide resources equally (Cooley & Killen, 2015; Kenward & Dahl, 2011; Olson & Spelke, 2008). With age, as contextual variables are introduced, such as scarce resources, in-group and out-group dynamics, effort, and disadvantaged status, children ages 7–9 years will distribute on the basis of both equity and merit (Olson, Dweck, Spelke, & Banaji, 2011; Rizzo, Elenbaas, Cooley, & Killen, 2016; Sigelman & Waitzman, 1991). When distributing equally is not an option, and children are forced to decide between giving to an advantaged versus a disadvantaged other, children as young as 4 will choose distributions that favor those who have less. When asked to share resources (at a cost to the self), children manifest analogous but delayed behavioral patterns —the preference for equality is strongly demonstrated in children age 7 or older compared to those 6 and under (Blake & McAuliffe, 2011; Fehr, Bernhard, & Rockenbach, 2008), and the act of allocating more to a person with greater need develops after, although the age in which one finds such a

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difference varies (Enright et al., 1984; Kienbaum & Wilkening, 2009).

Thus, these studies suggest that with age, children progressively develop the ability to flexibly update their view of what is fair when they choose to incorporate relevant contextual information. Furthermore, the results of Sigelman and Waitzman (1991) indicate that in certain situations even older children may choose equality, yet these same children may allocate equitably when the resources are very important for the recipients. Two studies on the developmental trajectory of how 3- to 8-year-old children incorporate the value of a resource (necessary or luxury) and the relative need of a recipient when making decisions about resource allocation found that children developed the ability to differentiate between necessary and luxury resources when allocating to a hard working character such that younger children gave more based on merit for both types of resources, but older children only took merit into account for luxury not necessary resources (Rizzo & Killen, 2016; Rizzo et al., 2016). Furthermore, the relative need of more than one potential recipient must be considered if attempting to allocate or donate based on equity. Over the course of development, children learn to incorporate such contextual information into their decisions about equity and equality (Killen, Elenbaas, & Rutland, 2016). There is mounting evidence that as children approach adolescence, they begin to integrate key contextual information on the recipient's need into their social decision making, yet the neural underpinnings and the computations involved in these decisions remain unknown.

A link between "other-regarding preferences," such as fairness, and prosocial behaviors has been documented in infants (Schmidt & Sommerville, 2011), children (Fehr et al., 2008), and adults (Dawes, Fowler, Johnson, McElreath, & Smirnov, 2007). One measure of ecologically valid prosocial behavior is the online game Free Rice, which allows individuals to donate rice to impoverished countries in return for answering questions correctly. This measure has been used to assess volunteerism, charitable giving, and prosocial behavior in adults (DeVoe & Pfeffer, 2010), and is a valuable tool given its real-world implications. Although it has not been used previously with children ages 8–16 years, the questions were adaptive and appropriate for children. Recent neuroscientific studies have also provided a correspondence between electrophysiological responses to social evaluation and prosocial dispositions and behaviors (Chiu Loke, Evans, & Lee, 2011; Cowell & Decety, 2015a), suggesting the existence of neural markers of these behaviors that may, in turn, relate to fairness and resource allocation decisions.

Developmental neuroscience research provides insight into the ontogeny of behavioral changes documented in childhood and the type of computations involved in resource allocation decisions. In preschool children, the rudimentary processing of the prosocial and antisocial actions of others is constructed from both immediate reactions and slower cognitively controlled appraisals (Cowell & Decety, 2015a). These slower appraisals may reflect the interpretation of the context of scenarios, integrating more complex cues with immediate responses and subsequently guiding children's own behavior. This last point is supported by findings that individual differences in the late positive potential (LPP; event-related potentials [ERPs]) when perceiving prosocial actions versus antisocial actions directly predict children's own sharing behaviors (Cowell & Decety, 2015a). Moreover, new evidence from developmental neuroscience work with infants and toddlers suggests that these slower ERP components that index cognitive appraisal and integration of context are also modulated by early parental views on justice. Children who showed the greatest midlatency differences in neural processing of prosocial versus antisocial actions tended to have parents who exhibited higher levels of sensitivity to injustice for others (Cowell & Decety, 2015b). Importantly, evidence for the role of both rapid and controlled responses in the processing of morally laden scenarios is not limited to young children. Atypical early and late ERP responses to harmful actions have been demonstrated in adolescents with a history of early childhood social deprivation relative to age-matched controls (Escobar et al., 2014). Thus, the time course of neurophysiological responses provides important insights into processing of sociomoral behaviors from infancy through adolescence.

During childhood and adolescence, a number of social-cognitive changes occur as a result of neural gray and white matter maturation. Functional MRI studies of age-related improvements in theory of mind (Moriguchi, Ohnishi, Mori, Matsuda, & Komaki, 2007), empathic responding (Decety & Michalska, 2010), and understanding moral situations (Decety, Michalska, & Kinzler, 2012) show a critical role of the developing prefrontal cortex (PFC) and posterior superior temporal sulcus. The desire to act prosocially and give to others is closely tied to the development of these social-cognitive abilities providing a neurobiological explanation for this shift from equality to the consideration of others' need, effort, and merit. The general ability to incorporate contextual information can be viewed through the lens of children's neurobiological development. Neuroimaging studies have contributed to understanding the importance of structural development (gray-to-white matter ratios), functional changes (recruitment of different neural regions based on task), and effective connectivity that influence children's improving cognitive abilities. Although decreases in gray matter density (a measure of the development of the cerebral cortex) are found throughout development, maturation does not occur across the entire brain simultaneously or even linearly (Giedd et al., 1999). Lower-level association areas show a decrease in density much earlier in development than regions such as the superior temporal gyrus, posterior parietal cortex, and PFC that reflect higher-order cognitive processes and executive function (Gogtay et al., 2004). This occurs in conjunction with gradual increases in white matter density through increased myelination and resulting in selectively strengthened neural connections (Paus, 2011). Regions associated with increasing cognitive control and executive function develop later than low-level association regions and limbic regions implicated in emotional processing (Sowell et al., 2003). These structural changes are complemented by an array of functional changes and effective connectivity in patterns of neural activation that can be demonstrated when children are presented with tasks associated with moral reasoning (Decety et al., 2012), executive function (Luna & Sweeney, 2004), and emotion regulation (McRae et al., 2012), which similarly show increasing activation in cognitive control areas and pathways over those involved in emotional processing. Neuroimaging studies that have focused on adolescence as a time of significant functional development of the social brain characterized by heightened self-consciousness increased importance and complexity of peer relationships and an improved understanding of others (Blakemore, 2008).

