Food availability differentially influences young males' and females' cognitive processes in accordance with sexual selection theory

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Sexual selection theory predicts that additional resources will have a greater impact on males' compared with females' reproductive success. Consequently, we expected that strong cues signalling increased resource availability should augment cognitive functioning associated with long-term maximization of reproductive outcomes (inhibition, working memory) in human males. In human females, who can rely on assistance in resource-rich environments, we expected the opposite effect. We tested this prediction in lower socio-economic status children, since their poverty increased the relative salience of the cues available in a limited experimental situation. We show that cues indicative of food availability increased impoverished young males' inhibitory and working memory capacities compared with males who viewed photographs of food. By contrast, cues indicating food availability exerted the opposite effect on females. These results indicate that cues related to resource availability have differential effects on basic cognitive functions associated with strategic behaviour in males and females. The findings also demonstrate remarkable plasticity in fundamental cognitive processes in young children, even those from impoverished backgrounds.

Keywords: food; status; cognition; sex differences

1. INTRODUCTION

From a life-history perspective, socio-economic status (SES) constitutes a broad combination of factors that affects children's internal appraisals of their environments (Evans 2004; Belsky *et al.* 2007; Del Giudice *et al.* 2009). More precisely, sexual selection theory (Darwin 1871) predicts that in a resource-rich environment, males generally benefit more than females in terms of greater reproductive success (RS). Additional resources typically permit linear increases in RS for males, whereas females reach an asymptote (Darwin 1871). The model applies to humans because of

greater maternal relative to paternal investment and a mating system that permits females to marry males with resources (Buss 1989).

Consistent with the model, evidence from humans demonstrates that resource abundance and status influence survival and RS of individuals of both sexes, but males benefit disproportionately (Montez *et al.* 2009). This sex differential results partially from the higher mortality and morbidity of males without resources (Daly & Wilson 2001; Montez *et al.* 2009). Further buffering SES effects on females, human females typically obtain resources, protection and status through partnerships with males and kin (Lancaster & Lancaster 1983; Smuts 1995; Sear & Mace 2008), and these forms of assistance are less available to females in low resource environments (Belle 1983).

Based on sexual selection theory, we reasoned that children's appraisals of environmental resources would activate sex-differentiated facultative cognitive responses. For males, access to resources should activate cognitive processes that facilitate long-term planning. Males without resources accept immediate payoffs, precluding the need for these higher level cognitive processes. By contrast, for females, lack of resources should activate higher level cognitive processes facilitating long-term planning because maternal investment alone determines RS. In poor environments, children confront myriad risks and assistance is minimal, so direct maternal effort determines RS. Increased access to resources diminishes the benefits of direct maternal investment, as children in resource-rich environments confront fewer risks, and mothers can rely more on others to invest in children. Consistent with this, a recent study showed that women who viewed photographs of desserts they were told they would eat reported more positive emotions, but exhibited slower reaction times to cognitive stimuli, relative to women who viewed photographs of the same desserts (with no expectation of eating them), or of neutral objects (Gable & Harmon-Jones 2008).

Experimental studies including both sexes further demonstrate sex-differentiated responses to resources. American men in a resource-rich environment (owing to having just eaten or having been induced to feel financially secure) chose lighter ideal mates compared with men without resources; the opposite effect occurred for women (Nelson & Morrison 2005). In a reverse study, men's inhibition of immediate monetary payoffs in favour of delayed but larger rewards was influenced by the attractiveness of photographs of women, whereas the same effect did not occur for women (Wilson & Daly 2004).

Inhibition permits individuals to plan and hence is considered a fundamental executive process (Hare *et al.* 2009). Resources signal future opportunities to men, thereby increasing the benefits of inhibition and other higher level cognitive processes. By contrast, lack of resources signals to women, heavy investment in children's survival, enhancing the benefits of higher executive processes. The importance of inhibition should therefore be higher in males with more resources and in females without resources.

Here, we test this prediction with young children from impoverished backgrounds. We reasoned that cognitive appraisals would be highly sensitive to cues

regarding degree of food availability in children from impoverished backgrounds. Consequently, we generated cues indicative of a resource-rich environment by displaying abundant food, with photographs of the same food serving as a control condition. Compared with actual food, photographs diminish the quantity of sensory cues while controlling for the presence of a novel intervention. They also suggest relative deprivation comparable with media advertisements that aim to activate observers' desire to obtain resources. Because inhibition is considered critical to higher level decision-making (Hare *et al.* 2009) and is related to status in males (Daly & Wilson 2001), we chose inhibition as the primary outcome. We chose working memory span as a secondary measure because it is also considered a critical component of overall higher level reasoning (Baddeley 2003).

2. MATERIAL AND METHODS

Fifty-one kindergarten children participated from three parochial schools serving low SES neighbourhoods in Boston, MA. Two of the schools did not serve any food, thereby maximizing the effect of our experimental intervention. Forty children were African-American, eight Hispanic, three Arabic and one Indian, and they ranged from 57 to 80 months. Mean age in months were $\chi = 71.54$ months, s.d. + 6.62, $n = 12$ for boys in food condition; $\chi = 70.69$, s.d. + 4.94, $n = 11$ for boys in photographs condition; $\chi = 67.36$, s.d. + 5.26, $n = 12$ for girls in food condition and $\chi = 68.09$, s.d. + 5.77, $n = 10$ for girls in photographs condition. Boys were significantly older than girls, $F_{1,50} = 4.53$, $p < 0.01$, because the schools' policies reflect their belief that boys are less mature than girls of the same age.

