



# OPEN Emotion regulation, not executive functioning, mediates longitudinal links between unpredictability in adolescence and social connectedness in young adulthood

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Prior research has demonstrated that environmental unpredictability is associated with poor social functioning, though the mechanisms that underlie this association are largely unknown. The present study examined whether cognitive reappraisal and executive functioning mediate the longitudinal associations between unpredictability in adolescence and social connectedness in young adulthood, evaluating distinct effects on perceived and objective measures of social connectedness. The sample included 167 adolescents (47% girls) who were assessed at six time points, beginning in early adolescence ( $M_{\text{age}} = 14$  years) and ending in young adulthood ( $M_{\text{age}} = 22$  years). Adolescents and their respective caregivers each reported on their perceived household chaos at Time 1 (ages 14–15). Adolescents reported on emotion regulation strategy (i.e., cognitive reappraisal) and completed behavioral tasks assessing executive functioning (i.e., working memory, inhibitory control, cognitive flexibility) at Time 2 (ages 16–17), and reported on social connectedness at Time 3 (ages 21–22). The results of testing the hypothesized mediation model using structural equation modeling indicated that household chaos was statistically predictive of lower cognitive reappraisal and lower executive functioning. In turn, lower cognitive reappraisal was statistically predictive of lower social connectedness in young adulthood. Significant indirect effects were found from household chaos to lower social connectedness through less frequent cognitive reappraisal. The findings highlight the importance of adolescent cognitive reappraisal in the maintenance of young adult social connectedness. The developmental cascades from unpredictable household conditions to poor social connectedness, and implications for prevention and intervention are discussed.

**Keywords** Household chaos, Unpredictability, Executive functioning, Emotion regulation, Social connectedness, Social relationships

The transition from adolescence to young adulthood is a critical developmental period marked by increased social, emotional, and cognitive maturation, yet heightened adaptational demands are also placed on the individual as one is introduced to new social situations<sup>1</sup>. Adolescents displaying high self-regulatory capabilities are more likely to engage in prosocial behaviors and less likely to engage in transgressive behaviors, which promotes well-preserved social relationships<sup>2</sup>. Extant research has highlighted household chaos, characterized by moment-to-moment unpredictability and a lack of routine in the home, as a pervasive environmental stressor and robust indicator of poor early self-regulation and social adjustment<sup>3,4</sup>. The current study used six years of longitudinal data to investigate prospective links from household chaos in early adolescence to social connectedness in young adulthood. Specifically, emotion regulation and executive functioning were examined as two distinct self-regulatory pathways linking early unpredictable experiences to later social functioning.

Environmental unpredictability is a common environmental stressor among households as families struggle to maintain structured routines that include time with each other<sup>5</sup>. A systematic review reported links between

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household chaos, an indicator of unpredictability, and higher likelihoods of deleterious outcomes including cognitive, socio-emotional, and behavioral problems in child and adolescent samples<sup>4</sup>. Furthermore, recent longitudinal studies have demonstrated that unpredictability is negatively associated with youth outcomes, over and above the known negative effects of poverty<sup>6,7</sup>. Together, these findings underscore the significance of understanding the developmental consequences of growing up in unpredictable environments.

When children experience a lack of routine and unstable parental support, their development may be disrupted in a way that facilitates more maladaptive behaviors across the lifespan<sup>6</sup>. In other words, unpredictable environments may leave a child unable to develop the capacity for exerting self-regulation, stemming from an inability to identify patterns in momentary outcomes of one's actions and reduced opportunities to learn about the rewarding nature of social bonds<sup>8</sup>. Self-regulation encompasses skills related to emotional regulation and cognitive control in service of a goal or to maintain socially appropriate behavior<sup>9,10</sup>. Deficits in these self-regulatory skills increase risk for maladaptive social functioning<sup>11</sup>.

Young adulthood is a period characterized by the need for social engagement, yet young adults in contemporary society face more barriers to social connectedness than ever before. A cross-temporal meta-analysis reported that loneliness among young adults increased steadily over a 43-year period<sup>12</sup>, and loneliness was particularly exacerbated during COVID-19<sup>13</sup>. Considering the deleterious social contexts that contemporary young adults face, high-quality social relationships are crucial for their well-being, as they can positively contribute to mental health outcomes by buffering stress and reducing the risk of psychopathology<sup>14,15</sup>. Prior research reports negative associations between early unpredictability and perceived social support in childhood and adolescence, suggesting that those who grew up in unpredictable environments may be less likely to benefit from close social relationships compared to those raised in more predictable environments<sup>16,17</sup>. In a sample of maltreated and non-maltreated adolescents, adolescents across both groups reared in unpredictable childhood environments were significantly more likely to engage in aggressive and exploitative (e.g., lying, cheating, stealing) behaviors, which jeopardizes future opportunities for prosocial interaction<sup>6</sup>.