To examine the neural and computational mechanisms related to children's sociomoral decisions about equity versus equality in resource allocation, event-related potentials (ERPs) were measured in participants required to judge third-party distributions of necessary and luxury resources. Drawing on Rizzo et al.'s (2016) study, necessary resources were those that are essential for the functioning of the place receiving the items. In contrast, luxury resources are those that were enjoyable to have but not required for the places in the community to be able to serve their patrons. Furthermore, extending findings from Elenbaas, Rizzo, Cooley, and Killen (2016) as well as Olson et al. (2011) that young children take into account disadvantaged status when allocation resources, targets were identified as having a high or low need or resources (rich or poor), which would call for equity not equality responses. Equity responses that involve rectifying an inequality has been interpreted as reflecting a more complex judgment than strict equality given that the latter approach may result in an "unfair" allocation as it perpetuates a disadvantaged state for one group over another. ERPs provide information about the time course of neurophysiological responses to stimuli, and the strength of such responses yield insights into the psychological processes involved in these decisions. Furthermore, ERPs are a useful method to examine how social context becomes incorporated in social judgments of others' distributing behaviors, as well as determining the relative salience of a given distribution. Finally, ERPs can serve as neurophysiological markers of individual differences in predicting resource allocation decisions and prosocial behaviors. Several ERP components of various latencies are of particular interest to this study. Relatively early components (200–300 ms poststimulus onset) such as the early posterior negativity (EPN) or P2 are considered to reflect fairly automatic processing of a stimulus with adult samples. The posterior EPN has been implicated in rapid preferential attention, particularly to stimuli with affective connotations (Schupp, Flaisch, Stockburger, & Junghöfer, 2006), especially when the stimulus valence is positive (Weinberg & Hajcak, 2010). Further evidence for a positivity bias in the EPN comes from a recent study with children, which finds a more negative EPN response to helping versus harming situations (Cowell & Decety, 2015a). A middle-latency component, the P3, typically occurs from 300 to 500 ms poststimulus, has been shown to respond preferentially to stimuli that are particularly salient, and can be influenced by top-down processes such as task demands (Duncan-Johnson & Donchin, 1977) as well as the inherent motivational value or emotional content of a stimulus (Kestenbaum & Nelson, 1992). Finally, the LPP, which usually follows the P300 response and occurs around 500–1,000 ms, is implicated in elaborative evaluation of valenced (positive or negative) material in both adults (Hajcak, MacNamara, & Olvet, 2010) and children (DeCicco, Solomon, & Dennis, 2012). Like the P300, the LPP can be modulated by cognitive control and is sensitive to task demands (Hajcak, Moser, &

Simons, 2006), can reflect appraisal strategies (Babkirk, Rios, & Dennis, 2015), and is strongest to affective over neutral stimuli (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000). In examining the full neural time course–early (EPN or P2), middle (P3), and late (LPP) components, we can examine the extent to which distributive justice evaluations and decisions are made in response to automatic, visceral neural responses, or deliberate and controlled ones. It may also provide information on whether equitable or equal distributions are the most emotionally evocative and motivationally important to children and adolescents.

The primary goal of this study was to determine the neurophysiological mechanisms that relate to children's and adolescents' evaluations of third-person distributions that incorporate both recipient need and resource importance. The examination of electrophysiological responses allows for a greater understanding of the connections between physiological and psychological processes that underlie the evaluations and first-person decisions, which remain an important yet uninvestigated area of interest. ERPs examining the timing of the neurophysiological response to viewing third-person distributions were recorded to determine when this contextual information is incorporated and whether the strength of the responses to various distributions differs by age. Based on prior work that found a stronger egalitarian bias in children versus adolescents (Sigelman & Waitzman, 1991), it was hypothesized that children (8–10 years old) would show larger, preferential ERP responses to equal distributions, relative to the preadolescents and adolescents (11–16 years). Furthermore, it was predicted that with increasing time and depth of processing, children and adolescents would show differentiation between necessary and luxury resources, as contextual information such as resource importance should require a certain level of cognitive, top-down input that is found in later windows (Hajcak et al., 2006).

A number of recent neurodevelopmental studies have linked electrophysiological responding while viewing morally laden or empathy-evoking situations to children's actual sharing behaviors (Cowell & Decety, 2015a), as well as prosocial preferences (Cowell & Decety, 2015b) and antisocial dispositions (Cheng, Hung, & Decety, 2012). This study relates children's neural responses during third-party judgments of distributive justice decision with their own behaviors when asked to make first-person allocations and third-person evaluations, as well as when acting prosocially. It was hypothesized that children who would demonstrate greater ERP responses to equal distributions would be more likely to rate equal distributions more positively and allocate resources equally. It was also expected that the neural responses predicting actual behaviors would differ based on age with adolescents' decisions predicted by a later, more cognitively controlled ERP component. This proposed effect is based on studies showing greater cognitive control in decision-making tasks in adolescents versus children (Zelazo & Carlson, 2012) and has been attributed in part to the increased development of the PFC during this time (Hooper, Luciana, Conklin, & Yarger, 2004). A final goal of this study was to use these neural and behavioral measures to gain an overall more comprehensive picture of how children and adolescents evaluate and make decisions about contextually based resource allocations and how they change with age from late childhood through adolescence. Based on previous behavioral research (Rizzo et al., 2016), it was hypothesized that in first-person decisions, children would differentially allocate resources to the various recipients based on the necessity of the resource. It was also predicted that the actual allocation decisions within each type of resource (whether to give equally or more to poor or rich), based on behavioral research by Elenbaas et al. (2016) and Olson et al. (2011), would show a developmental effect, with the adolescents better incorporating contextual information into their decisions to move away from strict equality. Together, the results of the neurodynamic responses, behavioral evaluations, first-person decisions, and real-life prosocial actions should form a more complete and precise picture of the mechanisms related to developmental behavioral changes in a contextualized resource allocation paradigm.

## Method

### *Participants*

Eighty-two children and adolescents between the ages of 8 and 16 years ($M_{age}$ = 11.6, $SD$ = 2.62, 45 females; 39% European American, 34% African American, 10% Latino, 4% Asian, and 13% bi- or multiracial) were recruited from a large Midwestern city and run through the study from May 2015 to October 2015. Participants' socioeconomic status (SES), as measured by household income, ranged from $25,000 to $200,000. Age groups examined were children (8–10 years of age) and preadolescents or adolescents (11–16 years of age). There were no significant SES differences between the older child and the preadolescent or adolescent age groups. Parents of all participants provided written informed consent and children provided verbal assent to study participation. The study was approved by the University of Chicago Institutional Review Board.

### *Procedure*

After arriving at the laboratory, parents completed demographic reporting about their child and themselves. Participants were set up with a 32-channel electroencephalogram (EEG) cap (EasyCap; Brain Products, Gilching, Germany) and once impedances were below 30 kΩ, the Resource Allocation Game began while EEG was recorded continuously. Following the game, the EEG cap was removed and participants completed a follow-up questionnaire related to the Resource Allocation game, a short survey to assess pubertal status (Pubertal Development Scale; Petersen, Crockett, Richards, & Boxer, 1988), and were given the option of playing the Free Rice Game.

