

Investigating the interrelations between systems of support in 13- to 18-year-old adolescents: A network analysis of resilience promoting systems in a high and middle-income country

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Abstract

Adolescents' ability to function well under adversity relies on a network of interrelated support systems. This study investigated how consecutive age groups differ in the interactions between their support systems. A secondary data analysis of cross-sectional studies that assessed individual, caregiver, and contextual resources using the Child and Youth Resilience Measure (Ungar & Liebenberg, 2005) in 13- to 18-year-olds in Canada ($N=2311$) and South Africa ($N=3039$) was conducted applying network analysis. Individual and contextual systems generally showed the highest interconnectivity. While the interconnectivity between the individual and caregiver system declined in the Canadian sample, a u-shaped pattern was found for South Africa. The findings give first insights into cross-cultural and context-dependent patterns of interconnectivity between fundamental resource systems during adolescence.

Keywords: Network analysis, adolescence, multisystemic resilience, ecological differences, Child and Youth Resilience Measure, culture

From a social-ecological perspective, resilience is defined as an ongoing process of acquiring and sustaining essential physical, psychological, social, and cultural resources that help to maintain an individual's functionality in times of significant stress (Ungar, 2011, 2019). These resources are associated with various systems at the level of the individual (e.g., traits, skills), relationships (e.g., caregiving system), and the proximal or distal environment (e.g., education or welfare systems). Even though individual, relational and environmental resources are fundamental to human resilience (Masten, 2014), the availability and significance of these systemic resources is dependent on contextual specificities such as one's age, socio-political environment and cultural values (Panter-Brick, 2015).

The resources that people rely on to handle stressful experiences change gradually from birth to early adulthood (Skinner & Zimmer-Gembeck, 2007; Zimmer-Gembeck & Skinner, 2011, 2016). While newborns rely significantly on the resources of their caregivers, developmental processes increase exposure to and interactions with broader socioecological resources that may be available outside of a young person's immediate family context. As young people become less reliant on caregiver resources, they begin to build an increasingly complex network of individual, caregiver, and contextual resources that can improve their capacity to cope with normative and non-normative stressors. Thus, the availability and accessibility of what have been termed "resilience resources" is potentially dynamic, leading to fluctuations in the strength of mutual interactions and dependencies between resource systems (Ungar, 2011). Which resources are preferred by specific groups of youth, however, might not be universal as the conditions of an individual's environment places different demands on the characteristics of a resilience network (Ungar, Ghazinour, & Richter, 2013). Hence, this study set out to explore potential differences in the interconnectedness between fundamental resource systems of adolescents in Canada (a high-income country with generally individualistic values and better safety, employment opportunities, social welfare and high

quality education) and South Africa (a middle-income country with portions of its population better described as living in a low-income country context that generally aspires to interdependent and collectivist sociocultural values)(Ramphela, 2012; Siqwana-Ndulo, 1998; United Nations, 2018).

Resource systems during adolescence and the influence of context

Adolescence accentuates the variable nature of the resources used to support psychosocial development, with concurrent processes of identity development and individuation (Berzonsky, 2011; Erikson, 1968; Steinberg & Morris, 2001). For example, peers and the wider social-ecological context typically become more important than caregivers as a caregiver's influence on a child's environment decreases as the child matures (Zimmer-Gembeck & Skinner, 2011; Yoon et al., 2019). Children use several strategies to develop a sense of autonomy, including provoking conflict with primary caregivers and straining social norms (Steinberg & Morris, 2001). Depending on the context, however, young people might be less inclined to disassociate from available resources. For instance, street-connected adolescents in North American contexts tend to maintain bonds with other street-connected peers (Koller, Santana, & Raffaelli, 2018); many orphaned and otherwise vulnerable adolescents in South Africa draw strongly on the support of their siblings (Sharer, Cluver, Shields, & Ahearn, 2016), faith-based communities (Hills, Meyer-Weitz, & Asante, 2016), or school systems (Van Breda & Theron, 2018). Put differently, adolescent resilience draws variably on multiple systems, including the self, immediate and extended family, peers, community and culture. Whilst this complexity is well-recognized (Masten, 2014; Yoon et al., 2019), the nature of the interactions between resource systems in different countries with different value systems remains unclear.

An ecological view on human development (Bronfenbrenner, 1979) and resilience (Masten, 2014; Ungar et al., 2013) has shown that contextual differences can impact an

adolescent's resource systems. For instance, the cultural values of individualism and collectivism (Hofstede, 2011) may influence the role caregivers play in their children's resilience during adolescence. A review of studies spanning the years 2009 to 2017 of the resilience of South African children and adolescents showed that the most prominent resilience-enablers were affective support (often by family) and relationally-facilitated opportunities for growth and development (most often facilitated by a child's extended family) (Van Breda & Theron, 2018). The salience of relational support – particularly from family – to the resilience of South African adolescents highlights underlying collectivistic values of interdependence and intergenerational care that are imbedded in African culture (Phasha, 2010; Theron & Ungar, 2019). Relational support – particularly from family – was similarly prominent in resilience studies from other parts of sub-Saharan Africa (e.g., Berckmoes et al., 2017; Betancourt et al., 2011). While more individualistic cultures focus more on autonomy and intergenerational independence with increasing age (as in the case in much of North America), collectivistic and interdependent family cultures value ongoing interrelatedness and support intergenerational interdependence (Kagitcibasi, 2013; Mhlongo, 2019; Ramphele, 2012). Even so, individual resources (such as autonomy and self-regulation) are central to the resilience of adolescents who are socialized to appreciate collectivist cultural values, including South and other sub-Saharan African adolescents (Pfeiffer, Ahorlu, Alba, & Obrist, 2017; Van Breda & Theron, 2018; Vindevogel, Ager, Schiltz, Broekaert, & Derluyn, 2015). Thus, a decreasing reliance on caregiver resources as children age may or may not be a global phenomenon.

