#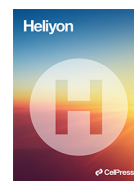 Inter-relationships between ADHD, ODD and impulsivity dimensions in emerging adults revealed by network analysis: extending the 'trait impulsivity hypothesis'

Research article

Inter-relationships between ADHD, ODD and impulsivity dimensions in emerging adults revealed by network analysis: extending the 'trait impulsivity hypothesis'

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ABSTRACT

Background: The trait-impulsivity hypothesis posits impulsivity as the underlying substrate of Attention-deficit/hyperactivity disorder (ADHD) and Oppositional defiant disorder (ODD) symptom expressions. The current study applied network analysis to evaluate the inter-relationships of dimensions within ADHD (inattention and hyperactivity/impulsivity) and ODD (anger/irritable, vindictiveness, and argumentative/defiant behavior) with components of impulsivity as captured by the UPPS-P model (negative urgency, lack of premeditation, lack of perseverance, sensation seeking, and positive urgency).
Method: A total of 324 emerging adults (women = 246) from the general community completed questionnaires covering these dimensions.
Results: Our findings showed that the ADHD and ODD dimensions were associated differentially with different types of impulsivity, in their unique patterns of network connectivities, a possibility that has had little attention in the trait-impulsivity hypothesis literature.
Conclusions: This study is the first to tease out the unique associations of the ADHD and ODD dimensions with different types of impulsivity, and in that way provide new contributions to our understanding of the existing trait impulsivity theory. Our findings would be especially relevant to those interested in understanding how different dimensions of trait impulsivity underly the ADHD and ODD dimensions.

1. Introduction

Attention-deficit/hyperactivity disorder (ADHD) and Oppositional defiant disorder (ODD) are highly prevalent (Elia et al., 2008; Mitchison and Njardvik, 2019; Pliszka, 2015) and are frequently co-occurring disorders (Newcorn et al., 2001; Gadow and Nolan, 2002). According to the Diagnostic and Statistical Manual of Mental Disorders (DSM-5; American Psychiatric Association [APA], 2013), the two core dimensions of ADHD in children and adults consists of inattention (IA; difficulty concentrating and focusing attention); and hyperactivity/impulsivity (HY/IM; high

motoric activity and inability to control impulses). Also, the three core dimensions of ODD in children include anger/irritability (temper tantrums, anger, and touchiness), vindictiveness (spitefulness), and argumentative/defiant behavior (disobedience, purposefully annoying, and blaming others for one's own mistakes). The trait-impulsivity hypothesis model (Beauchaine et al., 2017) posits that a unidimensional general impulsivity factor underlies the behavioral expression of ADHD and ODD symptom dimensions. However, there is now robust evidence that impulsivity is multidimensional (Enticott and Ogloff, 2006; MacKillop et al., 2016). Whiteside and Lynam (2003) have proposed a

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multidimensional impulsivity model with dimensions for sensation seeking, lack of premeditation, lack of perseverance, negative urgency, and positive urgency. To date, no study has examined how different dimensions of impulsivity are related to ADHD and ODD dimensions, using the trait impulsivity hypothesis as a framework. Consequently, the current study used the edge weights from a network analysis to re-explore the trait impulsivity hypothesis by examining with precision how Whiteside and Lynam's impulsivity dimensions are associated with the different aspects of ADHD and ODD dimensions.

1.1. The trait-impulsivity hypothesis model

The trait impulsivity hypothesis model (Beauchaine et al., 2017) offers an insightful and dynamic explanation of how impulsivity underlies the development of externalizing disorders, such as ADHD, ODD, conduct disorder, intermittent explosive disorder, substance use disorder, and antisocial personality disorder (Beauchaine et al., 2017; Beauchaine and McNulty, 2013). According to this hypothesis, preschool-aged children with temperaments reflecting high irritability, negative affectivity, and poor inhibitory control will develop a liability (reflected behaviorally as rash responses that lack planning, premeditation, and difficulties in delayed gratification) for developing externalizing disorders. Developmentally, this liability contributes first to the development of HY/IM symptoms (during preschool years), followed soon after by ODD symptoms (during early childhood), and then conduct disorder (during the middle school period), and followed by substance use disorder (during adolescence), and lastly, antisocial personality disorder (in young adulthood) (Beauchaine et al., 2017; Hart et al., 1995). The trait impulsivity hypothesis postulates that IA develops by school entry and is secondary to the HY/IM symptoms (Beauchaine et al., 2010). The hypothesis also proposes that the subsequent development of the different externalizing disorders among children with high HY/IM (trait impulsivity) depends on their exposure to specific environmental risk factors. For example, the critical risk factors for developing ODD are coercive family processes and/or deviant peer group affiliation (Beauchaine and Constantino, 2017; Beauchaine et al., 2017).