Children of each sex were randomly assigned at each school to one of two conditions: food or photographs of food. The food condition consisted of three large bowls (32–45 cm diameter) of freshly prepared hot main dishes (fried chicken, pasta covered with cheese, rice mixed with beans), an additional large bowl (32 cm diameter) of dessert (chocolate pudding topped with whipped cream) and a large basket (50 cm diameter) of assorted fruit. Food was chosen after consultation with school officials to be maximally desirable to these children. The photographs of food depicted the same food as in the food condition and were enlarged to match the size of the actual food. At the conclusion of the entire study, all children who participated ate the food.

Children were taken in same-sex pairs by a female research assistant to a room where a male or female experimenter (blind to condition) administered the inhibition and working memory tasks (order counterbalanced by sex of child and experimenter). En route, children stopped for 5 min at a screened off table covered with a tablecloth that contained the food or photographs of the food. Upon encountering the food or photographs of food, the research assistant recited a script that highlighted the positive sensory qualities of the food and solicited the children's evaluations. Children then proceeded to meet the experimenters and perform the tasks.

To measure inhibition, we administered a computerized Go–No-Go task designed for use with children (Carver *et al.* 2001). Children completed two sets of 12 trials with the speed of the No-Go signal for the first 12 trials calibrated to 500 ms before each child's mean reaction time during the practice trials, and for the second set recalibrated to 500 ms before the child's mean reaction time during the first 12 trials. Six children (three males, three females) either could not attain the criterion for success during the practice trials in the allotted time or stopped participating after the first few trials, so no data were collected for them. The proportion of No-Go trials (maximum nine) on which children correctly inhibited a response constituted the dependent variable.

To measure working memory, the experimenter administered a standard letter span task (Wechsler 2003). Span ranged from 2 to 5.

3. RESULTS

An analysis of variance (ANOVA) with condition and sex as independent variables and age as a covariate on the number of correctly inhibited trials yielded a

Figure 1. Mean (+s.d.) proportion of trials inhibited correctly on No-Go trials by condition and sex. Grey bars designate food condition; black bars, photographs of food condition: (a) all schools and (b) only schools without food.

significant condition $\times$ sex interaction; $F_{1,40} = 12.83$, $p = 0.001$, partial $\eta^2 = 0.24$. Follow-up Tukey tests ($p < 0.05$) showed that as predicted males in the food condition ($n = 12$) correctly inhibited significantly more responses on No-Go trials than males in the photographs condition ($n = 11$). By contrast, females in the photographs condition ($n = 12$) correctly inhibited significantly more responses than females in the food condition ($n = 10$) (figure 1).

In the two schools without food, we expected the effect of the food to be accentuated, so we repeated the analysis with children only from these schools. Again, the condition $\times$ sex interaction was significant; $F_{1,22} = 34.27$, $p = 0.000004$, partial $\eta^2 = 0.58$. Follow-up tests showed that males in the food condition ($n = 8$) correctly inhibited significantly more responses on No-Go trials than males in the photographs condition ($n = 8$). By contrast, females in the photographs condition ($n = 8$) correctly inhibited significantly more responses than females in the

Figure 2. Mean (+s.d.) letter span by condition and sex. Grey bars designate food condition; black bars, photographs of food condition.

food condition ($n = 6$). No condition, sex or age effects were significant in either analysis.

Next, we performed an analysis of the letter span task using an ANOVA with condition and sex as the independent variables and age as a covariate. No significant effects were obtained. When the analysis was limited to the two schools without food, however, then the condition $\times$ sex interaction was significant; $F_{1,30} = 5.19$, $p = 0.03$. Follow-up Tukey tests ($p < 0.05$) demonstrated that males in the food condition ($n = 9$) recalled significantly more letters than males in the photographs of food condition ($n = 10$). The difference was not significant for females (figure 2).

4. DISCUSSION

Our results demonstrate that food activated male children's inhibition and recall, and depressed female children's inhibition relative to photographs of food, consistent with the greater reproductive benefits that accrue to males with resources (Darwin 1871; Buss 1989; Daly & Wilson 2001) and the increased direct maternal investment required of females in resource-poor environments (Belle 1983). Inhibition allows planning which permits males with resources to enhance RS and females' lacking resources to enhance children's survival. Increased resources permit females to relax, whereas lack of resources signals to males the need for a more immediate and less future-oriented strategy. Accurate environmental appraisals permit individuals of both sexes across animal species to adapt their cognitive-behavioural strategies to maximize RS.

Here we demonstrated that a simple intervention modified higher level cognition in impoverished young males and females in ways predicted by sexual selection theory. Future research is necessary to compare the magnitude of sex differences in individuals from higher versus lower SES backgrounds on additional cognitive measures, as well as to determine whether the plasticity of these algorithms diminishes over time.

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