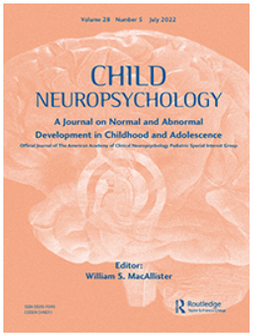

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Executive function moderates the relationship between temperament and psychological difficulties in middle childhood

Jennifer Wilson[a], Christy Hogan[b], Si Wang[a], Glenda Andrews[a] and David Shum[a,c]

[a]School of Applied Psychology, Griffith University Australia; [b]School of Applied Psychology and the Hopkins Centre, Menzies Health Institute Queensland, Griffith University Australia; [c]Department of Rehabilitation Sciences, The Hong Kong Polytechnic University

ABSTRACT

The current study examined the possible moderating influence of hot and cool executive function (EF) on the relationship between temperament and psychological difficulties in middle childhood. One hundred and twenty-six children and their parents (n = 105) participated. Children aged between 5 and 12 years completed three hot (motivational decision-making on the Cambridge Gambling Task (CGT), delayed gratification, and Theory of Mind [ToM]) and three cool EF (working memory, inhibition, and attentional set shifting) measures. Children's parents completed the Behavioral Inhibition Sensitivity (BIS) and Behavioral Approach Sensitivity (BAS) Scale and the Strengths and Difficulties Questionnaire. Hot EF (CGT, ToM) exacerbated the relationship between BAS and externalizing problems. Neither hot nor cool EF moderated the relationship between BIS and internalizing problems. The current findings provide further evidence of a hot-cool distinction in EF in middle childhood, suggesting that these constructs should be investigated separately when assessing EF. In addition, by considering potential interactions between temperament and EF, clinicians/researchers may be able to predict broad categories of psychological problems in middle childhood.

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KEYWORDS
Executive function; middle childhood; temperament; psychological difficulties; BIS/BAS sensitivity

The incidence of psychological difficulties in childhood is commonly believed to be related to temperament, a factor that appears to predispose children to difficulties (Colder & O'Connor, 2004; Vervoort et al., 2010). Executive Function (EF) refers to a range of high-level cognitive processes that support complex, goal-directed behavior, particularly in novel situations or when conscious effort or control is required (Diamond, 2006; Zelazo et al., 2004). EF has been linked with both psychological difficulties (Austin et al., 2020; Ogilvie et al., 2011) and temperament (Blair, 2003) in childhood. Previous research suggested that children's effortful control could moderate the relationship between their temperamental dispositions and social and emotional adjustment (Eisenberg et al., 2009). As a result, EF, also referring to a range of cognitive processes associated with effortful control, may play a role in moderating the relationship between temperament and psychological difficulties in children.

CONTACT David Shum david.shum@polyu.edu.hk Department of Rehabilitation Sciences, The Hong Kong Polytechnic University

Psychological difficulties

Childhood psychological difficulties are often grouped into either externalizing or internalizing problems. Externalizing problems are characterized by an outward expression of distress or behavior regulation difficulties (e.g., as observed in conduct disorders or ADHD), while internalizing problems involve an internal expression of distress, such as anxiety or depression (Krueger, 1999; Krueger et al., 2001). The identification of early risk factors for future behavior problems is an ongoing challenge for developmental psychopathology researchers, particularly when behaviors may be due to normal and transient difficulties often associated with developmental challenges (Stormont, 2000).

Temperament

Temperament is defined as biologically based individual differences in reactivity and self-regulation and is relatively consistent across situations and stable over time (Rothbart & Bates, 1998; Rothbart & Derryberry, 1981). Previous temperament research has highlighted the importance of individual differences in reactivity to reward (approach) and punishment (withdrawal; Rothbart & Bates, 1998). The tendency to experience sensitivity to environmental stimulation as well as positive and negative emotions is known as reactivity. This is easily observable from infancy and early life where behavior is often dictated by reactive systems. The current study is based on a theory of temperament and personality, namely, Gray's Reinforcement Sensitivity Theory (Gray, 1987; J. A. Gray & McNaughton, 2000).

This theory proposes that separate neural systems mediate responses to different situations that involve reward, punishment, and conflict (simultaneous punishment and reward). The self-report measure of behavioral inhibition sensitivity (BIS)/ behavioral approach sensitivity (BAS) sensitivity was developed by Carver and White (BIS/BAS scales; Carver & White, 1994) to assess adult individual differences in these two constructs. They found that one factor reflected the inhibitory system (the BIS scale) and three factors reflected the approach system (the BAS scales: BAS Drive, the tendency to persistently pursue desired goals; BAS Reward Responsiveness, the tendency to experience positive responses in anticipation or receipt of a reward; and BAS Fun Seeking, the desire for novel rewards and the willingness to approach potentially rewarding situations with minimal reflection). Individuals who are motivated to escape and avoid conflict tend to score high on BIS sensitivity and have lower degrees of extraversion, while those who are motivated to approach and pursue rewards score high on BAS sensitivity and tend to be higher in extraversion (J. A. Gray & McNaughton, 2000).

BAS/BIS and psychological difficulties

BAS has previously been linked with impulsivity, the tendency to experience positive affect and the personality dimension of extraversion (Carver, 2006; Rothbart & Bates, 1998). In contrast, the tendency to experience negative affect has been linked with BIS sensitivity and is aligned with the personality dimension of neuroticism (Rothbart & Bates, 1998). Recent research highlights links between high BIS sensitivity and internalizing problems in children (Colder & O'Connor, 2004; Vervoort et al., 2010). For instance, Colder and O'Connor (2004) reported that higher levels of BIS sensitivity were

associated with internalizing problems in a sample of 63 children aged 9–12 years. Vervoort et al. (2010) found that higher levels of BIS sensitivity were related with an increase in symptoms of anxiety and depression in both clinically anxious and non-anxious children and adolescents (aged 9 to 18 years).

Comparatively, previous literature has mixed findings on the role of BIS and BAS and their relationship with externalizing problems. Some research suggests that high BAS sensitivity is related to impulsivity, and therefore associated to conduct problems (Colder & O'Connor, 2004; Hundt et al., 2008). Other research suggests that low BIS sensitivity is associated with externalizing problems, namely hyperactivity, because it leads to shortfalls in behavioral inhibition when faced with impending punishment (Quay, 1997; Thorell et al., 2004). Given that BAS and BIS are theoretically independent, it is plausible that a combination of low BIS and high BAS would result in higher likelihood of externalizing problems. Hundt et al. (2008) tested this prediction in a sample of 273 college students and reported that BAS is more strongly related to externalizing problems than BIS as high BAS was linked to numerous externalizing problems, including hyperactivity, alcohol abuse, substance abuse, and psychopathy, whereas low BIS was only linked to substance abuse and hyperactivity (only when inattentive symptoms were partialled out).