1.2. The UPPS-P model of impulsivity and its measurement

In the trait impulsivity hypothesis, HY/IM is viewed as the index of impulsivity. Thus, the trait impulsivity hypothesis embraces a unidimensional view of trait impulsivity. Although there is still no clear consensus for a definition of impulsivity, most experts agree that the core feature of impulsivity is a predisposition for rapid responses without adequate forethought, planning, and due consideration of potential negative consequences, thereby leading to risk-taking, rash, and ill-judged actions. Notwithstanding this, it is now generally accepted that impulsivity is multidimensional (Nigg, 2000; Sharma et al., 2014; Whiteside and Lynam, 2001). To date, several multidimensional models of impulsivity have been proposed (e.g., Buss and Plomin, 1975; Dickman, 1990; Eysenck and Eysenck, 1978; Whiteside and Lynam, 2001). Whiteside and Lynam's (2003) model, which was subsequently expanded by Cyders et al. (2007), attempted to bridge the different models of impulsivity. The latest version of this model includes impulsivity trait dimensions for (i) sensation seeking (tendency to seek out novel and thrilling experiences); (ii) lack of premeditation (tendency to act without thinking); (iii) lack of perseverance (inability to remain focused on a task that can be long, boring, or difficult); (iv) negative urgency (the tendency to rash action while under extreme negative emotions); and (v) positive urgency (the tendency to rash action while in an intense positive mood). This model is generally referred to as the Negative Urgency (lack of) Premeditation, (lack of) Perseverance, Sensation Seeking, and Positive Urgency (UPPS) when it contains dimensions with these same namesakes, or UPPS-P (when it also includes positive urgency). Lynam et al. (2006) developed the 59-item Urgency-Premeditation -Perseverance-Sensation Seeking-Positive Urgency Impulsive Behavior

Scale (UPPS–P) to measure the five impulsive personality traits in the UPPPS-P model. From this, Cyders et al. (2014) have developed a shorter 20-item version (S-UPPPS-S) to measure the five impulsivity dimensions. In line with the theory, the proposed factor structure for UPPS-P/S-UPPS-P is a five-factor oblique model, with dimensions for negative urgency, premeditation, perseverance, sensation seeking, and positive urgency.

1.3. Existing studies of the association of the UPPS-P dimensions with ADHD and ODD symptoms

The various UPPS-P measures have been used extensively in research involving impulsivity (for a meta-analysis, see Berg et al., 2015). According to the proponents of the UPPS/UPPS-P, the dimensions reflect different developmental pathways to a shared impulsivity construct that predisposes individuals to different manifestations of impulsive behavior. Notably, differential UPPS-P impulsivity dimensions have generally shown specificity with other psychopathologies (Berg et al., 2015). Thus, when considered in relation to the trait impulsivity hypothesis, early temperamental factors (i.e., high irritability, negative affectivity, and poor inhibitory control), that are theorized to underlie the development of initial trait impulsivity liability, in terms of the HY/IM symptoms and will over time diversify into different types of impulsivities, and that these would, in turn, be linked to different externalizing dimensions. Considering the multidimensional nature of impulsivity, it could be argued that a unidimensional model of impulsivity, as embraced in the trait impulsivity hypothesis, may conflate different components of the impulsivity, thereby masking distinct pathways to impulsive action in ADHD and ODD symptom dimensions.