The link between environmental unpredictability and poor social connectedness may, in part, be explained by life history theory. According to life history theory, humans who are reared in environments rife with chaos or random variation may adjust to that environment by taking advantage of more immediate opportunities, adopting a cognitive schema that future rewards are uncertain, and consequently engaging in less self-regulation to avoid depleting resources<sup>18,19</sup>. Thus, this theory rooted in evolutionary psychology provides insight into how cognitive representations of the world may become rewired to propagate less regulated behaviors due to the lived experiences of unpredictability.

While life history theory explains *how* self-regulatory skills may develop differently within people reared in varying environmental conditions, socioemotional selectivity theory offers insight into *why* the motivation to employ self-regulation—or the selective use of specific self-regulatory skills—may be compromised following exposure to unpredictable conditions. According to socioemotional selectivity theory<sup>20</sup>, an expansive time horizon (i.e., a cognitive schema of time and opportunity as plentiful) is thought to result in more motivation towards learning one's social world (e.g., getting to know someone new). However, environmental unpredictability limits the perception of time because one becomes acclimated to focusing on the present rather than on the future<sup>21</sup>. Under this theoretical framework, an individual with a limited time-horizon may be less likely to make advances in deepening their relationships with people as each action may be perceived as trivial compared to other actions that may incur more emotionally salient rewards (e.g., earning money, using substances). Moreover, long-standing research on self-regulation suggests that humans generally tend to perceive self-regulatory endeavors as wasteful if time is perceived to be limited and uncertain<sup>22</sup>.

Greater emotional value may be placed on close relationships because more support is received, which would prompt a *smaller* number of *strong* social relationships. Scholarly work demonstrates that smaller social circles are more common for people who perceive their time as limited, which often makes these social circles be perceived as more meaningful<sup>23</sup>. Alternatively, greater emotional reward may be derived from the accumulation of novel social information, which may engender a *larger* number of *weak* relationships. Indeed, research within the sociological field suggests that novel social information is most often gathered from weak acquaintances or less strong social ties, whereas close friends are usually more up to date with one another, discussing novel information less often<sup>24</sup>. It is possible that some people find the retrieval of novel information more emotionally rewarding than close ties, where such retrieval is less common; however, further investigation is warranted, as no research to date has examined this possibility. Nonetheless, these nuances in the quantity and quality of social connections emphasize the empirical need to examine both aspects of social connectedness.

Social connectedness has been proposed as a multifactorial construct, emphasizing the importance of considering both structural (i.e., quantitative) and functional (i.e., qualitative) aspects of social connectedness to achieve a holistic view of engagement within one's social sphere<sup>25</sup>. Accordingly, the current study adopts a two-pronged approach to capture social connectedness: (a) social embeddedness, an objective or structural domain (e.g., number of social ties, number of social network domains in which one is highly involved) and (b) perceived social connectedness, a subjective or functional domain (e.g., feelings of closeness, feelings of trust and support among friends and family).

Self-regulation is integral to the success of social relationships, but the development of these skills is highly vulnerable to stressful family environments. Developmental science literature suggests that adolescence is a crucial time for both emotion regulation and executive functioning, two prominent indicators of self-regulation, as emotion regulation strategies and executive functioning improve reliably across adolescence, paving the way to emotional and cognitive maturity in young adulthood<sup>26–28</sup>. Robust negative links between environmental unpredictability and self-regulatory skills exist within both evolutionary and developmental psychology literature<sup>18,29,30</sup>, yet few studies have examined such skills during adolescence as potential mediators in the link between unpredictability and social functioning in adulthood.

Household chaos, a common form of environmental unpredictability, has been shown to deleteriously affect the development of self-regulatory skills including emotion regulation (i.e., management of the experience and expression of emotion)<sup>30</sup> and executive functioning (i.e., higher-order behavioral control)<sup>31</sup>. Specifically, household chaos is predictive of difficulties in modulating negative emotions like withdrawal, sadness, and fear among young children<sup>32</sup>. Among young adults, environmental unpredictability in early childhood negatively predicted romantic relationship quality, and this link was mediated by young adult emotion regulation difficulties<sup>33</sup>. In particular, cognitive reappraisal involves changing the interpretation of a situation and is considered an adaptive emotional strategy in most contexts<sup>34</sup>. Furthermore, it is strongly predictive of social competence and perceived social support<sup>35,36</sup>.

Likewise, good executive functioning—consisting of working memory, inhibitory control, and cognitive flexibility<sup>37</sup>—is crucial for high-quality social interactions. Inhibitory control difficulties, or difficulty restraining one's behavioral impulses, are also related to higher social anxiety and loneliness as well as poorer friendship quality<sup>38,39</sup>. Cognitive flexibility, a subcomponent of executive functioning involved in quickly shifting mental states, is helpful when building cognitive representations based on a description (i.e., seeing things from others' perspectives) and for building socially coordinated plans<sup>40</sup>. Additionally, this skill may be recruited when engaging with social ties within multiple social domains (e.g., church peers, high school peers, parents) as the ability to flexibly change behavior and speech is critical to navigating social situations with varying norms and rules. Indeed, working memory is also predictive of social network size<sup>41</sup>. Interestingly, some research on unpredictability and executive functioning suggests that exposure to unpredictability can produce adaptive changes in executive functioning<sup>42</sup>. Taken together, prior research does not present a clear pattern, highlighting the need for more research evaluating whether unpredictability positively or negatively affects executive functioning.