Furthermore, middle-income countries like South Africa show more social-structural vulnerabilities compared to high-income countries like Canada. Such vulnerabilities limit the availability of contextual resources (i.e., safety, social welfare, education or job opportunities) involved in promoting successful adjustment during adolescence (Cowden, Tucker, &

Govender, in press). Thus, young people in low and middle-income contexts are more likely to have fewer opportunities to expand their own resource networks and may remain more reliant on caregiver resources as they transition to adulthood (Nkosi & Daniels, 2008). For instance, it is possible that the chronically high rate of youth unemployment in South Africa, particularly among 15-19-year-olds in disadvantaged communities where adolescents are expected to work to support themselves and their families (De Lannoy, Graham, Patel, & Leibbrandt, 2018), obstructs typical adolescent patterns of individuation and reinforces adolescent reliance on caregivers. This pattern may be challenged if parents or other relatives are themselves highly stressed, in which case contextual resources such as educators, social workers, clergy and neighbors may assume the role as enablers for South African children's psychosocial development (Theron & Van Rensburg, 2019).

Taken together, these divergent patterns found in studies of adolescent development and resilience across countries suggest the need to better understand the interconnectivity between systems of resources during adolescence and whether context influences such interconnectivity.

The present study

A systemic perspective on resilience has only recently been introduced into the scientific literature (Masten, 2014; Ungar, 2018) and recent methodological advancements in network analysis (Costantini et al., 2015; Epskamp, Borsboom, & Fried, 2018) have motivated empirical studies in this domain. For example, a study with 17-to-25-year old university students from Belgium showed that psychological and familial resources form a network of positively interrelated resources (Briganti & Linkowski, 2019). A longitudinal study with adolescents from England has shown that inter- and intrapersonal resilience resources are mutually dependent and that childhood adversity can lead to a dysfunctional resource network that has lasting negative effects on access to the resources needed to support mental health at

14 and 17 years of age (Fritz, Fried, Goodyer, Wilkinson, & van Harmelen, 2018; Fritz et al., 2019). Another study with 7 to 9-year-old children from England that investigated a network of socio-economic risk factors, educational outcomes, mental health, and multiple indicators for cognitive and psychological resources showed that the negative effects of depression and anxiety on educational outcomes are indirect and moderated by cognitive resources (Dalmaijer et al., 2020). Hence, these studies give first insights into resilience being constituted by mutually dependent resources from different systems and that resource interactions can be influenced by contextual variables.

In this study, we use network analysis to investigate the absolute interconnectivity between resource systems of a multisystemic resilience network covering fundamental individual, caregiver and contextual resources which are associated with adolescent development in Canada and South Africa with cross-sectional data from 13-to-18-year old adolescents. Network analysis provides the possibility to model all unique connections between resources of the same support system as well as between resources that belong to different support systems at the same time (Costantini et al., 2015; Jones, Ma, & McNally, 2019). Thus, by modeling the interrelations between individual, caregiver and contextual resources separately for Canada and South Africa, network analysis can help to give an insight into how these interrelations differ between consecutive age groups within each country. The results can be used to explore cross-country as well as country-specific patterns.

This study was partly exploratory because hypotheses could not be derived for how consecutive age groups might differ in their overall network interconnectivity and how these differences might vary between the countries. As well, based on the cultural dimension of individualism (Canada) – collectivism (South Africa) it was assumed that increasing age might be associated with lower interconnectivities between the individual system and the other two systems for Canada given the value placed on individuation. In contrast, there might be no age

group differences between the individual and the other systems in the more collectivist context of South Africa.

This study was also partly confirmatory, since the following hypotheses were based on prior research: For both countries, we expected that (1) the individual and caregiver systems would show the strongest connection in younger age groups, while (2) the individual and contextual systems would show the strongest connection in older age groups as interaction with social networks beyond family grow. Further, (3) increasing age would be associated with lower interconnectivities between the resource system provided by caregivers and an adolescent's contextual resource system due to the increasing differentiation of the adolescent's social ecology from the influence and control of caregivers.

Methods

Measures

The analysis was based on the 28-item Child and Youth Resilience Measure (CYRM-28; Ungar & Liebenberg, 2005). The CYRM assesses fundamental resilience resources of young people aged 11-23 years using a five-point response format. The CYRM-28 covers three resource systems shown to be relevant in different cultures and stressful contexts for adolescents (Ungar & Liebenberg, 2011): individual (personal skills, peer support, social skills), caregiver (physical, psychological caregiving) and contextual resources (spirituality, education, culture). See supplementary table S1 for reliability statistics.