### *Resource Allocation Game*

The resource allocation game was designed to examine how children take into account important contextual information while evaluating third-person resource distributions. Contextual information such as the importance of a resource—whether it is a "necessary" resource that is essential for the functioning of the place (e.g., books in schools, drinking fountains in parks) or a "luxury" resource that is deemed as nice to have but not essential (e.g., candy in schools, birdfeeders in parks)—was included in this task, using language established in previous research with children (see Rizzo et al., 2016). To examine how the need of the recipients would shape children's decisions, the resources were distributed between a place that was described as very poor and not having most of the things it needs, and a place that was described as rich and already having most of what it needs, drawing on previous research with children concerning resource allocation with advantaged and disadvantaged groups (Elenbaas et al., 2016), and as described next.

In each block of this game, children were shown pictures of schools or buildings that looked dilapidated or wealthy (poor vs. rich) and a description of the two resources (referred to as "gifts") that corresponded to that set of places. All children were told that one place "is poor and did not have many of the things it needs" and one "is rich and does have most of the things it needs." They were also informed that the people of the community were giving these gifts to these places and the child's job was to decide if they gave the gifts the way they should have or not. They were asked to watch carefully as two gifts were distributed (both to the poor place, both to the rich place, or equally) and decide if the people of the community did a good job of giving the gifts. Children could respond "yes," they did a good job, "no" they did not, or they could say "maybe" if they could not decide or were not sure. Before starting a block of trials, children were asked if they could identify the poor place and the rich place on the screen, and describe which gift was very important, which was not, and why.

For each trial, children were first presented with a fixation cross that lasted 1,000 ms, and then pictures of the two places appeared side by side on the screen for 1,000 ms. The two gifts being given appeared in the center of the bottom half of the screen for 1,000–1,500 ms before they both appeared below the poor place, below the rich place, or one below each. ERP responses were time locked to the viewing of the distributions, which was jittered to last between 2,000 and 2,500 ms. Subsequently, the response screen appeared, and lasted for 5 s or until the child made his or her response on the keyboard.

Each block of 36 trials was divided into two smaller blocks with a break halfway through, where the rich and poor places switched sides. There were seven total places (train station, school, church, park, hospital, fire department, and playground) included in the task for a total of 252 trials, or 42 of each of the six conditions. All six conditions were presented in a completely randomized order with equal numbers of trial type within each smaller block.

### *First-Person Allocation Task*

Directly following the resource allocation game, the EEG cap was removed and children were asked to play a game called "What would you do?" where they made a first-person decision about how to allocate the resources. Children were presented with each of the situations they had viewed in the resource allocation game and told that now it was their turn to decide how they would give the gifts. For each of the seven places, children were reminded of which was rich and which was poor, and that one of the gifts was important, one was not important, and why this was so. For each resource type (necessary, luxury) they were asked to decide whether they would give both of the gifts to place A (poor place), give one to each place, or give both gifts to place B (rich place). The decision of how to give for each resource type was defined as the most commonly chosen response across all seven places.

### *Free Rice Game*

To assess prosocial and giving behaviors, participants were invited to play the online game, Free Rice (www.freerice.com), after they completed the first-person allocation task and filled out the Pubertal Development Scale. Children were told that there is a game where they can answer questions online and for every answer they get right, rice is donated to people who live in poor countries that cannot afford food. They were also told that it was completely up to them if they want to play or not, and it was okay either way. Children who opted to play were told they could play for as long as they liked, and were instructed to let the researcher know when they wanted to stop. Children were stopped after 15 min if they did not elect to do so themselves, and the time played was recorded by the researcher.

### *EEG Data Acquisition and Analysis*

EEG data were collected from a 32-channel active electrode system (actiCHamp; Brain Products) at 2 kHz, online referenced to electrode Cz, and all impedances were kept below 30 kOhms. Electrophysiological data analysis was performed using Brain Vision Analyzer 2 Software (Brain Products, Gilching, Germany). Statistical analyses were performed using SPSS Statistics (IBM; Armonk, New York). All comparisons were based on a specific a priori hypothesis, and as such, an alpha level of .05 was accepted.

Data were down-sampled offline to 256 Hz and referenced to the average of the two mastoid sensors. EEG data were then filtered using an infinite impulse response (IIR) band-pass filter of 0.1–30 Hz and a notch of 60 Hz. Ocular artifact correction was performed using the Gratton–Coles method (Gratton, Coles, & Donchin, 1983), seeded off electrode Fp1. Artifact rejection was carried out with a −200 to 200 μV threshold, as well as via visual inspection and rejection by trained researchers. Data were then segmented according to stimulus condition type. Epochs were created with a 200-ms prestimulus baseline and extended 1,500-ms poststimulus onset, timed-locked to the distributions. Epochs were baseline corrected and averaged by trial type. ERP averages per individual were combined for each trial type to create grand averages for each of the six conditions. Based on visual inspection of the data and prior research on cognitively and emotionally based ERP components (Hajcak et al., 2010; Schupp et al., 2006), we focused our analysis to three ERP components. The early occipital EPN component was examined from 200 to 300 ms (examined at electrode Oz). The central P3 (at Cz) was analyzed in a 300–500 ms time window, and finally, both midline (at Pz) and lateralized (at P3 and P4) LPPs from 500 to 1,000 ms.

## Results

### *Behavioral Results*

The behavioral results are provided first, followed by the neurophysiological findings, and a relation between them. Results are given across and within age groups (defined by a median split: older children [8–10 years] and preadolescents or adolescents [11–16 years]) as initial analysis of first-person allocations of necessary resources appeared to be influenced by age, both as a continuous measure ($r = .21$, $p = .06$) and particularly when examined as a function of a median split, Exp($B$) = 0.22, $p = .01$.

### *Actual Allocation Decisions*

When asked how they personally would allocate necessary resources, half of the children ($N = 41$) most frequently chose to give both resources to the individuals in the poor places, and half chose to give equally. For the luxury resources, 16 children chose to give both to those in the poor places, 63 chose to give equally, and 3 children chose to give both to those in the rich places (Table 1).

A Wilcox signed-rank test was performed to test the hypothesis that children differentially allocate necessary versus luxury resources. The results showed that the resource type was significantly related to children's allocation responses ($z = 3.881$, $p < .001$), with a greater tendency to give equally in the luxury condition than in the necessary condition, with the decision to distribute necessary resources to the poor group. A binomial logistic regression was run to examine the effects of age on the decision to give equally or both to poor for each resource type. Age did not significantly predict allocation decisions for necessary resources, Exp ($B$) = 0.926, $p$s = .37, or for luxury resources, Exp ($B$) = 0.977, $p$s = .99.