To date, several studies involving different age groups have examined how ADHD is associated with the impulsivity dimensions in the UPPS-P model. This includes children (Geurten et al., 2021; Miller et al., 2010; Watts et al., 2020), adolescents and emerging adults (Halvorson et al., 2021), undergraduate adults (Egan et al., 2017; Roberts et al., 2014), and adults (Lopez et al., 2015). In addition, studies have consistently shown that ADHD is associated with urgency (Miller et al., 2010; Lopez et al., 2015). This association has also been found for measures that involved separate scales for positive urgency and negative urgency (Geurten et al., 2021; Watts et al., 2020; Egan et al., 2017; Roberts et al., 2014). An exception is a study by Halvorson et al. (2021) that found an association with negative urgency but not positive urgency. Another consistent finding in all but one study (Halvorson et al., 2021) is a positive association between lack of premeditation with ADHD. With two exceptions (Geurten et al., 2021; Halvorson et al., 2021), the other studies found positive associations between lack of perseverance and ADHD. Finally, sensation seeking has generally not shown an association with ADHD. The exception is the studies by Watts et al. (2020) and Roberts et al. (2014). Watts et al. (2020) showed associations with ADHD, and Roberts et al. (2014) showed an association with HY/IM symptoms (but not IA symptoms). Interestingly, the study by Halvorson et al. (2021) found an association between negative urgency with ODD. The study by Watts et al. (2020) found associations for ODD with all five impulsivity dimensions. These studies underscore the utility of the UPPS-P model for understanding how the different components of impulsivity underpin ADHD and ODD.

Overall, existing findings indicate reasonably robust associations for ADHD with negative urgency, positive urgency, lack of premeditation, and lack of perseverance. Also, there is reasonable support for associations between ODD and negative urgency. More importantly, these findings can be interpreted as demonstrating the need for re-exploring and revising the trait impulsivity hypothesis, in terms of unique associations of different dimensions of impulsivity with the externalizing symptoms of ADHD and ODD. However, existing literature which addresses such comprehensive evaluation is limited.

1.4. Limitations of existing theory and studies

While ODD is well-recognized in children and adolescents, it is not commonly diagnosed in adults. However, recent findings which applied the same ODD symptoms to adults found that they persist into adulthood and that they are associated with functional maladjustments, including more social impairment, friendship problems, online antagonistic behavior, and conflict with a (non-parental) authority figure (Johnston et al., 2018). Like children, ODD is highly comorbid with ADHD in adults (Barry et al., 2013; Harpold et al., 2007). A community survey reported the lifetime prevalence of ODD to be around 10% (a risk consistent across five cohorts between the age of 18–44), with ODD showing high rates of comorbidity with ADHD (35%), substance misuse disorders (47%), and impulse-control disorders (68%) (Nock, 2007).

Even though both ADHD and ODD are relevant to adults, the trait impulsivity hypothesis literature on adults has primarily been on substance use disorder and antisocial personality disorder. The relevance of impulsivity and the trait impulsivity hypothesis has not been elaborated for ADHD and ODD in adults. In this respect, exploring these relations in emerging adults is particularly critical. Emerging adulthood is a transitional period in life between adolescence and adulthood (Lee et al., 2021). It is characterized by unique life tasks emerging in early adulthood (with increasing responsibility associated with developing independence and entry into higher education or employment) while still undergoing brain development (Arnett, 2014). This mismatch between life demands, skill levels, and brain maturity is exacerbated for those with impulsivity, impaired self-control, externalizing symptoms, and personality instability (Arnett, 2014). Thus, from a trait impulsivity hypothesis perspective, this period may constitute a major risk factor for emerging adults with ADHD and high impulsivity traits who cannot adjust to their developmental demands (LaCount et al., 2018; Persike et al., 2020). However, this group has only minimal data available on how the externalizing spectrum symptoms are associated with different dimensions of impulsivity (Halvorson et al., 2021). Such studies would be needed to better understand ADHD and other externalizing disorders in emerging adulthood and more generally in adults (Abecassis et al., 2017; Jarrett, 2016; Lee et al., 2021). The absence of such data in the literature is a major gap and limitation.

Another major limitation is that the multidimensional nature of ODD has not been considered in previous studies. Indeed, the three sub-dimensions of ODD predict different outcomes: the angry/irritable dimension predicts emotional problems and poorer social skills; the argumentative dimension predicts hyperactivity/conduct problems; while the vindictiveness dimension predicts externalizing, internalizing, and prosocial problems (Wesselhoeft et al., 2019). Exploring the associations of different subcomponents of impulsivity interplaying with the different aspects of ODD symptoms will provide a novel avenue to probe the interplay of specific active psychological variables in ODD with greater precision.