Sample demographics

The present study is a secondary data analysis based on cross-sectional data drawn from distinct studies conducted in Canada ($k = 3$) and South Africa ($k = 4$). These studies have used the CYRM-28 to assess resilience in youth who live under various chronic stressful circumstances such as structural disadvantages, poverty, violence, abuse at home, or psychopathology to differing degrees (see supplementary table S1 for detailed demographics).

The data for Canada was collected in three out of the ten provinces of Canada (Nova Scotia, Newfoundland and Labrador, Alberta). The first study was conducted in 2009 and the last in 2019. The data for South Africa was collected in four out of the nine provinces of South Africa (Free State, Mpumalanga, Gauteng, KwaZulu-Natal). The first study was conducted in 2010 and the last in 2019. To explore how consecutive age groups during adolescence might differ in how their resource systems are related to each other, these datasets were first compiled into one cross-sectional dataset for each country and then groups were derived out of these overall datasets for each year from age 13 to 18.

The Canadian sample consisted of $N = 2311$ adolescents ($M_{\text{age}} = 15.3$, $SD_{\text{age}} = 1.4$). The majority were female (50.9%) and identified as white (51.5%). The South African sample consisted of $N = 3039$ adolescents ($M_{\text{age}} = 15.1$, $SD_{\text{age}} = 1.5$). The majority were female (52.9%), and most identified as black (88.4%). Sex and race characteristics of samples from both countries were largely representative of the populations from which they were drawn (see supplementary table S1). The 18-year-olds were the smallest age group in both samples. In both countries, the youngest age group was found to have the most resources available, while the oldest group had the least (see table 1 for characteristics of each age group per country).

Table 1. Sample characteristics

Age	<i>n</i> (% ♀)	Individual resources <i>M</i> (<i>SD</i>)	Caregiver resources <i>M</i> (<i>SD</i>)	Contextual resources <i>M</i> (<i>SD</i>)	Total resilience <i>M</i> (<i>SD</i>)
Canada					
13	410 (52.68)	46.23(6.12)	30.31(4.64)	39.69(6.66)	116.23(15.35)
14	585 (52.65)	45.97(5.57)	29.80(5.15)	39.49(6.38)	115.26(14.79)
15	367 (51.23)	44.77(6.26)	28.32(5.30)	37.51(7.05)	110.61(15.93)
16	455 (49.23)	44.87(6.41)	28.55(5.50)	37.55(7.02)	110.96(16.56)
17	363 (50.14)	44.54(6.71)	28.00(6.19)	37.15(7.07)	109.69(16.99)
18	178 (44.38)	45.06(6.19)	26.84(7.68)	36.92(7.22)	108.81(17.16)
South Africa					
13	543 (54.09)	27.83(5.38)	30.44(5.21)	57.84(9.16)	116.12(17.18)
14	550 (56.70)	27.41(5.56)	29.71(5.11)	56.61(9.20)	113.73(16.82)
15	718 (55.20)	27.78(5.47)	29.49(5.09)	55.79(9.35)	113.06(17.22)
16	646 (52.15)	27.59(5.35)	29.31(5.26)	56.96(8.94)	113.85(16.52)
17	414 (46.25)	27.34(5.28)	29.36(5.59)	57.54(9.13)	114.23(16.71)
18	221 (47.44)	25.87(6.02)	28.15(6.42)	55.06(10.35)	109.08(19.29)

Note. *n*: size of age group. % ♀: percentage of females in each age group. *M*: mean. *SD*: standard deviation. The number of items for the individual and contextual subscale differ between the countries.

Data analysis

Only individuals with complete data were included. Studies investigating the factor structure of the CYRM-28 have shown different structures between Canada (Liebenberg, Ungar, & Vijver, 2012) and South Africa (van Rensburg, Theron & Ungar, 2019) using all 28 items. Hence, a preliminary confirmatory factor analysis (CFA) using a maximum-likelihood estimator with robust standard errors (MLR) was performed to find the best fitting model for both countries using *Mplus* 8.0 (Muthén & Muthén, 1998-2017). This pre-step of the main analysis was not meant to indicate that the resource systems should be independent of each other, which would be in contrast to the underlying systemic perspective on resilience of this

study. Instead, it served the need to take potential cultural specificities into account when studying different countries so that the relations between the resource systems can be adequately studied for each country using network analysis. The results favored the country-specific factor structures that have been identified in previous studies (Liebenberg, Ungar, & Vijver, 2012; van Rensburg, Theron & Ungar, 2019): four items from the CYRM-28 that belonged to the individual resource system in the Canadian sample belonged to the contextual system in the South African sample (see table 2 for the items and subscales, and supplementary table S2 for the model fit criteria of the CFA). Thus, in line with previous research, country-specific resilience networks were analyzed which only allowed for numerical comparisons between the age groups within each country and not across countries.

Network analysis was performed using *R* version 3.6 in *RStudio* 1.2.1335. A network model has two elements: nodes, which are the manifest variables (resources), and edges, which are the connections between the nodes (Costantini et al., 2015). The CYRM-28 items were used as nodes for the analyzed networks. Additionally, the nodes can be grouped into communities based on existing theory that represent the resource systems (the subscales of the CYRM-28 in the case of this study) (Jones et al., 2019). Hence, two types of edges exist: edges between resources of the same system and so-called bridge edges that indicate associations between resources of different systems. This study focused on bridge edges.