Executive function: Hot vs. Cool distinction

Executive function (EF) encompasses the set of higher-order cognitive abilities involved in controlling thought and action to support complex, goal-directed behavior (Diamond, 2006; Zelazo et al., 2003). It follows a relatively protracted developmental course, improving throughout childhood and beyond into adulthood (Anderson, 2002; Anderson et al., 2001), then declining with advanced age (Zelazo et al., 2004). Although EF is often considered as a domain-general cognitive function (Zelazo et al., 1997), recent research suggests that EF can be further differentiated. One proposal is that EF can be broken into two components, dependent on motivational significance: cool EF and hot EF (Hongwanishkul et al., 2005; Kerr & Zelazo, 2004; Prencipe et al., 2011).

Cool EFs, namely, working memory, inhibition, and shifting (Lehto et al., 2003; Miyake et al., 2000), are used when problem solving is relatively abstract and decontextualized. Hot EFs, such as decision-making within a motivational context (i.e., gambling or delay of gratification) or social reasoning (i.e., theory of mind; ToM), are used in situations that have emotionally significant consequences (i.e., loss or rewards; Andrews & Moussaumai, 2015; Bunch & Andrews, 2012; Bunch et al., 2007; Zelazo et al., 2004). Effective EF in childhood is associated with positive academic and social outcomes (Wilson et al., 2021) whereas EF deficits have been linked with poor mental health outcomes in childhood (Nigg et al., 1999; O'Toole et al., 2017).

EF and psychological difficulties

Impairments in EF are important in the development and persistence of conduct problems (Ogilvie et al., 2011). Cool EF skills, such as working memory and inhibition control, are pivotal for socially appropriate behavior (Morgan & Lilienfeld, 2000; Ogilvie

et al., 2011). Deficits in theory of mind, (ToM, one hot EF component), have been related to externalizing behavioral problems (Hughes & Ensor, 2006), callous unemotional behavior (Dadds et al., 2009), and conduct problems in children aged 9 to 11 (Sharp, 2008). Studies have also revealed positive associations between ToM abilities and prosocial behavior in 2- to 12-year-olds (Imuta et al., 2016). A recent longitudinal study has revealed a negative relation between cool EF measured at time one and conduct problems measured at time two in a sample of 1,657 6- to 11-year-old children, which was fully mediated by hot EF (ToM abilities) measured at time one (Austin et al., 2020).

EF and BAS/BIS

Gray's Reinforcement Sensitivity Theory describes how individuals' behavior follows from activity in two systems: the BAS and BIS. Both systems function independently from one another and are sensitive to different types of reinforcement. The tendency to experience sensitivity to environmental stimulation as well as positive and negative emotions is known as reactivity. Effortful control is the process that modulates these basic reactive systems (Rothbart & Posner, 2005). Moreover, EF and effortful control are similar constructs in that they both provide top-down control of thought, action, and emotion and they both develop slowly during childhood.

The iterative reprocessing model of EF (Zelazo & Cunningham, 2007) suggests that information that travels via the thalamus and amygdala is rapidly processed in the orbitofrontal cortex first to simply judge whether to approach or avoid a situation. The anterior cingulate cortex will then determine if further reflective processing is needed to weigh up and generate alternate responses. If more reflective processing is required, it is done so through a hierarchically arranged prefrontal system, starting in the orbitofrontal cortex, then sent to the ventrolateral, and finishing in the dorsolateral PFC. Therefore, reflective reprocessing represents a shift from hotter to cooler decision-making, wherein hotter decision-making is motivationally driven while cooler decision-making is more concerned with maintaining and manipulating abstract rules (Zelazo et al., 2010). In line with this model, it has been suggested that EF may help to control the tendency to experience strong emotions or one's response to environmental cues (Carver et al., 2008).

Recent studies have suggested a positive link between working memory (a component of cool EF) and the behavioral approach system (BAS composite scores) in a sample of 14 19- to 27-year-old adults, with activation often observed in the anterior cingulate cortex (J. R. Gray & Braver, 2002). Campbell et al. (2011) measured college students' extroversion based on their composite scores on BAS and Eysenck Personality Questionnaire-Revised and examined the associations with measures of EF. They found that participants with high extroversion performed best on updating tasks (e.g., Letter Rotation Task) which assessed the ability to integrate new information in ongoing cognitive processing, whereas those with low extroversion performed better on set shifting tasks (e.g., Wisconsin Card Sorting Test) which examined the ability to modify goal-seeking behavior based on changes in the rules. Similarly, Fino et al. (2014) found that 16 to 18-year-old adolescents' low BIS and high BAS composite scores indicated poorer ability to inhibit responses and enhanced reactivity to environmental cues, affecting their set shifting. Inconsistent with J. R. Gray and Braver's (2002) findings, Unsworth et al.

(2009) found that BAS composite scores were not related to any EFs in 138 college students with a mean age of 19.1 years, however the authors noted that only the operation span task was used in the study; therefore, it may not be sufficient to reflect participants' working memory capacity. Furthermore, Thorell et al. (2004) investigated the effect of EF and temperament on psychological problems in childhood (5-year-olds). Behavioral avoidance (BIS) was found to be negatively associated with social initiative but positively associated with social anxiety (internalizing problem). However, when examined in combination with an EF inhibition task (go/no-go task), social anxiety was only predicted by a combination of both high BIS and better inhibition. Therefore, the children with the highest levels of social anxiety were those who showed a strong tendency to withdraw and who were better at inhibiting dominant responses. This finding is surprising because, theoretically, individuals with poor executive control over strong behavioral predispositions would be expected to present with more psychological difficulties (Carver, 2008; Carver et al., 2008). This finding emphasizes the need to consider both cool and hot EF and highlights the possible moderating role of EF in understanding the relationships between BAS/BIS and psychological difficulties in childhood.