The purpose of the present study is to examine emotion regulation and executive functioning in middle adolescence (ages 16–17) as potential mediators in the link between environmental unpredictability in early adolescence (ages 14–15) and social connectedness in young adulthood (ages 21–22). Adolescents in the current sample transitioned into young adulthood (ages 19–20) during the COVID-19 pandemic. The current study contributes to the literature on early environmental stress and young adult social connectedness in several important ways. First, it uses a longitudinal approach to examine young adult social connectedness following stressful environments in adolescence—a link that has yet to be evaluated across the transition from adolescence to adulthood. Second, it goes beyond identifying distal outcomes of environmental unpredictability by evaluating two theoretically poignant mechanisms that may underlie those associations and may represent targets for prevention and intervention following early environmental unpredictability. Despite evidence that both cognitive reappraisal and executive functioning can independently affect social relationships, no systematic distinction has been made between them when examining their mediating roles in the link between environmental unpredictability and social connectedness. In other words, it is unclear which self-regulatory capacity plays a stronger role in propagating poor adult social outcomes following unpredictability. Third, research has yet to simultaneously evaluate distinct effects on structural and functional domains of social connectedness, which may help elucidate differences between the two as a function of self-regulation.

It was hypothesized that (1) environmental unpredictability in early adolescence would statistically predict weaker social connectedness in young adulthood, (2) less emotion regulation (cognitive reappraisal) would mediate the association between unpredictability and adult social connectedness, and (3) poorer executive functioning would mediate the association between unpredictability and adult social connectedness. Given the lack of information available in the current literature, there were no specific hypotheses about differential effects on the structural (i.e., social embeddedness) and functional (i.e., perceived social connectedness) qualities of social connectedness, but we were interested in potential differences that may arise depending on the mediating mechanism.

## Results

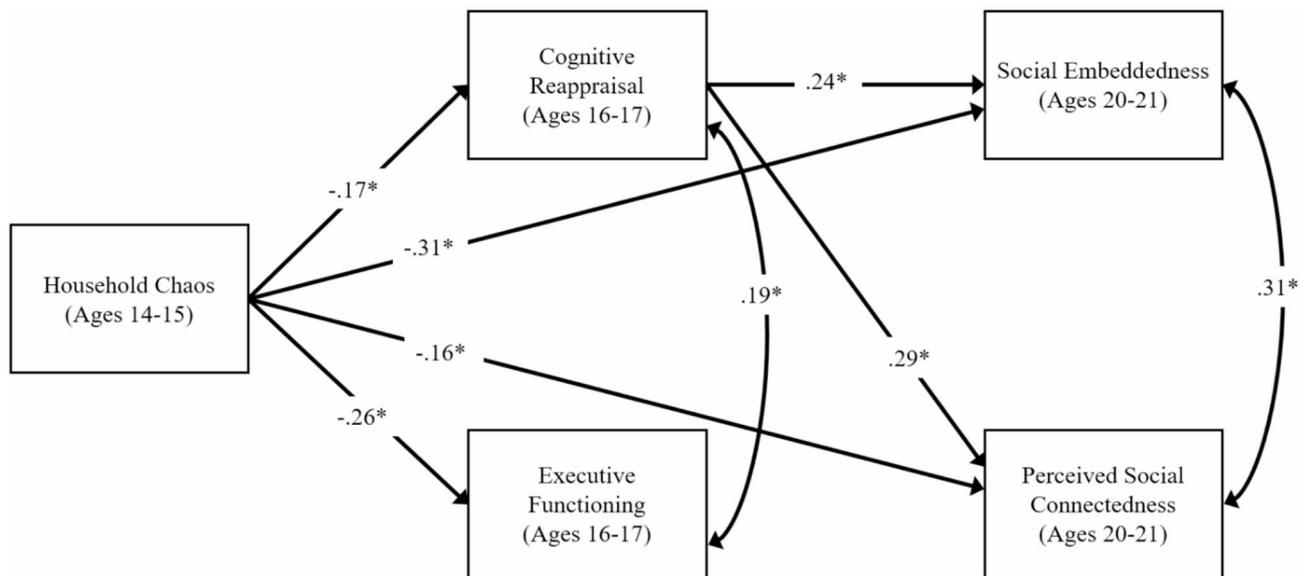
Descriptive statistics and correlations for all study variables are presented in Table 1. Outliers ( $N=2$ ) were winsorized to attenuate bias resulting from elimination and to retain statistical power<sup>43</sup>. When using the winsorized variables in the model, the change in the estimation of the model paths was minimal. Thus, non-winsorized variables were used in the model to preserve unmodified participant responses in the model estimations. Multivariate GLM analyses were conducted to examine whether demographic variables were significant statistical predictors of our study variables. These demographic variables included sex (0 = Male, 1 = Female), race (0 = White, 1 = Non-White), and income (income-to-need ratio at the baseline). These analyses indicated that adolescent race was associated with executive functioning ( $p=.007$ ) and social embeddedness ( $p=.048$ ), and income was associated with executive functioning ( $p=.048$ ). However, when race and income were added to the hypothesized model as covariates, the links between race and social embeddedness and between income and executive functioning were not significant. The link between race and executive functioning was significant ( $p=.028$ ), but the inclusion of adolescent race in our baseline model did not produce significant change in the estimation of the direct or indirect paths (see Table S1 for model results including income and race). As such, race and income were omitted from the model for parsimony.

