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Social Influences on Executive Functions Development in Children and Adolescents: Steps Toward a Social Neuroscience of Predictive Adaptive Responses

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Abstract This commentary discusses the findings and implications of four empirical papers that establish a reciprocal, longitudinal link between the social environment and executive functions from childhood to adolescence. Two future directions are suggested by this work. The first is a call for measurement research to clarify the nomological network of various measurements of self-regulation and executive functions across a variety of methods and procedures. The second new direction is to broaden the analysis of executive function to include a wider array of predictive adaptive responses to various environmental conditions, including those where youth are chronically marginalized or otherwise stressed. Findings from these studies suggest that the executive functions within the brain guide adaptation in both deviant as well as competent responses to the social environment. Understanding various forms of adaptation will enhance the potential for prevention as well as avoid iatrogenic intervention strategies with misinformed targets.

Keywords Executive function · Adaptation · Aggression · Peers · Social neuroscience

The Reciprocal Effect Hypothesis

The reports in this special section study the reciprocal effect between children's executive functions development and experiences within teacher and peer relationships. The reports take a refreshingly broad perspective to investigate both sides of the reciprocal equation, each providing similar answers to a complex question. Several aspects of cognitive functioning are explored, including a behavioral assessment of self-regulation (Cadima et al. 2015), parent ratings, self-report and specific tests of executive functioning (Holmes et al. 2015), tests of working memory (de Wilde et al. 2015) and rejection sensitivity as measured in the fMRI under conditions of exclusion (Will, van Lier, Crone, & Güroğlu, this issue). Two of the four studies used a crossed-lagged longitudinal modeling strategy (de Wilde et al. 2015; Holmes et al. 2015), and one a longitudinal model controlling for prior levels of self-regulation (Cadima et al. 2015). Will and colleagues used neuroimaging to study individual differences in neurocognitive activations to social rejection, revealing increased demands for emotional regulation among children with a chronic history of peer rejection in the school setting. All four studies support the hypothesis that social experiences in the natural environment impact neurocognitive development broadly defined, especially within systems known to be relevant to normative self-regulation.

Conversely, three of the four innovative studies suggest that individual differences in neurocognitive development may also enhance or undermine the formation of satisfying and healthy relationships with teachers and peers. Findings such as these are quite consistent with the general conclusion coming from basic research on brain plasticity, concluding that there are reciprocal linkages between environmental experience and brain development throughout the lifespan (e.g., Kolb and Gibb 2003).

After four decades of research on environmental experiences relevant to children's growth in competence and psychopathology, we have come to understand *nurturing environments* as

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those relatively low in conflict and coercion and high in proactive structuring and positive behavior support. A recent review of the literature provides compelling evidence that nurturing educational environments, parenting practices, and prevention programs actively support both growth in competence as well as reductions in mental health problems in children and adolescents (Biglan 2015). These conclusions are consistent with the findings on the influences of teacher and peers on neurocognitive development established in this special section. These findings build on an emerging developmental literature that links nurturing family environments to self-regulation in early childhood (e.g., Eisenberg et al. 2010) and adolescence (e.g., Fosco et al. 2012).

Conclusions regarding the reciprocal linkages between the environment and neurocognitive development are buttressed by randomized trials involving interventions known to increase nurturing environments showing corresponding improvements in children's self-regulation. During early childhood, Lunkenheimer et al. (2008) found that randomization to the Family Check-Up increased parents' use of positive behavior support as observed in the home, which in turn predicted gains in self-regulation by age 4. More recently, my colleagues and I extended these findings (Chang et al. 2015) to show that early childhood increases in parents' use of positive behavior support had long lasting effects on children's regulation into middle childhood as rated by both parents and teachers.

Clearly, the evidence supports a reciprocal link between environmental experiences and children's development of core neurocognitive capacities that underlie the broad domain of self-regulation. I argue for two broad programs of research to advance our scientific understanding of the interplay between the ecology of children's development and emerging neurocognitive abilities through adolescence. First, I suggest we need to study the nomological network of measurements that define neurocognitive development, in general, and self-regulation, in particular. Second, I suggest we expand our definition of neurocognitive capacities to include what has been traditionally referred to as *maladaptive behavior*. From an evolutionary framework, maladaptation can be thought of as a predictive adaptive response to stressful social environments (see Ellis and Boyce 2008; Nettle et al. 2013). Improving our understanding of measurement issues as well as broadening the array of neurocognitive capacities we investigate will move the field forward in the effort to understand reciprocal links between the social environment and neurocognitive development.