Aims and hypotheses

The current study aimed to investigate whether cool and hot EFs moderated the relationship between temperament and psychological difficulties, measured as internalizing and externalizing problems. In addition, Carver and White (1994) pointed out that the three subscales of BAS (Drive, Reward Responsiveness, and Fun Seeking) represented related but different concepts and should be examined separately. Unlike previous research that mainly used the composite score of BAS scales, the current study will treat the BAS scales independently to identify the potential links between EF, temperament and psychological difficulties. Previous research examining the associations of temperament and BIS/BAS with EF has focused on cool EF, whereas the current study will include measures of both cool EF and hot EF. It was hypothesized that hot and cool EFs would moderate the relationship between the three BAS scales and externalizing problem. Specifically, for children with poorer EF, there should be a positive association between BAS scores and externalizing problems. For children with higher EF, no significant associations were expected because good executive processes should serve a protective function. It was also hypothesized that hot and cool EFs would have a moderating effect on the relationship between BIS and internalizing problems. For children with poor EF, BIS scores should be positively related to internalizing problems, whereas for children with higher EFs, no significant associations were expected, again because better executive processes were expected to serve a protective function.

Method

Design

The current study used a cross-sectional design to examine the moderating effect of EF in the association between temperament and patterns of psychological difficulties in middle childhood.

Participants

One hundred and twenty-six children (67 females) aged between 5 and 12 years old and a parent/guardian of each child participated in the current study. Participants were recruited through a Brisbane suburban primary school via a school distributed information package sent home with students. Ethical clearance was obtained from the Griffith University Ethics Committee and all participants were treated in accordance with the National Statement of Ethical Conduct in Research involving Humans. Written consent was obtained from both the school principal and from each parent/guardian prior to study commencement. The study aims and methods were verbally described to each child and each child gave assent prior to participating in the study. Parents reported no history of brain injury, or diagnosis of learning or behavioral disorders in their children prior to assessment. The sample was predominately middle class according to parental socio-economic status ($M = 3.53$, $SD = 0.92$) as measured by the Scale of Occupational Prestige ranging from 1.2 to 6.9, with lower numbers reflecting higher SES (Daniel, 1983). The school from which participants were recruited scored 1118 on the Index of Community Socio-Educational Advantage (ICSEA; available from the *My School* website; www.myschool.edu.au) at the time of recruitment, which was somewhat higher than the national average of 1000. Despite the higher score, students were from a broad distribution of families from all income brackets.

Measures

Participants completed an assessment battery as part of a larger study. The cool and hot EF measures were administered in the same fixed order to all children: Gift Delay, Spatial Working Memory, Stop Signal, Intra-Extra Dimensional Shifting, Cambridge Gambling Task, and Strange Stories. Each child was assessed in two 1-hour sessions conducted 1 week apart. All the tasks except Strange Stories were conducted in the first session and they were piloted prior to the research to ensure that children as young as 5 years were able to understand the task instructions and make the required responses. The psychological difficulties and BIS/BAS sensitivity questionaries were responded to by parents.

Cool EF measures

Three cool EF measures were chosen from the Cambridge Neuropsychological Test Automated Battery (CANTAB; Cambridge Cognition, 2006). Working memory was measured using the Spatial Working Memory Task (SWM). The SWM required children to find hidden squares by searching through boxes displayed on a computer screen over 12 trials with varying difficulty (i.e., four, six, or eight boxes). The squares were hidden under predetermined but seemingly random boxes and once found under a box a square would not be found under the same box in the same trial. Thus, children were required to remember their previous search locations and avoid searching the same boxes or they would receive a between search error. Children would receive a within search error when they searched a previously empty box. The total error score was calculated to give an overall measure of working memory, with lower scores indicating better performance.

Inhibition was assessed using the Stop Signal Test (SST). Participants were instructed to respond as quickly as possible to arrows presented on the computer screen but to withhold their response when an arrow was paired with an auditory tone. Children were required to press the left button when a left arrow was displayed and vice versa for a right arrow unless the arrow was accompanied by an auditory stop tone. If a tone was played, participants were to refrain from pressing any button and just wait for the next trial to start. The SST contained five blocks with 64 trials each, with 25% being stop trials. If a participant made an incorrect left-right judgment, the word *wrong* was displayed. Correct responses and commission errors on stop trials did not illicit any feedback and length of the delay prior to stop signals was adjusted dynamically dependent on previous performance. Thus, the stop signal delay (SSD) increased after a successful inhibition and decreased after an unsuccessful inhibition, based on a staircase method. The stop signal response time (SSRT) quantifies the covert stopping process, providing an efficiency of inhibitory control index, with lower scores indicating better performance. The SSRT was calculated by subtracting the arithmetic mean of the measured SSD at which the participant was able to stop 50% of the time (SSD 50%) from the go trials median response time.

Attentional set shifting was assessed using the Intra-Extra Dimensional Shifting Task (IED). The computer screen displayed four boxes and two colored shapes whose location changed on each trial. Children were instructed to select a shape at random on the first trial. After each choice, feedback was provided to the participants. Children were to use this feedback to discern the sorting rule. When the sorting rule had been learned to criterion (i.e., six consecutive correct responses), the rule changed. The feedback displayed indicated that the previously correct choice was now incorrect (i.e., the other colored shape was now the correct choice). Rule changes reflected intradimensional shifts and occurred in stages 1 through 7. Stages 3 through 7 included white lines in the display, however, remained irrelevant to the task; therefore, children were required to filter out the irrelevant information to complete the remaining stages successfully. Stages 8 and 9 saw a rule change, wherein the white lines were now the relevant sorting dimension, reflecting an extra-intradimensional shift. Children needed to recognize that the white lines were now relevant to the task and refrain from using the color of the shapes as the relevant sorting rule. If the sorting rule was not discerned within 50 trials at any stage, the test was discontinued. Shifting ability was scored as the total number of errors adjusted for stages that children completed (range 1–9), with lower scores indicating poorer performance.