The baseline model was fully saturated ( $\chi^2=0.00$ ,  $df=0$ ,  $p=0$ ; RMSEA=0.00; CFI=1.00) and the direct effects from executive functioning to social embeddedness ( $b = -0.14$ ,  $SE=0.58$ ,  $p=.804$ ) and perceived social connectedness ( $b = -0.18$ ,  $SE=0.39$ ,  $p=.650$ ) were non-significant. The indirect paths via executive functioning to social embeddedness ( $\beta=0.01$ ; 95% CI:  $[-0.119; 0.146]$ ) and perceived social connectedness ( $\beta=0.01$ ; 95% CI:  $[-0.056; 0.112]$ ) were also non-significant.

A trimmed model was fit by omitting the non-significant paths from executive functioning to social embeddedness and perceived social connectedness to aid model fit evaluation. The subsequent model fit the

Variables	1	2	3	4	5	6	7	8
1. Sex	--							
2. Race	0.06	--						
3. Income-to-needs	-0.02	-0.20*	--					
4. Household chaos (Ages 14-15)	0.14	0.10	-0.23*	--				
5. Cognitive reappraisal (Ages 16-17)	-0.13	-0.07	0.04	-0.19*	--			
6. Executive functioning (Ages 16-17)	-0.12	-0.25*	0.21*	-0.26*	0.23*	--		
7. Social embeddedness (Ages 21-22)	0.05	-0.16	0.13	-0.34*	0.26*	0.10	--	
8. Social connectedness (Ages 21-22)	0.07	-0.07	-0.02	-0.19*	0.29*	0.06	0.39*	--
M	47% (F)	78% (W)	2.44	2.41	4.93	-0.01	2.28	4.39
SD	--	--	1.86	0.50	0.89	0.60	1.08	0.90
Min	--	--	0.00	1.21	2.17	-1.70	0.50	1.75
Max	--	--	8.25	3.71	7.00	1.27	5.50	6.00

**Table 1.** Descriptive statistics and bivariate correlations of study variable. Note. F = Female, W = White. \* $p < .05$ .



**Fig. 1.** Path analysis model of longitudinal associations among household chaos, executive functioning, cognitive reappraisal, perceived social connectedness, and social embeddedness. Note. All estimates are standardized, with significant paths indicated in bold. \* $p < .05$ .

data well ( $\chi^2 = 0.21$ ,  $df = 2$ ,  $p = .900$ ,  $RMSEA = 0.00$ , and  $CFI = 1.00$ ). As shown in Fig. 1, significant direct effects were observed from household chaos to social embeddedness ( $b = -0.70$ ,  $SE = 0.17$ ,  $p < .001$ ) and perceived social connectedness ( $b = -0.30$ ,  $SE = 0.14$ ,  $p = .038$ ), indicating that higher household chaos statistically predicted both lower social embeddedness and lower perceived social connectedness. Significant associations were also observed from household chaos to cognitive reappraisal ( $b = -0.32$ ,  $SE = 0.15$ ,  $p = .032$ ) and from household chaos to executive functioning ( $b = -0.10$ ,  $SE = 0.03$ ,  $p = .001$ ), suggesting that higher household chaos was statistically predictive of both lower executive functioning and cognitive reappraisal. Finally, significant associations were observed from cognitive reappraisal to social embeddedness ( $b = 0.30$ ,  $SE = 0.10$ ,  $p = .003$ ) and to perceived social connectedness ( $b = 0.29$ ,  $SE = 0.10$ ,  $p = .005$ ), indicating that lower cognitive reappraisal statistically predicted both lower social embeddedness and lower perceived social connectedness. Significant indirect effects were found for household chaos to both social embeddedness ( $\beta = -0.04$ ; 95% CI:  $[-0.205; -0.001]$ ) and perceived social connectedness ( $\beta = -0.05$ ; 95% CI:  $[-0.213; -0.001]$ ) via cognitive reappraisal, indicating that higher levels of household chaos statistically predicted lower cognitive reappraisal, which, in turn, statistically predicted lower social network embeddedness and lower perceived social connectedness. The effect sizes of the standardized structure coefficients were small for the statistical effect of household chaos on cognitive reappraisal and small-to-medium for the statistical effects of cognitive reappraisal on social embeddedness (total variance explained  $R^2 = 0.19$ ) and social connectedness (total variance explained  $R^2 = 0.13$ ) (see Fig. 1). The effect sizes for the mediated effects via cognitive reappraisal from household chaos to social embeddedness ( $R^2_{med} = 0.03$ ;  $PM = 30\%$ ) and from household chaos to perceived social connectedness ( $R^2_{med} = 0.02$ ;  $PM = 66\%$ ) were

relatively small. A specificity analysis using expressive suppression instead of cognitive reappraisal reaffirms the uniqueness of cognitive reappraisal as a mediator in the link between household chaos and *both* the structure and function of social connectedness (see Table S3 for results).