Table 1
*Number of Children in Each Age Group That Chose a Given Allocation Strategy*

| | Necessary resources | | | Luxury resources | | |
|---|---|---|---|---|---|---|
| | 8–10 years old | 11–16 years old | All | 8–10 years old | 11–16 years old | All |
| Both to poor | 16 | 25 | 41 | 8 | 8 | 16 |
| Equal | 24 | 17 | 41 | 31 | 32 | 63 |
| Both to rich | 0 | 0 | 0 | 1 | 2 | 3 |

*Task-Based Responses*

To test if children evaluated third-person resource allocations differently based on whether the resource was necessary or a luxury, a 2 (resource type) × 3 (distribution) × 2 (age group) analysis of variance (ANOVA) on the mean rating of each condition was performed. Mean ratings ranged from −1 (all ratings for a condition were "No," not a good job) to 1 (all ratings were "Yes"). Ratings of "Maybe" were given a value of 0. The results showed a main effect of resource type, $F(1, 79) = 16.25$, $p < .001$, $\eta_p^2 = .17$, with distributions of necessary resources ($M = 0.16$, $SD = 0.34$) rated as better than those of luxury resources ($M = -0.03$, $SD = 0.3$). There was also a main effect of distribution, $F(2, 78) = 177.85$, $p < .001$, $\eta_p^2 = .82$, with equal ($M = 0.63$, $SD = 0.41$) rated more positively than both-to-poor distributions ($M = 0.19$, $SD = 0.57$; $p < .001$) and none-to-poor distributions ($M = -0.61$, $SD = 0.41$, $p < .001$), and both to poor rated better than none to poor ($p < .001$). A significant interaction of resource type and distribution, $F(2, 78) = 8.94$, $p < .001$, $\eta_p^2 = .19$, showed that although there were no differences in ratings of none-to-poor allocations based on resource type (*p*s = .61), resource type did influence ratings of equal distributions, $t(80) = 3.01$, $p = .004$, Cohen's $d = 0.67$, and ratings of both-to-poor distributions, $t(80) = 5.51$, $p < .001$, Cohen's $d = 1.23$. In both cases, allocations involving necessary resources (equal: $M = 0.71$, $SD = 0.42$; both to poor: $M = 0.38$, $SD = 0.67$) were rated more positively than ones involving luxury resources (equal: $M = 0.54$, $SD = 0.47$; both to poor: $M = 0.00$, $SD = 0.64$). Additional post hoc *t*-tests of the relative difference between ratings of necessary and luxury resources for a given distribution showed that there was a greater difference in necessary over luxury resources for both-to-poor distributions ($M = 0.54$, $SD = 0.73$) than for equal distributions, $M = 0.33$, $SD = 0.91$; $t(80) = 2.904$, $p = .005$, Cohen's $d = 0.65$; Figure 1. Furthermore, the ANOVA yielded a significant three-way interaction, $F(2, 78) = 3.27$, $p < .05$, $\eta_p^2 = .077$. Post hoc *t*-tests showed that ratings within none-to-poor distributions did not differ based on resource type or age. However, in equal distributions, the 8- to 10-year-old group showed a significant difference between necessary ($M = 0.72$, $SD = 0.37$) and luxury ($M = 0.49$, $SD = 0.43$) resources, $t(38) = 3.08$, $p = .004$, Cohen's $d = 1.0$, but the 11–16 years of age group did not (*p*s = .19). In addition, *t*-tests between the two groups did not yield significant differences in any conditions (all $p > .23$) except both-to-poor distributions of necessary resources. The older group ($M = 0.53$, $SD = 0.58$) rated these distributions significantly better than did the younger group, $M = 0.21$, $SD = 0.72$; $t(79) = 2.15$, $p = .034$, Cohen's $d = 0.48$.

*Relations Between Behavioral Measures*

To examine whether third-person evaluations of distributions (task-responses) predicted actual first-person allocation decisions, a binomial logistic regression was performed for each resource type. The mean response average for both-to-poor distributions was subtracted from that for equal distributions, and this was used to predict whether a participant gave equally or gave both to the poor place. In necessary resources, third-person evaluations were significantly related to the actual allocation decisions, Exp(*B*) = 6.24, $p < .001$, 95% CI [2.66, 14.64]. In luxury resources, evaluations also predicted these allocation decisions, Exp(*B*) = 2.81, $p < .05$, 95% CI [2.81, 6.52].

When analyzed across the entire sample, no relation was found between first-person allocation decisions and the measure of prosocial behavior, that is, time spent playing the charitable giving game, Free Rice (*p*s = .34). However, when the binomial logistic regression was performed within age groups, longer Free Rice time was associated with giving both necessary resources to the poor in the older group, Exp(*B*) = 0.88, $p < .05$, 95% CI [0.77, 0.99], but there was no such relation in the younger (*p*s = .35).

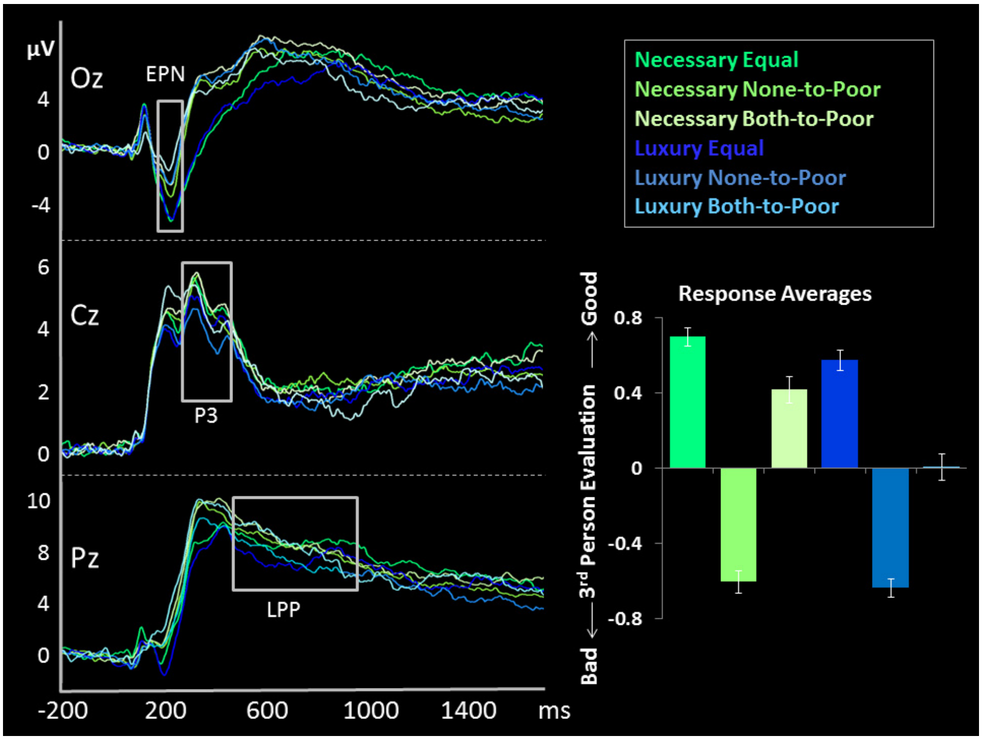


*Figure 1.* Equal distributions evoke the largest responses in the early component (EPN) but become attenuated at later (P3, LPP) windows. (left) Grand average ERP waveform for the EPN component at Oz (top), the P3 component at Cz (middle), the LPP component at Pz (bottom) for each of the six conditions (equal, none-to-poor, and both-to-poor distributions for necessary and luxury resources), and the corresponding online ratings of each of the conditions (right) where higher ratings are more favorable. [Color figure can be viewed at wileyonlinelibrary.com]