Table 2. CYRM-28 items, country-specific subscales and short names

Short names		Item
Canada	South Africa	
A1	A1	I cooperate with people around me
A2	<i>C1</i>	I know how to behave in different social situations
A3	A2	I try to finish what I start
A4	A3	People think that I am fun to be with
A5	A4	I am able to solve problems without harming myself...
A6	A5	I feel supported by my friends
A7	<i>C2</i>	I know where to go in my community to get help
A8	A6	My friends stand by me during difficult times
A9	<i>C3</i>	I have opportunities to show others that I am becoming an adult and can act responsibly
A10	A7	I am aware of my own strengths
<i>A11</i>	<i>C4</i>	I have opportunities to develop skills that will be useful later life
B1	B1	My parent(s)/caregiver(s) watch me closely
B2	B2	My parent(s)/caregiver(s) know a lot about me
B3	B3	If I am hungry, there is enough to eat
B4	B4	I talk to my family/caregiver(s) about how I feel
B5	B5	My family stands by me during difficult times
B6	B6	I feel safe when I am with my family/caregiver(s)
B7	B7	I enjoy my family's/caregiver's cultural and family traditions
C1	C5	I have people I look up to
C2	C6	Getting an education is important to me
C3	C7	Spiritual beliefs are a source of strength for me
C4	C8	I am proud of my ethnic background
C5	C9	I feel I belong at my school
C6	C10	I am treated fairly in my community
C7	C11	I participate in organized religious activities
C8	C12	I think it is important to serve my community
C9	C13	I enjoy my community's traditions
C10	C14	I am proud to be a citizen of _____

Note. A = items of the individual resilience subscale, B = items of the caregiver resilience subscale, C = items of the contextual resilience subscale. *Italics* indicate the items that belong to different subscales between the countries.

Regularized partial correlation networks were estimated for each age group separately for each country via *EBICglasso* using *bootnet* (Epskamp et al., 2018). This resulted in a total of 12 networks, six per country. In partial correlation networks, two resources are supposed to be conditionally dependent if an association can be identified between them, by controlling for all other edges in a network. If an edge cannot be found between two nodes then they are supposed to be conditionally independent and do not share a unique association (Fried et al., 2018, Rhemtulla et al., 2016). In order to minimize the risk of false positive interrelations and to derive parsimonious, interpretable networks with mainly meaningful edges, the regularization method *graphical lasso* (glasso) was employed (Epskamp & Fried, 2017). This method uses an empirically derived tuning parameter based on information criteria such as the Extended Bayesian Information Criterion (EBIC) that shrinks many small and spurious edges to zero and avoids the disadvantages of multiple testing (Costantini et al., 2015). Networks were visualized with a circular layout that only depicts bridge edges in order to visually represent how the systems relate to each other in each age group using *qgraph* (Epskamp, Cramer, Waldorp, Schmittmann, & Borsboom, 2012). For Fruchterman-Reingold layouts on the country-level, which places the nodes relative to the strength of their associations, please see supplementary figure S1.

Normalized bridge strength (BS) was used as an absolute indicator for the interconnectedness of the resource systems of each age group and was calculated using *networktools* (Jones et al., 2019). Bridge strength is based on bridge edges and indicates the absolute interconnectivity of a single resource (e.g., a resource of the individual system) with its connected resources of the other systems of the network (e.g., resources of the caregiver and contextual system). It is derived by summing the absolute weight (regularized partial correlation coefficient) of every edge that connects a resource of one system with resources of other systems. Hence, the accumulated absolute BS of all resources of a network was used to

indicate a network's total interconnectivity between all its systems at each age per country. This procedure excluded the relations between resources of the same system. Also, the absolute BS of each pair of resource systems were summed as indicators for the absolute interconnectivity between two resource systems (e.g., adding all absolute BS between the individual and caregiver subscale). Normalized bridge strength was specifically used because it takes the number of resources per resource system into account so that systems with an unequal number of resources can be compared (Jones, 2020).

Further, two analyses were performed to test for significant differences between the network structures of each pair of age groups within each country. First, Bayesian posterior predictive check tests were used as a global test to test if the network structure of two age groups significantly differed from each other using *BGGM* (Williams, Pericchi, Rast, & Mulder, 2019). Second, post hoc tests with Holm-Bonferroni correction for multiple testing were used on the Network Comparison Test to derive the total number of significantly different edges and the number of significantly different bridge edges only between two age groups using *NetworkComparisonTest* (van Borkulo et al., 2017; Fried et al., 2018). This way it was possible to indicate if the differences in the network structure between two age groups were due to differences in resource associations between or within resource systems.

Furthermore, 95% bootstrapped confidence intervals were used to indicate the accuracy of the edge weight estimates, and case-dropping subset bootstraps were applied to indicate the stability of the bridge strengths using *bootnet* (Epskamp et al., 2018; Jones et al., 2019). The correlation stability coefficient (CS) was also inspected for each network as an additional indicator of stability (Epskamp et al., 2018). The CS should have value of at least .25, but should preferably be above .5 for sufficient stability. The results of the stability and accuracy analyses can be found in the supplementary figure S2.

The code for all these analyses can be found in the supplementary material.

