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Commentary: On the importance of looking at nonlinearity and developmental effects - a reflection on Flom et al. (2017)

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Abstract

By examining both linear and curvilinear associations between mental development and activity level, the study by Flom and colleagues (2017) highlights the importance of going beyond linear associations in psychological fields of research. Results from Flom et al. (2017) also raise interesting questions for future research. First, studies should look at variables that may explain the associations between activity level and mental development, such as self-regulation and attention. Second, longitudinal changes in the strength of the association between activity level and mental development should be examined to determine when this association is at its strongest. Finally, longitudinal research looking at bidirectional effects is needed to confirm the direction of the associations between activity level and mental development. Answers to these questions will allow the identification of the best targets and developmental periods for interventions to take place.

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Flom and colleagues (2017) examined linear and curvilinear associations between mental development and activity level. Activity at two and three years old was assessed using three sources, i.e., parent ratings, observations during a play and test situation, and actigraphs in the lab and at home. In their introduction Flom et al. (2017) point out that although previous research showed that high activity levels were associated with lower mental development, theoretical models also suggest that low activity levels could be problematic, thus yielding a curvilinear association. Their findings of curvilinear associations between observer-rated activity level and mental development supported these theoretical models. These results have at least two broad implications for psychological research in general and understanding development in particular. First, formally testing an assumption of linearity between variables has potential implications for theory and practice. Second, these findings embedded in a longitudinal approach open up further questions for a better understanding of the sequence of developmental milestones.

With the majority of current research examining linear associations and most graduate statistics courses either not discussing or only briefly presenting non-linear models, it is not surprising to see a strong tendency for students and researchers to think of associations mainly in linear terms. However, the results of Flom et al. (2017) not only highlight the importance of going beyond linear associations when analyzing data, but also of using theory to guide those analyzes. For example, in a similar fashion to Flom et al. (2017), one study found a curvilinear association between maternal behavioral control and externalizing behaviors in 3-year-old children (Akcinar & Baydar, 2014). That study supports the idea that both high and low maternal behavioral control would lead to higher levels of externalizing behaviors by promoting an

inability in children to self-regulate. Furthermore, beyond evaluating theories that explicitly suggest curvilinear associations, looking for such associations can also allow the integration of seemingly competing theories, as illustrated by a recent study on social standing and peer victimization (Andrews, Hanish, Updegraff, Martin, & Santos, 2016). In that study the authors highlighted two competing theories about the associations between social standing and peer victimization: one theory suggesting that victimized youth were rejected and marginalized, and another suggesting that victimized youth were dominant and powerful. By examining curvilinear associations, they found that boys either high or low in social prestige were more victimized, thus reconciling the two seemingly opposing theories.

We also note that results from Flom et al. (2017) show consistent curvilinear associations of mental development in test and play lab situations but only with observer-rated activity level, not with activity level measured with actigraphs in those same situations. Whereas actigraphs reflect quantitative activity levels independent of situational demands, observer-rated activity levels take into consideration qualitative aspects such as the circumstances within which activity level is assessed and the level of activity compared to other children. This suggests that the children's capacity to regulate their activity level to meet situational demands might be more important for mental development than their general objective activity level. This is further supported by examining the differences in effect sizes between the test and play situations, with observed activity level in the test situation explaining more variance in mental development than observed activity level in the play situation. Indeed, the test situation may require more self-regulation than the play situation as it represents a context where sustained attention is required. Because attention also involves a capacity to modulate activity level (Ruff & Rothbart, 2001),

children's capacity to self-regulate in a test situation is more likely to be reflected in their test performance, as in Flom et al.'s (2017) study which measured mental development.

In an effort to further understand the underlying mechanisms of the curvilinear associations found, we ask: would both high and low activity levels be associated with a lack of attention during the test situation? On the one hand, a high activity level might indicate distraction from the task being performed when the child does not have a high enough degree of self-control necessary to regulate that activity level. On the other hand, a low activity level may be associated with low investment in the task, as children with a low activity level are sometimes passive and unreactive (Ruff & Rothbart, 2001). Consequently, an average activity level would reflect optimal concentration and attention when completing a test, thus yielding better cognitive performance. Hence, self-regulation and attention may partly explain the associations reported here between activity levels and mental development, and future studies could examine whether measures of self-regulation or attention moderate this relationship. Such an endeavour would be in line with early research that found that activity level was moderated by motor inhibition to predict intellectual performance (Loo & Wenar, 1971) and, from a clinical perspective, would also provide a greater pool of possible targets for intervention programs aiming for better development of mental abilities.

From a developmental perspective, the increase in capacity to regulate activity level may also be an explanation for larger effect sizes in the test situation at 3 years of age compared to 2 years of age (Flom et al., 2017). Indeed, self-regulation is not fully acquired at 2 years of age and the capacity for children to exert control to meet situational demands develops throughout childhood (Montroy, Bowles, Skibbe, McClelland, & Morrison, 2016; Ruff & Rothbart, 2001). While developmental changes were not examined in the study by Flom et al. (2017), previous

research showed that the association between temperament and developmental outcomes can change across development (Rioux, Castellanos-Ryan, Parent, & Séguin, 2016). This suggests an interesting avenue for future research, namely to examine whether and how the association between activity level and mental development changes with age. Indeed, one could expect a weaker association earlier in development when most children have not acquired the capacity to regulate their activity level, an association that would get stronger as children develop this capacity. Strength of association over time could also show a curvilinear trend, with the association between activity level and mental development decreasing once most children have fully acquired the capacity to regulate their activity level according to situational demands. The question would then become whether there is not only a tipping point in the association between activity level and mental development, but also a developmental tipping point - an age at which the association between mental development and activity level is at its strongest. This would be particularly useful in determining when interventions would have the potential to have the highest positive impact.

Finally, another question remains from a developmental perspective and with clinical implications. While we are assuming from the theory presented by Flom et al. (2017) and from previous research that activity level predicts mental development cross-sectionally and prospectively, the opposite is not ruled out and studies looking at bidirectional effects from a longitudinal perspective are needed to determine whether the association is in that direction and not the reverse. Indeed, although theory strongly suggests that activity level would predict mental development, alternative associations and explanations should not be ruled out until formally tested. For example, as the development of self-regulation relies partly on the development of the prefrontal cortex (Berger, Kofman, Livneh, & Henik, 2007), could it be that

mental development influences activity level through its association with self-regulation? It would be important to confirm the direction of this association before allocating resources to target activity level in prevention and intervention programs for mental development and cognitive performance.

In conclusion, Flom and colleagues (2017) offer an important contribution to the literature on activity level and mental development by venturing beyond linear associations, which could be given more consideration in most psychological fields of research. Still, future research should examine: (1) variables that may explain the associations between activity level and mental development, such as self-regulation and attention, (2) longitudinal changes in the strength of the association between activity level and mental development, and (3) confirm the direction of these associations. This will allow the identification of the best targets and developmental periods for interventions to take place.

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