Hot EF measures

Hot EF was assessed using measures of motivational decision-making, delayed gratification, and ToM. Decision-making in a motivational context was assessed using the Gambling Task from the CANTAB. Children started with 100 points and were tasked with accumulating as many points as possible by guessing the location of a yellow token. In each trial, blue and red boxes were displayed on the computer screen and children were to guess which box (blue or red) contained the yellow token. After their selection, children wagered a percentage of their points (viz., 5%, 25%, 50%, 75%, 95%) based on how confident they were in their decision. Wagering stakes were presented one at a time, in either ascending or descending order until the participant selected a value. The task

was made up of 4 blocks, each containing 9 trials of either ascending or descending order (72 trials total). A block was discontinued if the points reached 1 or 0 and risk taking was calculated as the mean proportion of available points that the participant wagered on each trial. Delay aversion was calculated as the difference in risk-taking scores between the descending and ascending sequences, with lower scores indicating better performance (ranging from −.90 to .90). Decision quality (range 0–1) was derived from the proportion of trials in which the participant chooses the more likely option. Risk adjustment scores (ranging from −4.6 to 4.6) reflected the tendency to bet a higher proportion of points when a large majority of the boxes are of the chosen color, with higher scores indicating better performance.

Delayed gratification was measured using an adapted version of the Gift Delay Task (Wilson et al., 2017). Children were shown a display box filled with gifts (i.e., novelty stationary items and toys) which was kept in view throughout the assessment session. Initially, the participants were presented with a small closed box so that they could not see the items inside. Participants were told that they could choose the small box now, a medium box containing more items midway through the assessment, or a large box that contained more items at the end of the assessment. If the participant chose to take the small box, they were allowed to open the box, examine the contents and play with them for a short time. If the participant chose to delay, the small box was placed on the table as to remain visible whilst other tests were administered. Halfway through the session, a medium box was presented, and participants were given a second choice of either getting the medium box right now or waiting for the large box until the end. If the participant chose to delay again, they received the large box after completing all tasks in the session. If a participant changed their mind during the assessment asking to open the previously offered box, they were given the box during a break and scored accordingly to the box that they received. Children received a score of 0 if they chose the small box, 1 if they chose the medium box, and 2 if they waited until the end for the large box. Higher scores indicated the ability to delay gratification for a longer period of time.

ToM was assessed using the Strange Stories Task which has previously been used to assess advanced ToM in typically developing children (Happe, 1994; O'Hare et al., 2009; Wang et al., 2021). The task was made up of 12 stories including the following scenario types: lie, white lie, joking, pretending, misunderstanding, persuasion, appearance reality, figure of speech, sarcasm, forget, double bluff, and contrary emotions. In each story, there was a character (X) who said something that was untrue. To check their understanding of the story, participants were initially asked "Is it true, what X said?." ToM was assessed by then asking, "Why did X say this?." If the child gave an incorrect or physical state response, they were given a score of 0. For partial psychological state responses, children were given a score of 1, and if children gave a full and accurate psychological state response, they were given a score of 2. For the current study, two authors independently classified (with 100% agreement) the stories according to their level of affective tone (low versus high). Stories with high affective tone, those requiring explanations that referred to emotional states and feelings of the protagonist (e.g., guilt, hurt, offense) were used to measure hot EF in the current study. Therefore, the average score for the five stories with high affective tone (i.e., lie, white lie, sarcasm, persuasion, and contrary emotions) made up the ToM score, with lower scores indicating less advanced ToM.

Psychological difficulties

Psychological difficulties were assessed using the parent form of the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997). The 25-item questionnaire is made up of five subscales: Conduct Problems, Emotional Symptoms, Hyperactivity, Peer Problems, and Prosocial Behavior. Responses are recorded on a 3-point scale ranging from *not true* to *certainly true*. In the current study, the Conduct Problems subscale was used as a measure of externalizing problems, and the Emotional Symptoms subscale was used as a measure of internalizing problems.

BIS/BAS sensitivity

BIS/BAS sensitivity was assessed using an adapted parent report version of the BIS/BAS scales (Blair, 2003; Carver & White, 1994) which was sent home with the children for parents to complete and return. The questionnaire contains 20 items, made up of 4 subscales: BIS (7 items; e.g., "My child worries about making mistakes"), BAS Rewards Responsiveness (5 items; e.g., "When my child is doing well at something, they like to keep doing this"), BAS Drive (4 items; e.g., "When my child wants something, they usually go all the way to get it"), and BAS Fun Seeking (4 items; e.g., "My child is always willing to try something new when they think it will be fun"). Responses were scored on a 4-point scale ranging from *not like them* to *very like them* and scores were computed for each of the four subscales. In the present sample, both the BIS and BAS scales had good internal consistencies. Cronbach's alpha coefficients were .83 for BIS, .85 for total BAS, .86 for BAS Drive, .75 for BAS Fun Seeking, and .72 for BAS Reward Responsiveness.

Statistical analysis

Data were inspected for univariate outliers, multivariate outliers, and skewness. Where variables were significantly skewed, the appropriate transformations were performed. Delay of gratification was negatively skewed without transformation and positively skewed with transformation; therefore, the untransformed scores were used in the analyses. The data were analyzed with and without outliers, and with and without transformations and if the pattern of statistical significance did not vary, then the untransformed data was used and/or all cases were included in the analyses (Tabachnick & Fidell, 2007). Composite measures of cool (SWM total errors reversed; SSRT reversed; and IED errors adjusted for stages completed and reversed) and hot EF (Gift delay score; Gambling task decision quality, delay aversion reversed, risk adjustment; and ToM high affective) were calculated from the averaged z score on each of the constituent measures and were centered around a mean of zero.

The SPSS PROCESS macro version 4.0 (Hayes, 2017) was used to examine any moderating effect of EF on the relationships between temperament (BIS and BAS) and psychological difficulties (internalizing and externalizing problems). Because of the large age range of the sample, age was included as an independent variable in all analyses. Questionnaire responses were obtained for 83% of participants (n = 105) as some parents did not return the questionnaire. Children whose parents did not return the questionnaires did not differ from those who did return them on any measure of EF, consistent with a pattern of missingness at random (Rubin, 1976). Therefore, data of these participants were excluded listwise for relevant analyses.

Results

Means, standard deviations, and correlational analyses for each EF composite score, age, gender, temperament, and psychological difficulties is displayed in Table 1. Gender was not significantly correlated with BIS, BAS, or parent-reported conduct (externalizing) and emotional problems (internalizing). All BAS scales (drive, reward responsiveness, and fun seeking) were significantly moderately correlated with one another, however only BAS Drive was significantly positively correlated with conduct problems (moderate relationship). There was a significant strong positive correlation between BIS sensitivity and emotional problems (internalizing) but no relationship was found between BIS and conduct problems (externalizing). BIS was not related to BAS Drive or Fun Seeking, which is consistent with the notion that these constructs are theoretically independent. However, there was a significant, albeit weak relationship between BIS and BAS Reward Responsiveness.