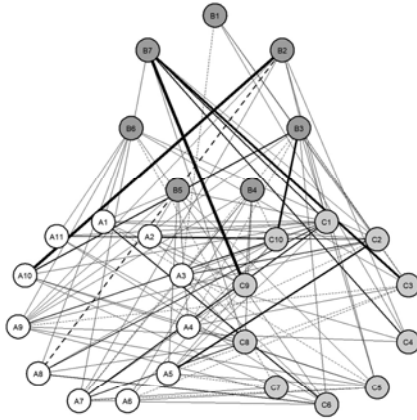
Results

Network analysis: Canada

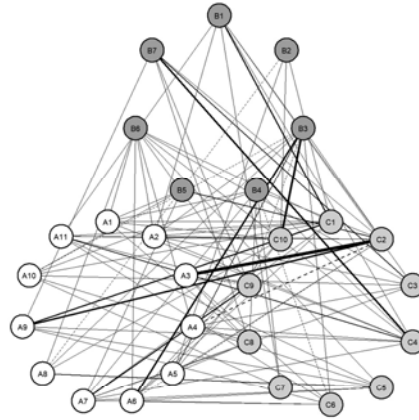
All Canadian age groups differed significantly in their network structure from each other (the p-values for all global tests were smaller than .001), given evidence of significantly different resource associations found for each network comparison (see supplementary table S3). On average, 29 resource associations differed significantly between the age groups. In 14 out of the 15 age group comparisons, more than 50% of the total significantly different resource associations were due to significantly different associations between resource systems. The least significantly different resource associations between systems were found between the 17 and 18-year-olds ($n = 4$) and the most were found between the 14 and 16-year-olds ($n = 31$). Furthermore, differences in total BS between consecutive age groups indicated that the interconnectivity of the whole resilience network declined over time (see figure 1).

Table 3 shows the interconnectivity of each pair of resource systems and how they differ between age groups. The interconnectivity between the individual and contextual systems (A-C) showed the strongest BS and most connections at each age. The relations between the individual and caregiver system (A-B) showed the weakest BS at each age. Furthermore, all three system pairs mostly showed a decline in their BS between consecutive age groups, with one intermediate increase in each pair, leading to a smaller BS at age 18 compared to age 13.

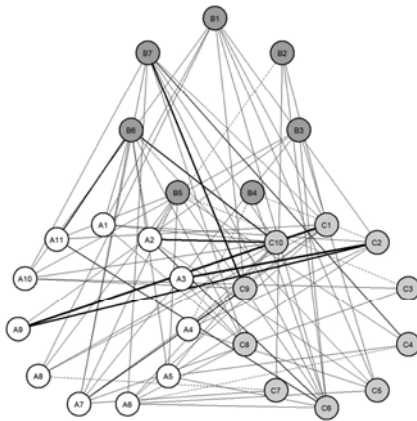
Age 13 (TBS = .356)



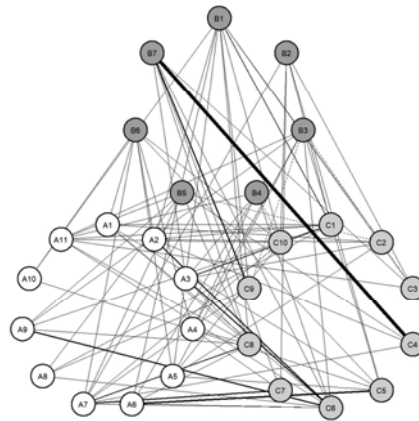
Age 14 (TBS = .293)



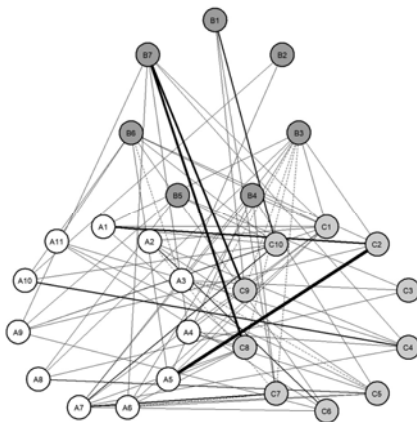
Age 15 (TBS = .249)



Age 16 (TBS = .271)



Age 17 (TBS = .261)



Age 18 (TBS = .210)

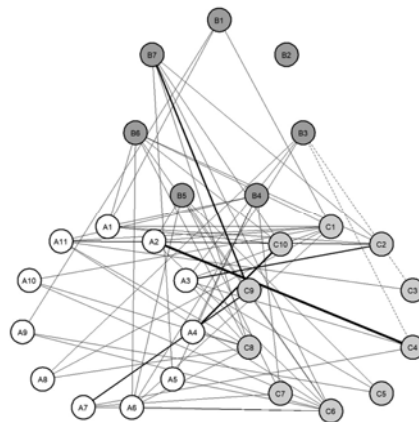


Figure 1. Network models at each age for Canada only showing bridge edges. TBS = total normalized bridge strength. A (white) = items of individual subscale, B (dark gray) = items of caregiver subscale, C (light gray) = items of contextual subscale. Straight lines = positive associations. Dashed lines = negative associations. Width of a line indicates the edge weight between two resources (the wider, the stronger the association).

Table 3. Accumulated bridge strength for each pair of CYRM subscales for Canada.