## Discussion

The transition from adolescence to young adulthood is characterized by alterations to internal processes including self-regulation, but it also represents a period of vulnerability because self-regulatory deficits may hinder healthy social adjustment<sup>44</sup>. Prior research has established a negative link between environmental unpredictability and social functioning, primarily in child and adolescent populations, leaving long-term outcomes and underlying mechanisms unknown<sup>4,45</sup>. Further, while previous studies have advanced our understanding of how these regulatory skills and social connectedness develop in tandem<sup>46,47</sup>, no studies to date have examined how the distinct effects of unpredictability on emotion regulation and executive functioning *differentially* predict social connectedness in young adulthood. Finally, despite the evidence that poor emotion regulation can bias one's perception of their own social connectedness<sup>48,49</sup>, few studies have examined distinct effects on functional and structural domains of social connectedness to ensure a comprehensive measure of one's social world in adulthood.

The present study addressed these gaps in the literature by clarifying which self-regulatory skills in adolescence are particularly important for the observed structure (i.e., social embeddedness) and function (i.e., perceived social connectedness) of social connectedness in young adulthood after experiencing environmental unpredictability in adolescence. Our results identified that lower cognitive reappraisal, not lower executive functioning, following environmental unpredictability is negatively linked to both the structure and function of social connectedness in young adulthood. Despite the significant negative link between household chaos and executive functioning, executive functioning was not associated with either the structural or the functional components of social connectedness in young adulthood when included in a competing mediation model with cognitive reappraisal. This result indicates that emotion regulation deficits may be more detrimental to young adult social connectedness than executive functioning deficits following unpredictability.

We found support for our first hypothesis that unpredictability in adolescence and social connectedness in young adulthood are negatively and significantly associated. This finding is in line with previous studies across this time period, suggesting that lower social connectedness may be observed in youth who experience moment-to-moment unpredictability (measured by household chaos)<sup>6</sup>. Child and adolescent research has shown that unpredictability, such as household chaos, is linked to poor social competence<sup>50,51</sup>. Recent findings linking unpredictability and psychopathology highlight the importance of social relationships, reporting that the negative links between childhood unpredictability and later anhedonia may occur indirectly through lower social support<sup>16</sup>. Collectively, these past and current findings suggest that an important avenue for preventative intervention efforts may be to target mechanisms that facilitate meaningful social relationships, which can help combat mental health problems.

Furthermore, we found support for our second hypothesis that lower cognitive reappraisal mediates the link between unpredictability and perceived social connectedness in young adulthood. The direct effects between household chaos and social connectedness remained significant, suggesting a partial mediation via less cognitive reappraisal. A previous study reported that childhood unpredictability indirectly predicted lower romantic relationship quality in young adulthood through greater emotional control difficulties. However, this study was limited by the fact that both emotional control difficulties and romantic relationship quality were assessed simultaneously in adulthood<sup>33</sup>. A recent systematic meta-review distinguished two processes of socialization involved in the development of self-regulation: the ability pathway (i.e., effects on the improvement of self-regulatory skills) and the goals and motivation pathway (i.e., effects on the willingness to engage in self-regulation)<sup>52</sup>. In line with this idea, our indirect effects may be attributed to (a) the learned use of less effective emotion regulation strategies when attempting to manage conflict within social relationships, rather than cognitive reappraisal, or (b) relationship-compromising behaviors that are activated because of lower social motivation and lower perceived relationship quality resulting from more negative appraisals of previous interactions within that relationship.

Contextualizing these results in evolutionary and socioemotional theoretical perspectives suggests two plausible avenues from environmental unpredictability toward poorer social connectedness. The evolutionary theoretical perspective relies on the ability pathway of self-regulation development, suggesting that self-regulatory resources developed in unpredictable environments may not be sufficient or may be inefficiently recruited for the maintenance of social relationships later. In line with life history theory, those who experience unpredictability may be less *able* to engage in successful self-regulation due to the environment's unpredictable nature which may prompt them to act more impulsively in social conflict scenarios. Indeed, prior research has provided important evidence supporting this idea, showing that unpredictability is associated with aggression, perpetuation of intimate partner violence, and intergroup conflict—all of which are indicators of poor social relationships<sup>6,33,53</sup>.

On the other hand, socioemotional selectivity theory is contextualized within the goals and motivation pathway, suggesting that differences may exist in the motivation to use self-regulatory skills in social contexts between those exposed to unpredictable and predictable environments. Specifically, the inability to predict social feedback or the potential future benefits of a social relationship may dissuade those with a limited time horizon from desiring social relationships<sup>20</sup>. Rather than simply lacking the ability to effectively recruit the emotion regulation strategies needed to maintain relationships, resignation may be more common when humans view social relationships as trivial or pointless<sup>54,55</sup>. A fruitful direction of future research would be exploring the links between motivation and emotion regulation in the context of social relationships in late adolescence and young adulthood.