BAS and externalizing problems

SPSS with the PROCESS macro, Version 4.0 (Hayes, 2017) was used to assess whether the relationship between BAS and externalizing problems (conduct problems) was moderated by hot and cool EF. Parent-reported conduct problems was the dependent variable, and the parent-reported BAS drive, hot EF, cool EF, age, and the product terms between the BAS drive and hot EF, and BAS drive and cool EF were the independent variables. All variables were standardized prior to entry. In combination, the independent variables explained 22.2% of the variance in conduct problems reported by parents, $R^2 = .22$, $F(6, 98) = 4.67$, $p < .001$. By Cohen's (1988) conventions, the combined effect is considered "medium" ($f^2 = .285$). The change in R^2 associated with the product of BAS drive and hot EF was significant, R^2 change = .087, $F(1, 98) = 10.95$, $p = .001$, but the R^2 change associated with the product of BAS Drive and cool EF was not significant, R^2 change = .025, $F(1, 98) = 3.12$, $p = .080$. Further details are provided in Table 2 (upper panel).

Table 1. Summary of means, standard deviations, and correlations for age, gender, EF, temperament and measures of psychological functioning.

Variable	M	SD	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. Gender			-	−.056	−.085	.024	−.161	−.146	−.049	−.129	.070	−.170
2. Age	8.43	2.12		-	.691**	.760**	.123	−.041	−.033	−.025	−.091	−.142
3. Cool EF Composite	.00	.77			-	.666**	.118	−.058	−.030	−.139	−.135	−.126
4. Hot EF Composite	.01	.68				-	.152	−.027	.020	−.094	−.097	−.139
5. BAS Drive[a]	5.07	3.13					-	.427**	.382**	.083	.317**	.045
6. BAS Reward Resp[a]	12.05	2.27						-	.480**	.247*	.063	.087
7. BAS Fun Seeking[a]	6.51	2.79							-	−.090	.155	−.062
8. BIS[a]	11.77	4.37								-	.078	.610**
9. Conduct Problems[a]	1.35	1.49									-	.266**
10. Emotional Problems[a]	2.00	2.04										-

* $p < .05$, ** $p < .01$; EF = Executive Function, BAS = Behavioral Approach Sensitivity; BAS Reward Resp. = BAS Reward Responsiveness; BIS = Behavioral Inhibition Sensitivity; [a] = parent reported data $N = 105$.

Table 2. Moderation of the association between BAS drive and parent-reported conduct problems by Cool EF and Hot EF composite scores, CGT risk adjustment, and ToM.

			95% *CI*			
Variable	*B*	*SE*	Lower	Upper	*p*	R^2 change
Age	.013	.071	−.127	.154	.851	
BAS Drive	.336	.090	.157	.514	< .001	
Cool EF	−.206	.170	−.543	.132	.230	
Hot EF	−.036	.228	−.489	.417	.876	
BAS Drive × Cool EF	−.296	.167	−.629	.037	.083	.025
BAS Drive × Hot EF	.578	.174	.231	.925	.001	.087
Both product terms					.005	.089
Age	.011	.062	−.1121	.133	.864	
BAS Drive	.327	.090	.148	.506	< .001	
Cool EF	−.275	.167	−.605	.055	.101	
CGT risk adjustment	.030	.110	−.188	.248	.784	
BAS Drive × Cool EF	−.150	.145	−.436	.138	.306	.009
BAS Drive × CGT risk adjustment	.322	.103	.119	.526	.002	.079
Both product terms					.008	.082
Age	−.022	.068	−.157	.112	.75	
BAS Drive	.360	.094	.173	.546	< .001	
Cool EF	−.213	.167	−.547	.116	.201	
ToM	.043	.123	−.202	.288	.730	
BAS Drive × Cool EF	−.070	.147	−.361	.221	.634	.002
BAS Drive × ToM	.234	.110	.016	.452	.036	.038
Both product terms					.093	.041

CI = Confidence Interval; BAS = Behavioral Approach Sensitivity; EF = Executive Function; CGT = Cambridge Gambling Task; ToM = Theory of Mind.

Figure 1 depicts the significant interaction between BAS Drive and hot EF. As per the procedure outlined by Aiken et al. (1991), the simple slopes represented the regression of BAS Drive on Conduct Problems, where hot EF values corresponded to the mean and one standard deviation above and below the mean, while cool EF was held constant. In contrast

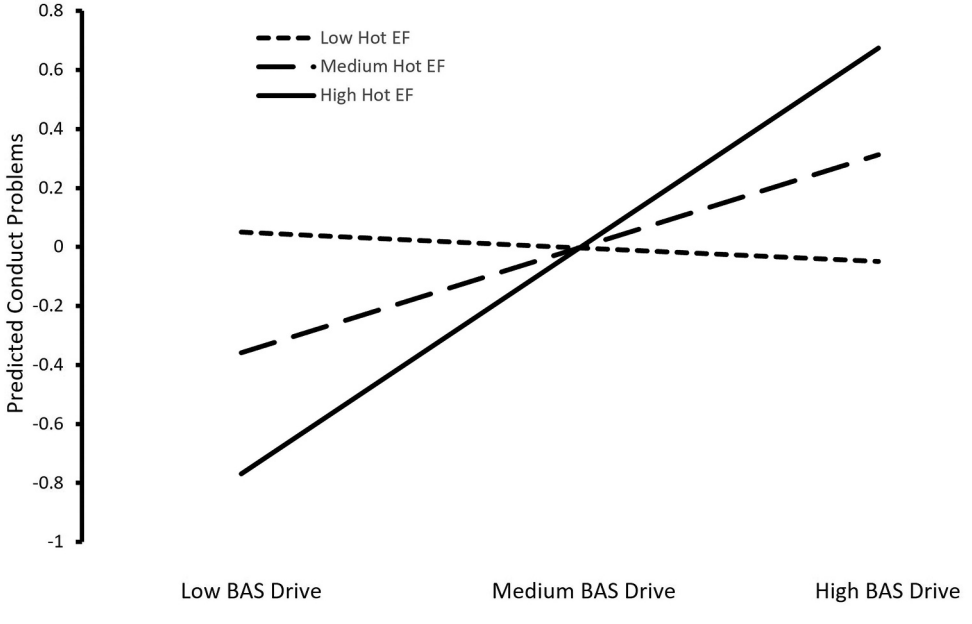

Figure 1. Predicted conduct problems at different levels of BAS drive and Hot EF functioning.

to expectations, the relationship between BAS Drive and conduct problems was strongest when hot EF task performance was high and weakest when performance was low. Inspection of the conditional effects confirmed that the association between BAS Drive and Conduct problems was significant when hot EF was at medium ($t = 3.73$, $p < .001$) and high ($t = 4.93$, $p < .001$) levels, but not at low levels of hot EF ($t = -0.33$, $p = .739$).