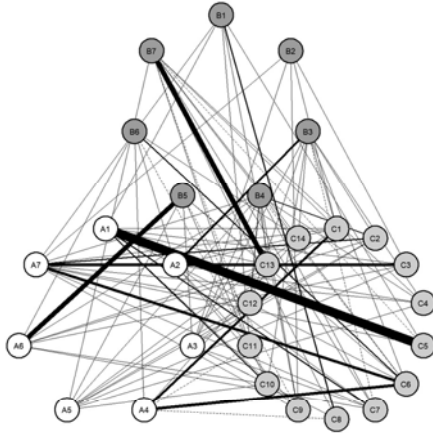
Age	A-B	A-C	B-C
13	.080	.177	.100
14	.046	.162	.085
15	.053	.135	.062
16	.050	.139	.082
17	.042	.153	.066
18	.026	.139	.044

Note. A = individual resources, B = caregiver resources, C = contextual resources. A-B: accumulated bridge strength for individual – caregiver subscale. A-C: accumulated bridge strength for individual – context subscale. B-C: accumulated bridge strength for caregiver – context subscale.

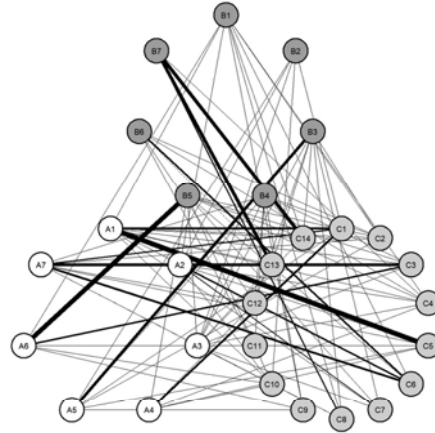
Network analysis: South Africa

All South African age groups differed significantly in their network structure from each other (the p-values for all global tests were smaller than .001), given evidence of significantly different resource associations found for each network comparison (see supplementary table S3). On average, 22 resource associations differed significantly between the age groups. In 10 out of the 15 age group comparisons, more than 50% of the total significantly different resource associations were due to significantly different associations between resource systems. The least significantly different resource associations between systems were found between the 17 and 18-year-olds ($n = 0$) and the most were found between the 15 and 16-year-olds ($n = 37$). Furthermore, differences in total BS between consecutive age groups indicated that the interconnectivity of the whole resilience network declined over time (see figure 2).

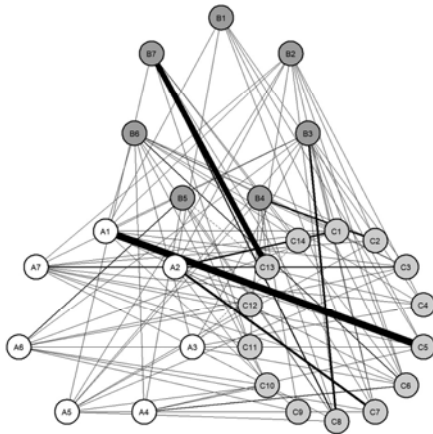
Age 13 (TBS = .348)



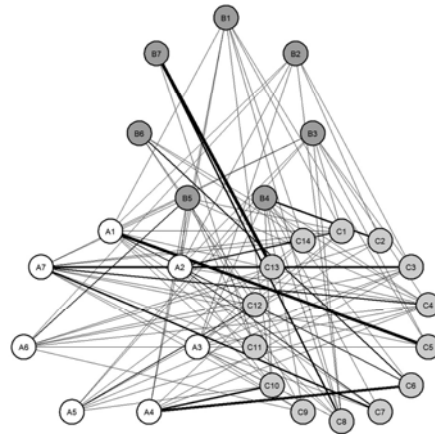
Age 14 (TBS = .298)



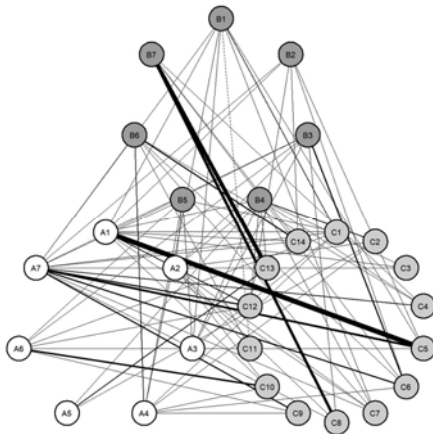
Age 15 (TBS = .301)



Age 16 (TBS = .285)



Age 17 (TBS = .282)



Age 18 (TBS = .248)

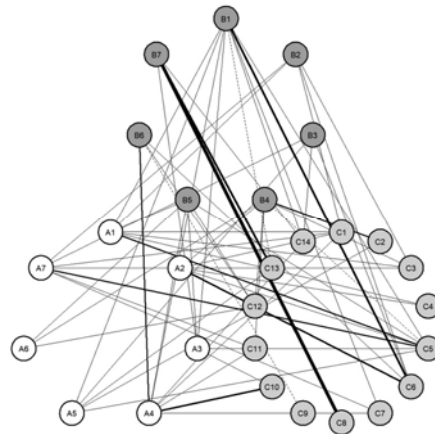


Figure 2. Network models at each age for South Africa only showing bridge edges. TBS = total normalized bridge strength. A (white) = items of individual subscale, B (dark gray) = items of caregiver subscale, C (light gray) = items of contextual subscale. Straight lines = positive associations. Dashed lines = negative associations. Width of a line indicates the edge weight between two resources (the wider, the stronger the association).