### *Electrophysiological Results*

To investigate developmental changes in ERP responses to these conditions, a series of correlations were conducted on EPN, P3, and LPP times window difference waves. These correlations suggested significant age-related change in several components, including the EPN and P3 (see Supporting Information). To further detail age-related differences in the neural processing of resource distribution and subsequent behaviors and evaluations, a median split of age (see above) was entered into subsequent analyses. A 2 (resource type) × 3 (distribution) × 2 (age group) ANOVA was performed on the participants' mean amplitude ERP averages for each condition.

#### *Early ERP Window*

The results of the ANOVA for the EPN component (200–300 ms at sensor Oz) showed a main effect of distribution, $F(2, 76) = 24.53$, $p < .001$, $\eta_p^2 = .392$, but resource type and the resource by distribution interaction were not significant (Figure 1). The EPN response was greater for equal distributions ($M = -4.24$, $SD = 4.44$) than both to poor ($M = -1.63$, $SD = 3.42$; $p < .001$) and none to poor ($M = -1.98$, $SD = 3.54$; $p < .001$). There was a main effect of age split, $F(1, 77) = 9.18$, $p < .005$, $\eta_p^2 = .107$, with children (8- to 10-year olds; $M = -3.74$, $SD = 3.29$) demonstrating an overall greater EPN than preadolescents and adolescents (11- to 16-year olds; $M = -1.57$, $SD = 3.08$). In addition, there was a trending interaction of age split and distribution, $F(2, 76) = 2.88$, $p = .062$, $\eta_p^2 = .071$. Post hoc *t*-tests showed that this interaction was related to a greater EPN to equal over the alternative distributions in the younger group than in the older group, none to poor: $t(77) = 2.06$, $p = .043$, Cohen's $d = 0.47$; both to poor: $t(77) = 2.37$, $p = .021$, Cohen's $d = 0.54$. When examined at lateral sensors, the ANOVA left-sided O1 showed the same significant distribution ($p < .001$) and trending age by distribution effects ($p = .06$) as Oz, and the main effect of distribution ($p < .001$) was similarly found at O2.

#### *Middle ERP Window*

The ANOVA for the central P3 component (300–500 ms at sensor Cz) yielded a significant main effect of resource type only, $F(1, 77) = 5.80$, $p < .05$, $\eta_p^2 = .070$, with necessary resources ($M = 4.46$, $SD = 3.44$) evoking a greater P3 response than luxury ones ($M = 3.98$, $SD = 2.84$; $p < .01$; Figure 1). This analysis also showed a trending effect of age split, $F(1, 77) = 3.95$, $p = .05$, $\eta_p^2 = .049$, where the older group's P3 response ($M = 4.95$, $SD = 3.75$) was overall greater than the younger ($M = 3.46$, $SD = 2.81$) and a significant age split by distribution interaction, $F(2, 76) = 6.68$, $p < .005$, $\eta_p^2 = .149$. The interaction was illustrated by the older group exhibiting a greater P3 response to none-to-poor over equal distributions, $t(77) = 3.51$, $p = .001$, Cohen's $d = 0.80$, and to both-to-poor over equal distributions, $t(77) = 2.87$, $p = .005$, Cohen's $d = 0.66$, than the younger group did.

*Late ERP Window*

In the midline LPP (500–1,000 ms at sensor Pz), there was a significant main effect of resource type, $F(1, 77) = 4.93$, $p < .05$, $\eta_p^2 = .06$, with necessary resources ($M = 6.89$, $SD = 4.41$) again eliciting a greater response than luxury ones ($M = 6.28$, $SD = 4.5$; Figure 1). The left-lateralized LPP (at sensor P3) showed an effect of distribution, $F(2, 76) = 7.17$, $p < .005$, $\eta_p^2 = .159$, where both-to-poor distributions ($M = 6.22$, $SD = 4.61$) produced a larger LPP response than none-to-poor ($M = 5.48$, $SD = 3.97$, $p = .011$) and equal ($M = 4.41$, $SD = 5.05$; $p < .001$) distributions, and none to poor also greater than equal ($p = .027$). The right-lateralized counterpart (at sensor P4) also showed an effect of distribution, $F(2, 76) = 9.01$, $p < .001$, $\eta_p^2 = .192$, also exhibiting the pattern of both to poor ($M = 5.75$, $SD = 3.97$) greater than none to poor ($M = 5.06$, $SD = 4.07$, $p = .016$) and equal ($M = 4.08$, $SD = 4.82$, $p < .001$), and none to poor greater than equal ($p = .041$). Furthermore, the LPP at P4 showed a significant effect of resource type, $F(1, 77) = 4.87$, $p < .05$, $\eta_p^2 = .059$, with necessary resources ($M = 5.30$, $SD = 3.97$) eliciting a larger LPP than luxury resources ($M = 4.63$, $SD = 4.05$). No age-related interactions were found in these LPP windows.

*Relation Among Age, ERPs, and Behavioral Measures*

As the early and mid-latency ERP components differed strongly by age, we sought to further investigate these age-related differences and carried out correlations between ERP responses and behavioral and dispositional measures within age groups. The ERP measures for each window examined were differences in mean amplitude between equal and none-to-poor distributions (equal greater than none-to-poor ERP component) and the differences between equal and both-to-poor distributions (equal greater than both-to-poor ERP component). The e-prime response used (third-person evaluations of distributions) was also a difference score of the rating for an equal distribution minus the rating for a both-to-poor distribution (equal greater than both-to-poor evaluation). Total time spent playing Free Rice (not playing [0 min]–maximum time [15 min]) was examined to determine if ERPs or behaviors predicted prosocial behaviors. For actual allocation decisions, binomial logistic regressions were performed with allocation decision (both to poor or equal) predicted by the ERP difference waves or behavioral measures.