Interestingly, we did not find evidence supporting our third hypothesis that executive functioning would mediate the link between adolescent unpredictability and social connectedness in young adulthood. Our data further suggested non-significant mediating effects of individual indices of executive functioning (working memory, inhibitory control, and cognitive flexibility; see Table S2). The findings support the idea that executive processes are less salient to the maintenance of social relationships in young adulthood than regulatory processes involving emotion<sup>56</sup>. Although no studies have examined executive functioning as a mediator in the relationship between unpredictability and social functioning in adulthood, studies demonstrate the prominent role of executive functioning in social functioning in early childhood<sup>57,58</sup>. Empirical evidence has supported the claim that the link between executive functioning and social behaviors becomes weaker across development, which may explain the lack of significant indirect effects through executive functioning in the current study. For example, in a sample of primary and secondary school students, primary school students with poorer executive functioning exhibited poorer social behaviors, whereas that association was not as apparent in secondary school students<sup>59</sup>. Similarly, better executive functioning reduced the likelihood of experiencing peer problems later in childhood and middle adolescence. However, these relations weakened as children moved into late adolescence<sup>60</sup>. Thus, further research is warranted to directly observe changes in the role that executive functioning plays in social relationships across development.

In adolescence, emotion regulation strategies are practiced within new independent social interactions, but the relationships forged in adolescence do not always translate to one's adult social sphere<sup>61</sup>. In adulthood, stable and effective emotion regulation strategies become essential in maintaining strong, long-term relationships<sup>44</sup>. Furthermore, maintaining high-quality relationships can buffer the negative effects of early contexts on psychopathology<sup>62</sup>, but this buffering becomes less probable when early contexts also lead to less effective emotion regulation. Our finding of the indirect effect through cognitive reappraisal and not executive functioning may suggest a developmental shift in the importance of distinct regulatory mechanisms that statistically predict social functioning from childhood to adulthood. Given the discrepancy between the equally important roles of emotion regulation and executive functioning in social relationships in childhood and the current findings suggesting that executive functioning may play a less crucial role in young adult social relationships, more longitudinal research is needed. This research would help to elucidate the importance of self-regulatory components in social relationships across developmental periods, allowing for the effective targeting of specific regulatory processes in at-risk populations based on their relevance within particular developmental periods. Considering the multidimensional nature of self-regulation across development, emotion regulation may represent more complex regulatory processes that become salient in adolescent and young adult social interactions, whereas executive functioning may represent the basic processes that provide a foundation for emotion regulation processes used later on<sup>52</sup>. Indeed, longitudinal evidence corroborates the idea that executive functioning supports later emotional regulation<sup>63</sup>.

The present study has several limitations. First, despite the longitudinal nature of the data used in the present study, any causal statements about the results should be restrained due to the correlational nature of the data. Moment-to-moment environmental unpredictability cannot be manipulated using experimental design, thus these findings cannot be interpreted in light of causality due to a non-experimental design. Second, the relatively small effect sizes of the indirect effects may reflect the stringent statistical tests of developmental cascade models spanning age 14 to age 22 and suggest that other underlying mechanisms partially explain this link. The relatively small effect sizes may reflect the stringent statistical tests of developmental cascade models spanning age 14 to age 22 and suggest that other underlying mechanisms partially explain this link. Nevertheless, we note that researchers have argued that even small effect sizes are noteworthy if they have clear implications for a significant theoretical or practical issue. Seemingly small effects can have important practical implications in the long run when they occur repeatedly, or when they predict the behavior of many individuals simultaneously on a single occasion, even if they may not seem highly consequential within a single episode or for a single individual<sup>64,65</sup>. A fruitful direction of future investigation includes exploring other possible mediating processes that explain the unpredictability-social connectedness link. Finally, empirical evidence supports the socialization of self-regulation development<sup>46,47,66</sup>, but the focus of the present study did not involve the reciprocal effects of social relationships on self-regulation due to the lack of social relationship data collected at earlier time points. Future research may evaluate the reciprocal effects of social relationships on self-regulation from adolescence to adulthood to gain more insight as to the dynamic associations between self-regulation and social relationships following unpredictability. Future research may evaluate the reciprocal effects of social relationships on self-regulation from adolescence to adulthood to gain more insight as to the dynamic associations between self-regulation and social relationships following unpredictability. Future studies would benefit from testing the reverse associations between household chaos, self-regulation, and social connectedness that were not explored here.

Those limitations notwithstanding, the theoretical contribution of the present study is to bring together the two separate lines of psychological theory (i.e., life history theory and socioemotional selectivity theory) and evaluate distinct developmental mechanisms of self-regulation (i.e., emotion regulation and executive functioning) that explain long-term environmental effects on structural and functional social connectedness. Methodological contributions of the present study include utilizing multi-informant and multi-method data as well as performing prospective analyses based on six years of longitudinal data from the beginning of adolescence to young adulthood, spanning multiple developmental periods and including the significant transition from adolescence to young adulthood.