Table 4 shows the interconnectivity of each pair of resource systems and how they differ between the age groups. The interconnectivity between the individual and contextual system (A-C) showed the strongest BS at each age. The relations between the individual and caregiver system (A-B) showed the weakest BS, with this pattern holding for all age categories.

Table 4. Accumulated bridge strength for each pair of CYRM subscales for South Africa.

Age	A-B	A-C	B-C
13	.049	.168	.131
14	.037	.161	.100
15	.034	.132	.134
16	.034	.162	.090
17	.040	.150	.092
18	.043	.117	.088

Note. CYRM subscales: A = individual resources, B = caregiver resources, C = contextual resources. A-B: accumulated bridge strength for individual – caregiver subscale. A-C: accumulated bridge strength for individual – context subscale. B-C: accumulated bridge strength for caregiver – context subscale.

When comparing consecutive age groups, the BS of the individual and caregiver system showed a u-shaped pattern with an initial decrease and later increase beginning at the age of 17 (see table 4). The interrelations between the caregiver and contextual system mostly showed a decline between increasing age groups with an intermediate increase at age 15. The BS between the individual and contextual system tended to fluctuate between consecutive age groups: a decrease from 13-15 years was followed by an increase at age 16 similar to the level at age 13 and followed by further declines between the subsequent age groups.

Discussion

This study adds to the literature on how the interrelations between fundamental resilience resource systems differ between consecutive age groups in adolescence and how these differences unfold in context. Specifically, the differences in interrelations between individual, caregiver and contextual resource systems in Canada and South Africa were analyzed in 13-to-18-year-olds who completed the same measure of resilience (the CYRM-28). While resilience is a major topic in child development, few empirical studies have examined resilience from a multisystemic and multi-country perspective or studied the interplay between different resource systems for different age groups in adolescence.

Direct numerical comparisons between the countries were not possible, because some resources that constituted the individual and contextual resource system differed between the countries (see table 2). However, the three studied resource systems are the same on a systemic level, i.e., they are considered as individual, relational and contextual resources in each respective country, even though the countries differ regarding what specific resources constitute these resource systems. Therefore, the following section will discuss patterns that were common to Canada and South Africa (even though these were found separately for each country), before discussing country-specific patterns.

Similarities between Canada and South Africa

Despite different value systems, the present analysis identified similar patterns in the support networks emphasized by adolescents of different ages in both countries. First, in line with previous resilience network studies (Briganti & Linkowski, 2019; Dalmaijer et al., 2020; Fritz et al., 2018, 2019), all resource networks were characterized by mostly positive resource associations giving further evidence that resources tend to positively influence each other.

Second, results indicated that the interconnectivity between the individual and contextual systems tends to be the strongest in all studied age groups, and the interconnectivity

between the individual and caregiver system seems to always be the weakest. This could indicate that the tendency for adolescents to detach from caregiver or family resources and move towards contextual resources (Yoon et al., 2019) might occur in the earliest years of adolescence (i.e., 10-12, see Sawyer, Azzopardi, Wickremarathne, & Patton, 2018). Future studies using samples with other socioeconomic backgrounds and/or different indicators for these resource systems are needed to replicate these results. Similarly, a study with early adolescents could clarify whether detachment from family systems occurs earlier than the current sample's age range (i.e., 13-18).

Third, when comparing the consecutive age groups of the two samples, the younger age group always showed a higher total interconnectivity between all systems of the network than the older age group. Hence, the youngest age group showed the highest and the oldest age group showed the lowest total interconnectivity between all systems in both countries. This finding might be due to the items of the CYRM. The measure assesses a limited number of child and youth resources (including school and caregiver resources) but does not account for other resources like intimate partners and workplaces that may become more important as adolescents move towards adulthood (Arnett, Žukauskienė, & Sugimura, 2014). This might especially be the case in South Africa where young people (particularly young men) from disadvantaged households are typically expected to contribute materially to their household's upkeep once they reach the minimum employment age (i.e., 15 or completion of Grade 9) and thus employment opportunity is likely to become an important resource (Branson, Hofmeyr, & Lam, 2014; Desai, Mercken, Ruiters, Schepers, & Reddy, 2019). Similarly, the identified decrease in the overall availability of resilience resources as assessed by the CYRM-28 may reflect a decline in the salience of resources that are relevant most to younger age cohorts in both countries. As young people develop and acquire new resources, previously important support networks could be displaced. However, the decreasing interconnectivity does not

necessarily indicate that lesser connected resources are less important for a person's resilience network, but only that the influence of resources on each other gets smaller (Fried et al., 2018). Thus, another way of interpreting our findings might be that multisystemic resilience networks that encompass individual, caregiver and contextual systems become increasingly differentiated over the course of adolescence. Although specific systems remain important, their influence becomes diffused in a social ecology that provides more and more social supports to young adults. This latter potential interpretation could be supported by the result that all age group comparisons within each country were found to be significant, meaning that no resilience network seemed to be the same between two age groups. More importantly, these differences were probably due to a higher number of significantly different resource associations between support systems (which indicates a higher differentiation of the resource systems) compared to resource associations within the systems for most age group comparisons. Future studies are needed that replicate these results with higher stability.