The Nomological Network

Following the Second World War, psychology assimilated a massive success experience in the use of psychological tests for assessing individual differences in young adults for the sole purpose of organizing an effective military force. The classic works that define the psychometric tradition emerged from academic settings in the 1950s, including Cronbach's classic work on construct validity of psychological tests (Cronbach and Meehl 1955). This work laid the foundation for a systematic distinction between method variance and construct variance as being two unique and separable dimensions of information underlying individual difference scores. Much later, a more comprehensive statistical framework for the analysis of both method and construct variance, as well as the interrelation among constructs (i.e., nomological network), became quite achievable with the use of structural equation modeling (Dwyer 1983). Structural equation modeling allowed developmental researchers to systematically test theories of measurement at the same time as causal hypotheses regarding influences on children's development (see Dishion and Patterson 1999).

To date, innovations in the measurement of neurocognitive processes underlying self-regulation have focused less on measurement issues. For example, fundamental breakthroughs in studying activation of the anterior cingulate cortex (ACC) enhance our understanding of self-regulation, but do not necessarily provide reliable estimates of individual differences (Posner 1980). The Attention Network Task (ANT) is used in high-density array EEG and fMRI contexts showing activation of the ACC during cognitive tasks that involve suppressing a prepotent response. As is typical within the neurosciences, the ANT task was not designed to reliably estimate individual differences in effortful control, but rather to investigate the neurocognitive origins of critical capacities underlying self-regulation such as effortful control (see Posner and Rothbart 1998).

As the technology of neurocognitive assessment progressed, we attended less to the methodological problems of reliability and validity. This oversight is particularly problematic if our scientific goals become linking changes in the social environment with changes in neurocognition over time, as cross-lagged models are less valid under conditions of low measurement reliability (Rogosa 1980). I began to doubt that various putative measures of self-regulation were actually measuring the same construct in findings from our own research group. Using a community sample, we studied various aspects of self-regulation in childhood in the etiology of more serious forms of antisocial behavior in preadolescents (see Racer et al. 2011). We found linkages between 'orienting' of attention as measured in the ANT (see Posner and Rothbart 1998) and individual differences in the child's psychopathic traits. More importantly, however, we did not find correlations among behavioral measures of self-regulation, ERP indices of brain activation during ANT tasks, and parent or self-reported levels of executive control of attention. In other words, the data did not support a construct of self-regulation. The lack of convergent validity of various neurocognitive indices of

self-regulation is not necessarily a problem of neuroscience, but it is a serious barrier to social neuroscience because of our interest in using such measurements to understand and predict individual differences in development.

Thus, at some point in the study of reciprocal linkages between social experience and emerging self-regulatory abilities, we need to study our measurements and come to some clarification on the nomological network of capacities that have been loosely defined as self-regulation. It would seem that the field of social neuroscience cannot move forward without clarifying the constructs being measured by the indices like those studied within this special issue.

Flight, Fight, or Manipulate

One of the most interesting issues we face in this line of research reflected in this special section is how the brain adapts to stressful ecologies. The approach to focusing on deficits is likely to be of only limited value for a thorough scientific study (Meichenbaum 1977). The lack of self control, self-regulation, and executive control is perhaps the most promising candidate for a deficit model, as there is considerable evidence for the prognostic value of poor self-regulation in childhood for growth in various forms of problem behavior and health problems through adolescence and adulthood (Moffitt et al. 2011).

An evolutionary framework allows us to shift our focus to skills, strengths, or capacities that may emerge among children raised in stressful social environments (see Ellis and Boyce 2008). In particular, a predictive adaptive response is a capacity supported within a developmental ecology that promotes survival and procreation within stressful life history trajectory (see Nettle et al. 2013). I have argued, from an evolutionary framework, that social marginalization (i.e., chronic peer rejection, teacher rejection, community stigmatization) is perhaps the most salient ecological feature evoking a predictive adaptive response associated with many forms of problem behavior and deviant peer clustering (Dishion 2015). I suggest three domains of abilities that children may develop in stressful and marginalized ecologies that may be detectable at both the neurocognitive and behavior level.