The EPN response was predictive of the e-prime (third-person) evaluation of distributions in the younger group but not in the older group. In the 8- to 10-year olds, the greater (more negative) equal over both-to-poor EPN for necessary resources was related to more favorable equal over both-to-poor evaluations for resources that were necessary ($r = -.338$, $p = .038$), and when collapsed across resources ($r = -.340$, $p = .037$). Because the EPN is a negative deflection, the negative correlations actually represent greater EPN responses—suggesting that the more pronounced the 8- to 10-year olds' EPN to equal distributions, the more likely they were to endorse equal distributions over both-to-poor distributions (Figures 2 and 3). No significant correlations were found in the 11- to 16-year-old group (all $p > .14$). Comparisons of the correlational analyses also showed that the significant relations found in the 8- to 10-year olds' EPN were significantly different from those of the 11- to 16-year olds' ($z = 2.37$, $p = .009$ and $z = 2.2$, $p = .014$, respectively).

The P3 component was not related to any behaviors in the younger group (all $p > .46$) but did predict both third-person evaluations and actual allocation decisions in the older group, as well as Free Rice time. The equal greater than both-to-poor difference for necessary resources was positively associated with a higher rating of an equal over both-to-poor evaluation with necessary resources ($r = .309$, $p = .049$). This correlation was significantly greater than that of the 8- to 10-year olds ($z = 1.65$, $p = .043$). This P3 difference for unequal versus equal distributions of necessary resources also significantly predicted a greater likelihood of a first-person equal allocation of necessary resources versus giving both to poor, Exp($B$) = 0.627, $p = .012$, 95% CI [0.47, 0.97]. Finally, the P3 for unequal versus equal distributions of necessary resources predicted time spent playing

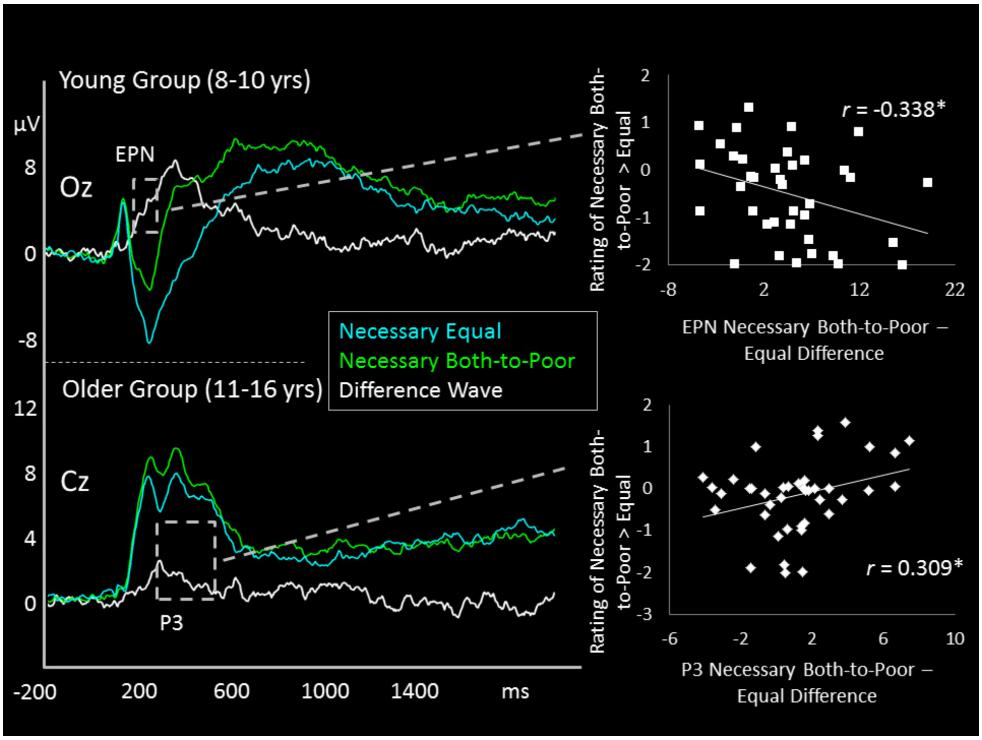


*Figure 2.* Positive evaluations of equal distributions of necessary resources are predicted by larger ERPs to necessary equal over both-to-poor distributions, but the children's (top) responses are predicted by earlier, more automatic, and visceral responses (EPN) compared to the adolescents and preadolescents later P3 responses (bottom).
**p* < .05. [Color figure can be viewed at wileyonlinelibrary.com]

Free Rice ($r$ = .318, $p$ = .043, Figures 2 and 3) and showed a trending difference from that relation in the 8- to 10-year olds ($z$ = 1.54, $p$ = .062). As a whole, these results indicate that the greater P3 to unequal over equal distributions of necessary resources predicts: a less favorable evaluation of necessary resource equal distributions, a greater likelihood of giving both necessary resources to the poor place, and a longer amount of time spent acting prosocially, using time spent on the Free Rice game as a metric. In the midline LPP, relations were found between difference wave amplitudes and Free Rice time in the older group only. Specifically, greater LPP amplitudes for unequal (average of both to poor and none to poor) over equal distributions of necessary resources positively predicted Free Rice time ($r$ = .375, $p$ = .016), and although no relation was found in the younger group ($p$s = .36), the two correlations were not significantly different overall ($z$ = 1.06, $p$s = .14).

## Discussion

Although children's relative judgments and actions regarding distributive justice have been the subject of investigation for decades (Damon, 1977; Turiel, 2002), recently, a renewed interest has emerged regarding the contextual factors that contribute to children's decision making regarding distributions based on equity (distributing according to need or effort) and equality (distributing evenly; e.g., Blake & McAuliffe, 2011; Fehr et al., 2008; Killen & Smetana, 2011). One primary finding has been that children begin to integrate considerations of complex contexts including necessity and merit into their notions of how to allocate different types of resources. Contextual variables such as the type of resource, the level of need of the recipient, and the validity of the recipient's claim are taken into account to render a fair and just allocation (Elenbaas et al., 2016; Olson et al., 2011). Our results support the new patterns of findings in the developmental literature by demonstrating that children are sensitive to the distinctions between necessary and luxury resources (Rizzo et al., 2016), and to the concerns about disadvantaged status (Elenbaas et al., 2016; Olson et al., 2011). A primary question that remains unknown is what are the neurophysiological relations of these judgments. We proposed that even though, with age, children are