The findings emphasize the importance of cognitive reappraisal as a developmentally appropriate target for preventive intervention efforts towards social functioning problems among young people at elevated risk due to their experiences of growing up in unpredictable home environments. As young people leave early adolescent environments and face new social challenges in adulthood, the cognitive schemas and motivations

shaped by early unpredictable contexts may reduce the use of emotion regulation strategies that contribute to the maintenance of good-quality social relationships and ultimately, overall well-being.

## Methods

### Procedure

Participants (adolescents and their respective primary caregivers) were recruited using flyers, email, and snowball sampling (word-of-mouth). Data collection sessions lasted an average of five hours and were conducted in university spaces. During these sessions, participants completed self-report surveys, behavioral and neuroimaging tasks, and verbal interviews administered by trained research assistants. All participants provided written informed consent (primary caregivers) or assent (adolescents) prior to participation, and all procedures were approved by the Virginia Tech Institutional Review Board. Upon reaching the age of 18, adolescent (now young adult) participants completed written informed consent. All participants were monetarily compensated for their time and participation. All methods were carried out in accordance with relevant guidelines and regulations.

### Participants

The current sample included 167 adolescents (47% female) and their respective caregivers (137 mothers, 21 fathers, and 9 others) who were recruited from rural, suburban, and urban communities in the southeastern United States as part of an ongoing longitudinal study. Data from six assessments were averaged in pairs to reflect each construct during a 2-year “timepoint” ( $M = 14.07\text{--}15.05$ ,  $SD = 0.54$  at Time 1;  $M = 16.07\text{--}17.01$ ,  $SD = 0.54\text{--}0.55$  at Time 2;  $M = 21.18\text{--}22.23$ ,  $SD = 0.60\text{--}0.65$  at Time 3). Adolescent participants were identified as White (78%), Black/African American (14%), more than one race (6%), American Indian or Alaskan Native (1%), or Asian (1%). At Time 1, the median family income ranged between \$35,000 and \$49,999.

From our final sample of 167 adolescents, some participants ( $n = 41$ ) ceased participation across ages 15–22 for various reasons: lost contact ( $n = 29$ ), declined participation ( $n = 6$ ), moved away ( $n = 2$ ), and extenuating family circumstances ( $n = 4$ ). Multivariate General Linear Model (GLM) analyses were used to determine whether participants’ rates of missing data were related to the study variables, none of our study variables were significantly predicted by participants’ rates of missing data ( $p = .08\text{--}.38$ ).

### Measures

#### *Household chaos*

Adolescents and parents reported on the level of household chaos (i.e., level of confusion and disorganization in the home) at Time 1 (ages 14–15) using a 6-item adaptation of the Confusion, Hubbub, and Order Scale<sup>58</sup>. Response options range from “1 = Definitely untrue” to “5 = Definitely true.” One example item is “You can’t hear yourself think in our home.” Item responses were averaged to produce a household chaos score, where higher scores are indicative of higher chaos in the home, and individual reports of household chaos were then averaged between adolescent and parent across adolescent ages 14–15 ( $r = .24\text{--}.28$ ,  $p < .01$ ) between adolescent and parent reports). Previous research evaluating this scale’s psychometrics demonstrates similar reliability to that of the current sample ( $\alpha = 0.59\text{--}0.68$ )<sup>3</sup>.

#### *Cognitive reappraisal*

Adolescents reported on the use of cognitive reappraisal as an emotion regulation strategy using the Emotion Regulation Questionnaire (ERQ)<sup>34</sup> at ages 16–17. This questionnaire used a 7-point Likert scale where 1 = “Strongly disagree,” and 7 = “Strongly agree” (e.g., “When I want to feel less negative emotion, I change what I’m thinking about”). Item scores were averaged from the 6-item cognitive reappraisal subscale to produce a cognitive reappraisal score where higher scores reflect more cognitive reappraisal. Gross and John (2003) reported high reliability with alphas between 0.75 and 0.82 for the cognitive reappraisal subscale, with similar estimates in the current sample ( $\alpha = 0.71\text{--}0.86$ )<sup>34</sup>.

#### *Executive functioning*

Executive functioning scores were created using a composite of three behavioral tasks that capture the construct of executive functioning through three underlying related but distinct constructs, as proposed by Miyake and colleagues (2000)<sup>37</sup>. Miyake and colleagues (2000) conceptualize executive functioning as a multidimensional construct that can be measured both using three separate indices as well as using a composite approach to capture the overall construct of executive functioning<sup>37</sup>. Empirical research also supports the idea that multidimensional constructs such as executive functioning are best represented using a simple aggregation (e.g., mean) of the indices that underlie the construct<sup>67</sup>.