First, under conditions of chronic marginalization, children become adept at the early detection and avoidance of punitive and/or rejecting environments and relationships (Will et al. 2015). From a deficit framework, this tendency can be thought of as a hostile attribution bias (Dodge et al. 2003). However, from an evolutionary framework, early detection of rejection or hostility from a peer is the foundation of adaptation, as reveal in the work by Will and colleagues (Will et al. 2015), showing enhanced ACC activity in rejection episodes among chronically rejected youth, compared to those with healthy peer relationships. Thus, the same regulatory process can form the basis for any adaptive response, from a socially skilled strategy of engagement to a preemptive or aggressive attack (see Frankenhuis and de Weerth 2013). One can imagine that individual differences in the ability to quickly discern disingenuous intentions, or dangerousness, can be a survival advantage in such environments. Such situations, if detected early, can be avoided.

Alternatively, early detection of threat can help prepare one for preemptive attacks to reduce the likelihood of future aggressive exchanges by virtue of 'winning' the coercive bout (Patterson et al. 1967). Within hostile environments, managing coercion by peers may require a qualitatively different emotional regulation than what is typical for studies of normative development. For example, the ability to manage the fear response is critical for standing down an aggressive peer in a chaotic and/or aggressive social environment. Across species, standing down aggressive gestures from an opponent is the cornerstone of dominance. Resolving issues of dominance and leadership promotes cohesion and organization in small groups of primates (de Waal 2000). However, the self-regulatory capacities associated with establishing and maintaining dominance in a social group are not well understood from a strengths-based perspective.

As children become adolescents, they likely develop neurocognitive capacities that provide perspective on them relative to the large social environment (Piaget 1970). Several developmental psychologists make compelling scientific arguments for changes in brain development in adolescence demarcating a general increase in risk propensity (Dahl and Spear 2004; Silk et al. 2009; Steinberg 2007) as well as reward responsiveness (Galvan 2010). We argue that youth with a history of social marginalization become particularly attentive to social reward, and seek out and create highly rewarding groups and situations on their own terms and with their own rules in a process often referred to as deviancy training (see Piehler 2015). The most rewarding social interactions are those leading to sexual involvement (Dishion et al. 2012). The evolutionary-based model emphasizes deviance as a predictive adaptive response, in which adolescents become particularly adept at joining with like-minded peers to create highly rewarding situations, behaviors, and interactions. These interactions define a mutual influence process of deviancy training in adolescence, thus allowing marginalized youth to flourish socially as well as to propagate their genetic code (Dishion 2015).

The shift from a deficit model to an evolutionary framework requires the study developmental patterns of problem behavior as also entailing a unique set of abilities and capacities that define the broader adaptation (Frankenhuis and de Weerth 2013). For example, the ability to navigate two worlds (socializing adults, deviant peers) requires a careful read of the attitudes and vulnerabilities of individuals in both social worlds. Youth involved in problem behavior, for example, may become skilled at manipulation of adult perceptions to

avoid being detected, as well as socially skilled in joining or conning peers into nefarious endeavors such as drug acquisition and sales. Although adolescents involved in high levels of 'problem behavior' may not be skilled at tuning out distractions or persisting in mundane homework activities, they may be very capable of patiently navigating other distractions or barriers in favor of obtaining highly valued rewards such as drugs or sex. In the effort to recover from substance dependence in adulthood, it may be equally challenging to relinquish manipulative approaches to interpersonal relationships formerly learned within a drug using subculture.

Summary and Concluding Discussion

The four papers in this special section add to compelling literature on the reciprocal nature of the social environment and neurocognitive development. As such, the studies fall within the nexus of social neuroscience and developmental psychopathology. There are several noteworthy strengths to the studies represented in this special issue, including sound measurement, longitudinal design, and statistical analyses that control for competing explanations. The findings from these studies support the reciprocal effects hypothesis, which has implications for both intervention and developmental science.

The questions addressed in this special issue suggest two future directions. The first is to build on the rich psychometric and statistical tradition of clinical psychology, which provides tools for systematically studying the nomological network of neurocognitive abilities that define self-regulation. The measures of working memory, executive attention, behavioral regulation, and rejection sensitivity, included in these studies, are particularly germane to this effort. The second, and more challenging, new direction is to move away from a deficit model in favor of the study of the unique neurocognitive capacities supported in stressful developmental contexts that define a predictive adaptive response, such as adolescent problem behavior. Progress on these two steps will likely improve our understanding of the interplay between the social environment and neurocognitive development, as well as inform programmatic efforts to improve the lives of children and adolescents.

Compliance with Ethical Standards

Conflicts of Interest There are no conflicts if interest in this commentary.

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