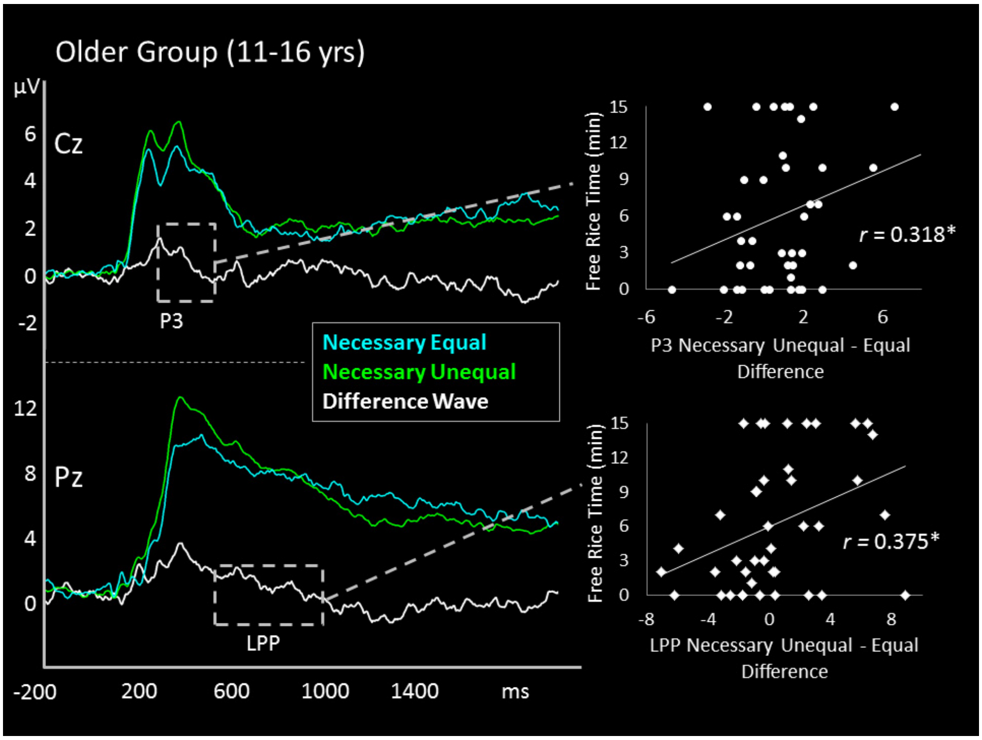


*Figure 3.* A larger mid- to late-latency ERP response to unequal distributions predicts the amount of time preadolescents and adolescents will engage in a game that helps those in need; (top) average ERP waveform at Cz during P3 window and (bottom) Pz during LPP window for unequal over equal distributions of necessary resources and the difference wave which predicted more time spent playing the Free Rice.
$^*p < .05$. [Color figure can be viewed at wileyonlinelibrary.com]

increasingly able to incorporate contextual factors into their understanding of distributive justice (Rizzo et al., 2016; Sigelman & Waitzman, 1991), there may be unobservable neural mechanisms that drive any given child's behaviors based on his or her age.

Thus, a central goal of this study was to understand the complex interaction between psychological and neurophysiological processing associated with the evaluation of others' distributive justice decisions and to relate these to actual behaviors. Evidence for extensive individual differences in social decision making was found. Furthermore, age-related findings were discovered for the neural processes that contribute to children's decisions but not for how children actually allocated resources.

Findings from this study provide critical insight into the nature and timing of children and adolescent's complex, contextually sensitive, social decision making. Children's decisions about the importance of resources and the need recipients, both as the evaluation of a third-party distribution and a first-person allocation, as well as their environmental and neural foundations were assessed. These results across multiple levels, from behavior to neural (ERP), provide a more complete understanding of the cognitive and emotional processes that lead to children's judgments and actions regarding allocation of resources, and illuminate the current theoretical debates about the importance of equity versus equality in such allocations.

### *Neural Time Course of Evaluating Distributions*

To determine the neural and psychological processes that contribute to participants' decisions and judgments in complex resource allocation scenarios, children's neurophysiological time courses of viewing third-person resource distributions were examined using ERPs. Early (200–300 ms poststimulus), middle (300–500 ms), and late (500–1,000 ms) ERP windows were examined to gain a thorough understanding of how children respond to each type of distribution.

The results of the EPN component showed a preferential response to equal distributions of resources over allocations that benefitted a poor group or a rich group, regardless of resource type. The EPN response is typically stronger to positively valenced stimuli (Weinberg & Hajcak, 2010) and is thought to represent “natural selective attention” to emotional targets (Schupp et al., 2006). The 8- to 10-year olds had a stronger EPN to equal versus other distributions when compared to the 11- to 16-year olds. Thus, the selective EPN to equal distributions suggests that children find an even, equal split of resources to be the most inherently positive and motivationally relevant early on, and this is the case for children more than for adolescents. An alternative interpretation of this result is that the perception of equality or inequality in resource distribution, as indexed in modulations to the EPN, is coopting general perceptual processes that detect bilateral versus unilateral stimuli (e.g., Luck, Heinze, Mangun, & Hillyard, 1990). However, as the nature of the differentiated EPN response also predicted higher evaluations of this behavior in children, this explanation is less likely.

We examined a P3 window from 300 to 500 ms at central sensor Cz. The P3 component demonstrated greater amplitudes for necessary over luxury resources. The P3 response has been well documented as responding to salient or emotional stimuli (Kestenbaum & Nelson, 1992). It is also highly influenced by task demands and expectation (Duncan-Johnson & Donchin, 1977), suggesting an incorporation of both stimulus-driven features (valence, salience) and cognitive control mechanisms. The older group of participants exhibited larger P3 amplitudes in response to both-to-poor and none-to-poor over equal distributions compared to the younger group. These results support that the younger group demonstrates a greater preference for equality than the older group does when there are both influences of intrinsic emotional content and an extent of top-down processing. This may indicate a substantial developmental difference between late childhood and adolescence, with regard to the persistence of an egalitarian bias in children’s neural time courses. In complex situations, adolescents and perhaps adults will prefer equal allocations over those based on equity when the rationale for equity may not be well understood. Moreover, individuals may prefer to be viewed as an “equal allocator” than to benefitting one group over another, even when a prior disadvantaged status warrants an equity rather than an equality response. For fairness to be ensured there may be times when “leveling the playing field” necessitates an equity rather than an equality response; these judgments require a careful examination of the contextual parameters. A promising finding, however, is that adolescents appear to use deliberative processing styles to make decisions about the more complex contextual variables.

In later windows, effects of both resource type and distribution were found. In the midline LPP, necessary resources again evoked a greater ERP response than did luxury resources. When examined at lateralized sites, an overall attenuated response to equal distributions was present, as well as a larger LPP response to both-to-poor over none-to-poor distributions. Notably, at this point all children and adolescents showed this pattern, absent any age-related interactions. The LPP is believed to reflect sustained, elaborative processing and most responsive to emotional or arousing stimuli (Cuthbert et al., 2000; Schupp et al., 2006; Weinberg & Hajcak, 2010). As such, the current findings may suggest that at this later, deliberate stage of processing, equal distributions are already well rehearsed and familiar (based on years of equality focused allocations from 3 to 8 years of age) and differ from allocations that involve new contextual considerations such as type of resource and recipient need (Killen Elenbaas & Rutland 2015). Although one cannot rule out that equal distributions are simply the least valenced, it is not likely the only reason for the attenuated LPP, as the EPN response was largest for these distributions.