Further analyses were conducted to explore significant interaction of BAS Drive with hot EF. These analyses were the same as the moderation analysis described above except that a single measure of hot EF was entered instead of the composite hot EF measure. In each analysis, parent-reported conduct problems was the dependent variable. Age, BAS drive, cool EF, the single measure of hot EF, and the product terms between the BAS drive and the hot EF measure, and between BAS drive and cool EF composite were the independent variables. The interaction term involving a measure of hot EF was significant in two of the five analyses.

In the analysis with CGT risk adjustment scores as the measure of hot EF, the independent variables accounted for 21.65% of the variance in conduct problems, $R^2 = .217$, F (6, 98) = 4.51, $p < .001$. By Cohen's (1988) conventions, the combined effect is considered "medium" ($f^2 = .280$). The change in R^2 associated with the product of BAS drive and CGT risk adjustment was significant, R^2 change = .079, F (1, 98) = 9.86, $p = .002$, but the product term involving BAS Drive and cool EF was not, R^2 change = .009, F (1, 98) = 1.06, $p = .306$. Further details are provided in Table 2 (middle panel). Figure 2 suggests that the relationship between BAS Drive and conduct problems was strongest when CGT risk adjustment performance was high and weakest when performance was low. Inspection of the conditional effects confirmed that the association between BAS Drive and Conduct problems was significant when risk adjustment scores were at medium ($t = 3.62$, $p < .001$) and high ($t = 4.82$, $p < .001$) levels, but not at low levels of risk adjustment ($t = -0.01$, $p = .990$).

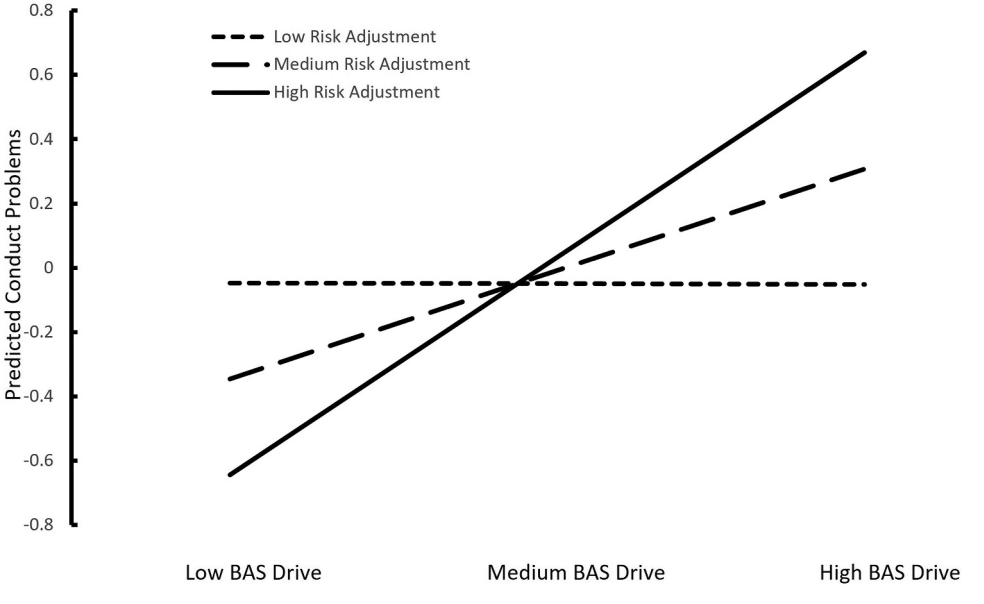

Figure 2. Predicted conduct problems at different levels of BAS drive and risk adjustment.

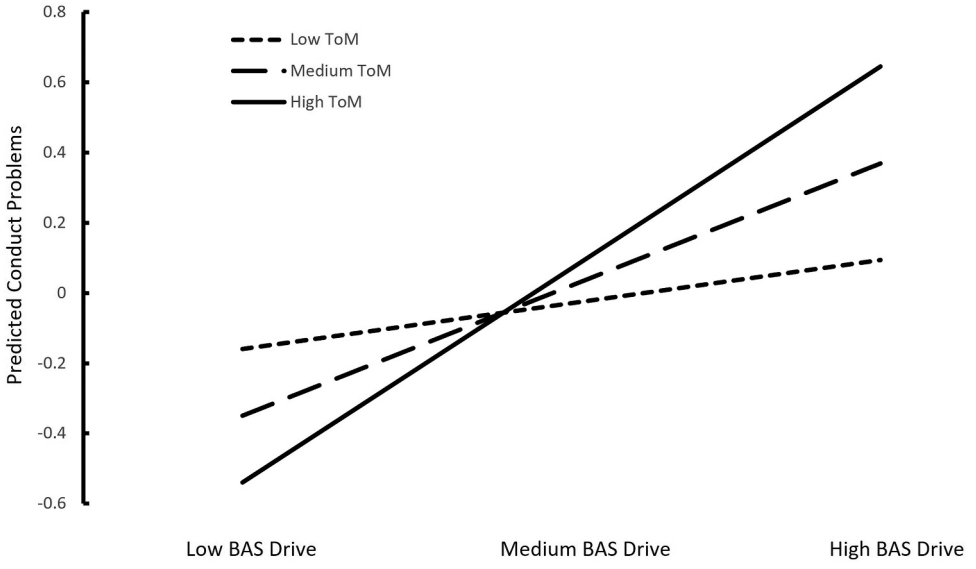

Figure 3. Predicted conduct problems at different levels of BAS drive and theory of mind.