Fourth, both country samples were characterized by an overall decrease in the interconnectivity between the caregiver and contextual resource systems from younger to older age groups. Thus, one potential interpretation of the results could be that the adolescent's social ecology tends to become more separated from the influence and support of caregivers over time. In turn, this might support an ongoing construction of an adolescent's personal life apart from caregivers in the studied countries, each of which differ in their sociocultural value systems.

Specific patterns within the Canadian sample

A steady decrease emerged for the interconnectivity between the individual and caregiver system when looking at the differences between consecutive age groups in the Canadian sample. This could be expected among young people who originate from an individualistic high-income country which is usually reflective of an ongoing progression of

autonomy and intergenerational independence over the course of adolescence (Berzonsky, 2011; Steinberg & Morris, 2001).

A similar pattern was found for the interrelations between the individual and contextual system which also mostly indicated a decrease between consecutive age groups. However, the interrelations seemed to increase from age 16 to 17 and then again a decrease from age 17 to 18. Young people in Canada usually finish their high school when they are about 17-years old which might explain why there is a sudden increase at this age. The overall decrease in the interconnectivity between these two systems over time could be traced back to living in a culture that typically values individuation and autonomy. However, valuing intergenerational independence and the societal opportunities available in a high-income country might afford a short-term resurgence of the connectivity between the individual and contextual system in this time of transition at age 17 from school to work-life or post-secondary education and the simultaneous acquisition of adult responsibilities when separating from caregivers. Such transitions are known to be stressful for adolescents (Arnett, 2006; Masten et al., 2004).

Specific patterns within the South African sample

A u-shape was found when consecutive age groups of the South African sample were compared for the interconnectivity between the individual and caregiver systems (i.e., higher interconnectivity at ages 13 and 18 but lower interconnectivity during the years between). The initial decrease could suggest that ages 13-16 (when most adolescents would still attend school) is a potential time for individuation and identity development. The subsequent increase (beginning at age 17) could reflect the high rates of school attrition when adolescents have completed Grade 10 and thereby lose the relative security of school (Hall, 2018), and/or the chronically high (i.e., around 50%) unemployment rate for South Africans aged 15 to 24 (StatsSA, 2019). These realities are associated with adolescents' prolonged physical and psychological dependence on caregivers (Hall, 2018).

A further volatile pattern was found for the interrelations between the individual and contextual system: a decrease from age 13 to 15, then a return to almost baseline at 16 years and then a similar decrease till age 18. The increase from age 15 to 16 could be explained by the expectation that disadvantaged South African adolescents take on adult roles (such as contributing materially to the upkeep of their household) once they reach the minimum employment age (i.e. 15) or have completed compulsory schooling (end of Grade 9; usually around age 16). Their capacity to fulfil these obligations will be largely influenced by contextual resources. The co-occurring lesser interconnectivity between the individual and caregiver systems could perhaps also explain South African adolescents' higher reliance on contextual resources during this transition period.

Limitations and future directions

The present study comprised cross-sectional datasets from Canada and South Africa that have used the same measure to assess multisystemic resources of adolescents. Network analysis was employed to explore how the interconnectivity between individual, caregiver and contextual resource systems differs between consecutive age groups. The results were discussed using a developmental and ecological perspective. However, the identified age differences that are based on our cross-sectional data might be due to other characteristics of the studied groups besides their age. Hence, true developmental processes can only be studied with longitudinal data which would also give an insight into the directions of resources over time and how resource systems influence each other over time (Bringmann, 2013; Ungar, 2018). Future studies should include more countries with other socio-economic characteristics such as low-income, and pre- or early adolescents in order to identify the expected shift from a higher interconnectivity between individual and caregiver resources to a higher interconnectivity between individual and contextual resources (Yoon et al., 2019). Also, even though most of the models showed sufficient stability and accuracy (see supplementary figure S2), four models

need to be replicated with larger sample sizes. Especially in the case of the 18-year-old age group from Canada a too low centrality stability (below .25) raises the question of whether the identified bridge centrality is adequately estimated. Furthermore, missing factorial invariance of the CYRM subscales between the two countries as was indicated by the CFA only allowed for theoretical comparisons and not numerical comparisons. However, given the novelty of network analysis and the complexity of resilience, theoretical comparisons at least offer first insights into how resilience is impacted by culturally diverse contexts. A next step would be future studies to assess multisystemic resilience resources either with multidimensional instruments that show the same factor structure across countries or use distinct single-scale instruments that assess only one specific resource system. Finally, network analysis, a still novel statistical analysis method, does not yet provide formal tests that indicate if the change in bridge strength between two age groups are significant. Future improvements of this method are awaited that make such tests possible.

Conclusion

In summary, the findings of this study involving two countries that differ in socio-structural resources and predominating cultural values provide new insights into the complexity of development during adolescence. Adolescent resilience appears to require an interplay of all three studied resource systems: individual, caregiver and context. The study highlights a general, culturally-independent differentiation of these systems between consecutive age groups during adolescence. However, which systems are in closer interaction seems to be sensitive to the context in which development occurs.

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