Viewing the time course as a whole, the similar P3 and LPP effects found for resource type suggest that necessary resources elicit a greater response than luxury resources overall. Interestingly, the direction of the distribution effects differed between the EPN and later components, where the automatic response (EPN) showed a preference for equality, the more controlled responses (P3 and LPP) were weakest for equal distributions, and in the latest window (LPP) further differentiation occurred between both-to-poor and none-to-poor distributions. Our results provide support for the interplay of a rapid preferential attention to equality and a slower, more deliberate evaluation of the distributions for this age group, 8–16 years of age, that was greatest for both to poor over none to poor and lowest in response to strict equality.

Taking into account the pattern of age-related ERP effects, we see that the two age groups differ primarily in their relatively rapid to middle-latency processing of distribution types. As evidenced by the EPN and P3 effects, the 8- to 10-year-old children’s preference for equality may persist past the point of an automatic response and into the time where the older group has already manifested a lessened response to equality over alternative distributions. Importantly, no age effects were found in later windows, suggesting that the greatest developmental differences are, in fact, when the neurophysiological responses are rapid and semiautomatic. These effects ultimately are characterized by the critical point in time when the salience of equality is overtaken by a larger response to more contextually based distributions. In the older group, this happens very rapidly. Although the adolescents and preadolescents (11–16 years) did exhibit an early attentional preference (indexed by the EPN) to equality, it is certainly attenuated relative to the younger group. Furthermore, the younger group shows a lessened preference for equity relative to the older group even in the P3 window.

*Incorporation of Context into Resource Allocation*

The results of the first- and third-person allocation tasks suggest that behaviorally, children and adolescents between the ages of 8 and 16 years consider the necessity of a resource being given when making a distribution. This extends previous research on the type of resource and the need of the recipient, which has focused on early and middle childhood but not adolescence. Participants exhibited a tendency to allocate important resources to the place with greater need (both to poor) and distribute luxury resources equally. In evaluating others' decisions, children-rated distributions involving necessary resources more favorably than luxury ones, and this effect was qualified by an interaction where no differences were found between resource types in the none-to-poor distributions but the necessary better-than-luxury effect was found in both equal and both-to-poor situations. Equal distributions were rated most favorably, followed by both to poor, and none to poor least positively, regardless of resource type. The result that equality continued to trump equity in resource allocation decisions is not consistent with one previous study, wherein by the age of 8, most children were giving more resources to the poor character than a rich one (Rizzo et al., 2016). Moreover, some evidence from preschool children indicates that by 5 years of age, children already begin integrating considerations of need and merit into their resource allocations (Paulus, 2014). These distinctions may have to do with the greater complexity in the contexts being evaluated in this study compared to research with younger children. Age was not a significant predictor of first-person allocation decisions for either necessary or luxury resources, but age did selectively influence certain ratings of distributions. The older group rated both-to-poor distributions of necessary resources as better than the younger group. This greater appreciation for distributing necessary resources to the poor recipient that increases with age is consistent with studies finding a transition from equality to consideration of need from middle and late childhood to adolescence (Damon, 1977; Sigelman & Waitzman, 1991). Overall, children's third-person evaluations strongly corresponded to their first-person distributions in both resource types. This particular finding is important for two reasons. First, it demonstrates consistency in participants' reasoning between the behavioral and judgment measures (Turiel, 2008), and second, it does so because it provides evidence for developmental patterns across different methods.

*Neurophysiological and Developmental Influences on Behaviors*

The results of this study allude to a complex construction of and development in resource allocation considerations in late childhood and adolescence. The age-related changes in actual behaviors are highly related to individual differences in neural responsivity and modulated by age. The psychological and neurophysiological processes that contribute contextually based resource allocation decisions and their relations to resulting behaviors change across development. In the younger group, the greater EPN response to equal over both-to-poor distributions of necessary resources predicted more favorable evaluations of these distributions. In the older group, this same association was found later, in the P3 component. Furthermore, for this older group, the P3 response to unequal versus equal distributions of necessary resources reliably predicted first-person allocations of both necessary resources to the poor place. In the 8- to 10-year olds, evaluations were predicted by the strength of automatic preferential attention to equality as indexed by the EPN. In contrast, the older group's decisions were predicted by the P3 component, implying the necessity of secondary appraisal and top-down cognition in complex social decision making as adolescents mature.

Importantly, in older children, neural differences in the processing of equality versus equity directly predicted adolescents' engagement in a charitable giving game. A consistent relation between the older group's ERP responses and prosocial behaviors (as measured by time spent playing Free Rice) was found in the P3 and the LPP time windows. Specifically, a larger amplitude difference for unequal versus equal distributions was predictive of longer time spent playing the Free Rice game, which assesses real-life charitable giving. That this effect occurred in late windows that are known to represent elaborative, controlled processing suggests that those children who may be reflecting most upon unequal versus equal distributions are more likely to act prosocially toward those in need. These results are consistent with studies that find associations between P3 or LPP responsivity to social or moral scenarios and prosocial behaviors in adults (Chiu Loke et al., 2011) and young children (Cowell & Decety, 2015a).

### *Conclusion*

Drawing on current behavioral research with children regarding their resource allocation decisions in complex contexts involving type of resource, the need of the recipient, and the source of the allocator (first person or third person; Killen et al., 2015; Rizzo et al., 2016), this study investigated the behavioral, neural, and brain–behavior relations in complex resource allocation decisions strongly supporting the protracted developmental weighing of equity and equality. Consistent with a growing body of studies in developmental social neuroscience, children and adolescents exhibited early and immediate neural differences in their processing of morally laden decisions, followed by differences in later components indexing cognitive integration and appraisal of emotional stimuli (Cowell & Decety, 2015a, 2015b). These early reactions to equality were almost immediately modulated by considerations of equity and the necessity of resources and individual differences in early neural indices of perception of equality and necessity were predictive of children and adolescents' actual allocation decisions in similar scenarios. However, in adolescents, individual differences later components (P3, LPP) for simple reflection on inequality (over equality) were directly predictive of the amount of time participants engaged in a charitable giving game. These findings illuminate a complex integration of equality, equity, and necessity into children and adolescents' resource allocation decisions across multiple levels, from neural to cognitive to behavioral.

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## Supporting Information

Additional supporting information may be found in the online version of this article at the publisher's website:

**Table S1.** Event-Related Potential (ERP)—Age in Years Correlations

**Table S2.** Event-Related Potential (ERP)—Behavior Correlations