First, working memory was measured using the Stanford-Binet memory for digits (digit-span)<sup>68</sup> in which participants were instructed to repeat a series of numbers read by the experimenter backward. Second, inhibitory control was measured using the Multi-Source Interference Task (MSIT)<sup>69</sup>, where participants were asked to respond with a target number that is either in the same ordinal position as the digit itself (neutral condition) or in a different position (interference condition). This task requires that participants detect and respond to conflicts that introduce cognitive interference, using larger differences in reaction time to indicate less inhibition of cognitive interference or lower executive functioning. Intraindividual standard deviation (ISD) of reaction time was calculated for use in the final executive functioning composite score as an index of inhibitory control. Third, cognitive flexibility was measured using the Wisconsin Card Sort Task (WCST)<sup>70</sup> in which participants were instructed to sort a series of cards based on color, number, and shape under changing conditions of reinforcement. The number of perseverative errors was used, which is when participants continue to follow the wrong condition (i.e., perseverance), as a measure of cognitive flexibility. The inhibitory control and cognitive

flexibility scores were reverse-scored so that across all three measures higher scores represented better executive functioning, resulting in significantly correlated indices of executive functioning ( $r_s = 0.20 \sim 0.26$ ). Finally, scores for all three measures were standardized and averaged together across ages 16–17 to produce the final executive functioning composite score.

#### *Social embeddedness*

Participants completed the Social Network Index (SNI)<sup>71</sup> reporting on persons they were in contact with, the frequency of contact with each person, and social network domains they were actively engaged in (e.g., family, friends, church/religious group). Social embeddedness is also more than just a simple quantitative measure of social connectedness since its scoring is highly dependent on the frequency of social interactions within each social network. Participants were considered actively engaged in a social network domain if they reported having contact with 4 or more people within that domain at least once every two weeks. In the case of the family domain, respondents were required to report participation in at least 3 high-contact family roles and interact with at least 4 high-contact people to meet criteria for social embeddedness in that domain. For each domain, the participant received a score of 1 if they met the necessary criteria and all domains were summed to produce a total social network embeddedness score, with the maximum number of network domains being 8. The total social embeddedness scores were averaged across ages 21–22 to produce a final score of social network embeddedness. As social embeddedness was conceptualized as a formative construct, an index of internal consistency across independent facets was not appropriate<sup>72</sup>. Higher scores were indicative of more social embeddedness across social domains.

#### *Perceived social connectedness*

Participants reported on their perceived social connectedness using the Social Connectedness Scale-Revised<sup>73</sup>. This scale measures participants' sense of belonging and interpersonal closeness with others in their social world. The current study used 8 items out of 10 positive items following recommendations from previous psychometric research<sup>73,74</sup>. The SCS-R uses a 6-point rating scale (1 = strongly disagree to 6 = strongly agree) with example items including "I am able to relate to my peers," and "I am able to connect with other people." Items were averaged together to produce scale scores where higher scores are indicative of greater perceived social connectedness ( $\alpha = 0.9\text{--}0.91$ ); scale scores were averaged across ages 21–22 to produce the final scores.

### Data Analytic Plan

Descriptive statistics were examined for all study variables to determine normality of distributions and outliers. For skewness and kurtosis, acceptable levels were considered to be less than 3 and less than 10, respectively<sup>75</sup>. Additionally, outliers were identified as values that were above 3.29 SD from the mean ( $n=2$ )<sup>76</sup>. Our model sought to estimate the main effects of household chaos on social connectedness in young adulthood (both structural and functional components) as well as indirect effects of household chaos on social connectedness through the use of cognitive reappraisal and executive functioning. The hypothesized models were tested via the Structural Equation Modeling (SEM) framework in *Mplus* statistical software version 8.11<sup>77</sup>. Model fit was assessed by  $\chi^2$  value, degrees of freedom, corresponding p-value, Root Mean Square Error of Approximation (RMSEA), and Confirmatory Fit Index (CFI). RMSEA values less than 0.08 and CFI values greater than 0.90 were considered an acceptable fit<sup>78</sup>. Full information maximum likelihood (FIML) estimation procedure was used to retain all participants regardless of missing data, yielding a final sample of 167<sup>79,80</sup>. Indirect effects were examined using 10,000 sample bootstrapping and 95% confidence intervals (CI), where a CI that includes zero indicates a null or statistically non-significant parameter<sup>81</sup>. Effect sizes for indirect effects were calculated using R-squared mediated ( $R^2_{med}$ ) and proportion mediated (PM)<sup>82</sup>.

### Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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## Author contributions

J.K-S. and B.C. conceptualized and designed the study and supervised the entire work; M.L., C.C., and C.M. carried out data collection and contributed to data interpretation; M.L. C.C., J.K-S. completed data processing and supervised data analysis; C.M. and J.K-S. drafted the manuscript. K.D-D. edited the manuscript. All authors discussed the results, contributed to the text, and approved the final version of the manuscript for submission.

## Declarations

### Competing interests

The authors declare no competing interests.

### Additional information

**Supplementary Information** The online version contains supplementary material available at <https://doi.org/10.1038/s41598-025-11579-6>.

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