In the analysis with ToM scores as the measure of hot EF, the independent vaiables accounted for 17.3% of the variance in conduct problems, $R^2 = .173$, $F\,(6, 98) = 3.42$, $p = .004$. By Cohen's (1988) conventions, the combined effect is considered "small" ($f^2 = .21$). The change in R^2 associated with the product of BAS drive and ToM was significant, R^2 change = .038, $F\,(1, 98) = 4.54$, $p = .036$, but the product term involving BAS Drive and cool EF was not, R^2 change = .002, $F\,(1, 98) = 0.23$, $p = .63$. Further details are shown in Table 2 (lower panel). Figure 3 suggests that the relationship between BAS Drive and conduct problems was strongest when ToM performance was high and weakest when ToM performance was low. Inspection of the conditional effects confirmed that the association between BAS Drive and conduct problems was significant when ToM scores were at medium ($t = 3.83$, $p = < .001$) and high ($t = 3.94$, $p < .001$) levels but not a low level ($t = 0.92$, $p = .361$).

BIS and internalizing problems

A similar analysis was conducted to investigate whether the relationship between behavioral inhibition sensitivity (BIS) and internalizing problems (emotional problems) was moderated by hot and cool EF. Parent-reported emotional problems on the SDQ (internalizing) was the dependent variable. Age, BIS scores, cool EF composite, hot EF composite, and product terms between BIS scores and hot EF, and BIS scores and cool EF were the independent variables. Together the predictors accounted for a significant 41% of the variance in emotional problems, $R^2 = .410$, $F(6, 98) = 11.33$, $p < .001$. By Cohen's conventions, the combined effect is considered "large" ($f^2 = .69$; Cohen, 1988). The change in R^2 associated with the product of BIS drive and hot EF was not significant, R^2 change = .017, $F\,(1, 98) = 2.74$, $p = .101$. Similarly, the change in R^2 associated with the product term involving BIS and cool EF was not significant, R^2 change = .011, $F\,(1, 98) = 1.90$, $p = .172$. Further details are provided in Table 3.

Table 3. Moderation of the association between BIS and parent-reported emotional problems by Cool EF and Hot EF composite scores.

			95% *CI*			
Variable	*B*	*SE*	Lower	Upper	*p*	R^2 change
Age	−.092	.063	−.216	.032	.15	
BIS	.635	.080	.477	.794	< .001	
Cool EF	.133	.149	−.163	.430	.375	
Hot EF	−.001	.198	−.395	.392	.995	
BIS × Cool EF	.209	.152	−.092	.511	.172	.011
BIS × Hot EF	−.308	.186	−.677	.061	.101	.017
Both product terms					.244	.017

CI = Confidence interval; BIS = Behavioral Inhibition Sensitivity; EF = Executive Function.

Discussion

The current study aimed to investigate whether EF moderated the relationships between temperament and psychological difficulties, as measured by internalizing and externalizing problems. Partly in line with the hypotheses, hot EFs moderated the relationship between BAS Drive and externalizing problems. However, inconsistent with the hypotheses, neither cool nor hot EFs moderated the relationship between BIS and internalizing problems.

BAS and externalizing problems

Scores on BAS Drive were significantly associated with conduct problems reported by parents, however BAS Reward Responsiveness and BAS Fun Seeking were not. One possible explanation is that whereas Reward Responsiveness and Fun Seeking involve positive affect, desired events, and the pursuit of pleasure, Drive involves the motivation to initiate and maintain goal-directed behavior largely independent of whether these goals are pleasurable. Another distinction is that BAS Drive measures the strength with which reward outcome impacts on subsequent behavior whereas Reward Responsiveness indexes the degree to which individuals derive pleasure from reward (Hickey et al., 2010). While parents might interpret positive responses to rewards and the pursuit of pleasure as reasonable, they might interpret the sustained pursuit of goals for which there are no obvious rewards as naughtiness or unreasonable behavior in their children. This would explain why BAS Drive was positively correlated with conduct problems, while the other BAS subscales were not.

Other explanations relate to the psychometric properties of the BAS subscales. In the current research, reliability was somewhat higher for the Drive subscale than for Reward Responsiveness and Fun Seeking. Other researchers (Smillie et al., 2006) have argued that the focus of the Fun Seeking subscale is broader than the other subscales and that it lacks sensitivity in school-aged samples. These differences in reliability and sensitivity might also have contributed to the current findings.

Hot but not cool EF significantly moderated the relationship between BAS Drive and conduct problems, such that the relationship was observed when performance on Hot EF was at or above average levels, but not at the below average level of Hot EF. This finding, however, was opposite to what was expected. It was anticipated that poorer executive control over reactive temperament would lead to a stronger association between BAS Drive and conduct problems.

Overall, the levels of conduct problems reported in the current sample was considered low but consistent with levels found in a sample of the normal Australian community (Mellor, 2005). However, for the subset of children with high BAS Drive and high hot EF levels, conduct problems approached levels that would be of clinical significance, if accompanied by reports of significant impact by parents. This finding is reminiscent of previous childhood psychopathy research. One study investigated reward dominance and psychopathology in 132 children aged 6 to 13 years old (O'Brien & Frick, 1996). The children completed a computer task, measuring reward dominance, wherein they were given an initial number of points and they would play a game where they could lose or win a point on each trial following unsuccessful or successful outcomes, respectively. The children could choose to exchange their points for prizes at any stage, with the value of the prizes increasing with higher points. The probability of a successful outcome trial decreased over the course of a game from 90% to 0%, therefore the higher the number of trials that a child played indicated a higher level of reward dominance. The persistent pursuit of rewards is consistent with a high BAS Drive (Carver & White, 1994). The study reported that conduct disorder was associated with reward dominance response styles that reflect high BAS only for children without a comorbid anxiety disorder and argues that this subgroup of children fit within the construct of psychopathy (Frick et al., 1994), and that the relationship in this subgroup suggests a possible moderating role of emotion regulation. Perhaps the ability to effectively manage anxiety during goal pursuit/risky decision-making (as would be expected with high performance on hot EF tasks) allows individuals to perform well in risky or motivationally significant situations. Therefore, these children may be motivated to pursue goals that are of personal significance even if they are contrary to societal or parental expectations. This notion may account for the current study's findings that high levels of conduct problems were more likely in the subgroup of children with high BAS Drive and average and higher hot EF.

Further analyses showed that two measures of hot EF (CGT risk adjustment and ToM) underpinned the observed moderation involving hot EF. The relationship between BAS Drive and conduct problems was significant and positive when CGT risk adjustment or ToM scores were at or above average, but not when performance was below average.

As noted, the positive relationship between Drive and conduct problems was observed for children with average or above average CGT risk adjustment performance and was strongest when performance was above average. To the extent that higher risk adjustment scores on the CGT translate to risk adjustment in other situations, higher performing children might demonstrate higher confidence to initiate and pursue goals in their daily lives, perhaps beyond the level that their parents think is appropriate or feel comfortable with. If so, higher risk adjustment ability would exacerbate/strengthen the overall positive association between Drive and conduct problems. This interpretation is tentative, but it suggests an avenue for further research.

The finding that ToM moderated the relationship between BAS Drive and conduct problems might also be consistent with previous research showing that children who bully others scored higher on social cognition (measured by ToM and emotion understanding) than those who are the recipients of bullying or children who either assist or reinforce those who bully (Sutton et al., 1999). It was concluded that those who bully may use their superior knowledge of other children's mental states to manipulate others and maintain power. Future research should continue to

examine the interactive effects of BAS drive and hot EF skills, particularly risk adjustment and ToM, in order to understand the psychology of bullying and conduct problems in children.

BIS and internalizing problems

Regarding the relationship between BIS sensitivity and internalizing problems, as measured by parents reports of their children's emotional problems, BIS was found to account for significant variance, and the effect was large according to Cohen (1988). Neither hot nor cool EF significantly predicted emotional problems, and no additional variance was accounted for by the interactions between BIS and hot EF, and BIS and cool EF. Previous theory suggests that poorer executive control of temperament would result in greater expression of psychological difficulties (Carver, 2008; Carver et al., 2008); however, some research has found the opposite, wherein high levels of both BIS and cool EF (inhibition) predicted the highest level of social anxiety (Thorell et al., 2004). Inconsistent with previous research neither hot nor cool EF was found to differentially moderate BIS in the current study or uniquely predict internalizing problems.

It is important to note that the sample used in the current study had low levels of emotional problems, consistent with levels found in a normal Australian community sample (Mellor, 2005). However, for the subsets of children with high BIS and high cool EF performance and high BIS and low hot EF performance, the levels of predicted emotional problems approached levels of clinical significance if accompanied by significant impact reports from parents. This pattern is suggestive of equifinality, that is, there may be more than one pathway to emotional problems (Cicchetti & Rogosch, 1996). More research is needed to understand whether hot or cool EF differentially moderate the relationship between BIS and emotional problems in middle childhood. Moreover, one previous study highlighted the limited agreement between parent and child reports of problem behavior on SDQ in a clinical sample of 37911- to 18-year-old Australian children and their parents (Van der Meer et al., 2008). As a result, another possible reason for the lack of moderating effect of EFs on the relationship between BIS and internalizing problems could be that the emotional problems were measured by parent-reported data on SDQ.

It may be beneficial to examine the interactive effects of BIS and hot and cool EF with a clinical sample to determine whether the different subtypes of internalizing problems can be differentiated by individual EF profiles. Take the view of ego control from the psychoanalytic personality dimension theory (Block, 2002; Block & Block, 1980). It is proposed that ego control lies on a continuum, from extreme under control to extreme over control (Derryberry & Rothbart, 1997), and that an individual with excessive under control is likely to be impulsive and immediately express affect, even when it is socially inappropriate or may have a negative impact on them. On the other hand, those who have excessive over control would inflexibly control affect expression and would delay gratification even when it is not necessary. In situations with conflict, those with high BIS sensitivity and high cool EF may use their cool EF to control their strong anxiety response. If applied in excess and inflexibly, the restriction of appropriate affect may lead to internalizing problems, consistent with the over controlled personality previously

described (Block & Block, 1980). An individual with high BIS sensitivity and low hot EF performance on the other hand would have difficulty regulating affect in situations with strong motivational significance or conflict, more likely responding to these situations impulsively and with high levels of emotion expression. If applied excessively and inflexibly, the lack of emotional control may also lead to internalizing problems, consistent with the previous description of an under controlled personality (Block & Block, 1980). The current sample had low levels of emotional problems, therefore, examining samples with higher levels of emotional problems may help to distinguish whether hot or cool EF moderates the relationship between BIS and internalizing problems.

Implications

Overall, the relationship between temperament, measured by BAS, and psychological difficulties, measured as conduct problems, was moderated by EF, particularly hot EF. Therefore, by examining the interactions between temperament indices, such as BAS sensitivity, and EF, we may be able to predict broad categories of psychological problems in middle childhood. This is not a new idea, as previous literature has outlined that specific EF profiles may discriminate between control and clinical populations such as Autism, ADHD, and Tourette's Syndrome (Ozonoff & Jensen, 1999). Additionally, the different relationships between hot and cool EF with BIS and BAS and internalizing and externalizing problems provides evidence of a hot-cool distinction in middle childhood, further supporting the importance of these constructs and that they should be investigated separately.

In the current study, hot EF was found to exacerbate the relationship between BAS and conduct problems. High BAS Drive, which reflects strong tendencies to pursue goals persistently, when combined with high hot EF, which reflects the ability to perform well in risky or motivationally significant situations and higher levels of social understanding, predicted more conduct problems. Children with this combination may seek to use these skills to satisfy their own goals, despite the expectations of their parents or society, therefore it may be more difficult to parent these children effectively. A review of impulsivity and adolescent substance abuse (Gullo & Dawe, 2008) found that while a strong reward drive is often associated with higher risk of negative health behaviors (i.e., substance abuse), reward drive (when associated with extraversion and positive affect) can also be a protective factor for later social support and general life adjustment. In addition, other social and contextual factors (i.e., peer and family relationships) are also important in shaping children's outcomes. More research is needed focusing on how EF impacts BIS and emotional problems.

Limitations and future directions

The external validity of the study may be limited by the participant sample. While the sample was recruited from a middle-class community and had relatively unconfounded socio-economic differences, the findings may not be generalizable to a more diverse range of socioeconomic groups or residential settings (i.e., rural communities). Future research would also be strengthened by including multiple informant (i.e., parents, teacher, peers, and self-report) measures for the questionnaires to obtain a clearer picture of functioning (Achenbach, 2006). Research should continue to identify risk factors for

later psychological difficulties (Stormont, 2000) and it is suggested that future research investigate whether the concurrent relationships observed in the current study are evident when followed longitudinally.

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ORCID

Christy Hogan http://orcid.org/0000-0001-7325-9695
Si Wang http://orcid.org/0000-0001-9458-8914
Glenda Andrews http://orcid.org/0000-0001-8047-9151
David Shum http://orcid.org/0000-0002-4810-9262

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