A third major limitation is the statistical approaches applied in past studies. More specifically, although there are considerable overlapping variances across the externalizing spectrum of symptoms and impulsivity dimensions, this was not considered (controlled) in the statistical analyses. Thus, the finding may be confounded by multicollinearity. In this respect, it would be desirable to control for such confounding effects.

In summary, three major limitations have been noted in the existing findings in this area. First, even though both ADHD and ODD are relevant to adults, in the trait-impulsivity hypothesis literature, the relevance of impulsivity and trait impulsivity hypothesis has not been elaborated for ADHD and ODD in adults. Second, the multidimensional nature of ODD has not been considered in previous studies. Exploring the associations will provide a novel avenue to probe the interplay of specific active psychological variables in externalizing psychopathology with greater precision. Third, although there are considerable overlapping variances across the externalizing spectrum symptoms and impulsivity dimensions, this was not considered (controlled) in the statistical analyses, thereby raising the possibility that existing findings may be confounded by multicollinearity. To this end, it is argued that the regularized partial correlation approach used in the network analysis model of psychopathology provides a meaningful and sound framework to explore the unique associations between the externalizing spectrum dimensions with impulsivity as it can model all the multicollinearity between the variables in the network model (Epskamp and Fried, 2018). Further information regarding this approach is provided in the following paragraph.

1.5. Network model of psychopathology

Unlike the latent view of a clinical disorder that proposes that a latent construct (which is the disorder) causes a range of responses (i.e., symptoms of the disorder), in network analysis, a set of symptoms is viewed as a causal system, which interacts with each other in meaningful ways, resulting in the disorder (Borsboom and Cramer, 2013). A popular approach used to estimate relationships between variables in the network analysis model is a cross-sectional partial correlation (von Klipstein et al., 2021). In this approach, partial associations are estimated controlling for all other variables in the network. The relations are estimated using Markov Random Fields (Epskamp et al., 2018), often with regularization, so those spurious associations (i.e., those due to sampling variation) are suppressed (Borsboom and Cramer, 2013; Epskamp and Fried, 2018). The cross-sectional partial correlation is theorized to provide a conditional independence structure, reflecting the causal structure that underlies it (Borsboom and Cramer, 2013). There is now support for this view (von Klipstein et al., 2021). Expressed differently, network analysis results can be understood as a causal system, revealing the more important causal relations between the variables (Borsboom and Cramer, 2013).

Although the network model is explained in terms of a clinical disorder, it needs to be emphasised that this model can be applied more generally to a set of variables or even sets of dimensions (such as the externalizing spectrum dimensions of HY/IN, IA, and ODD). Seen in the context of a network model that includes HY/IN, IA, ODD, and different types of impulsivity dimensions, this would mean that the trait impulsivity hypothesis can be reframed as indicating causal relations of different dimensions of impulsivity with HY/IM, ODD, and IA.

Martel et al. (2017) successfully applied network analysis to a sample of children and adolescents with ADHD and ODD, evaluating the changing symptom networks over age cohorts during consecutive developmental stages (preschool, early childhood, middle childhood, and adolescence periods). Consistent with the trait impulsivity hypothesis, the study found that impulsivity was the core dimension underlying the externalizing spectrum dimensions. However, this study did not explore how the externalizing spectrum dimensions were related to impulsivity, viewed in terms of its multidimensional nature.

1.6. Research objective and predictions of the current study

The current study aimed to address the aforementioned gaps in the literature. From a group of emerging adults (between 18 years to 30 years) from the general Australian community, the present study used network analysis to explore whether and how the trait impulsivity theory can be reframed as indicating causal relations involving the dimensions of impulsivity as proposed in the UPPS-P model of impulsivity (sensation seeking, lack of premeditation, lack of perseverance, negative urgency, and positive urgency) with the externalizing spectrum dimensions of ADHD (IA and HY/IM) and ODD (anger/irritable, vindictiveness, and argumentative/defiant behavior).

Based on the trait impulsivity hypothesis and our literature review, it is hypothesized that (i) HY/IM will be more closely related to urgency (both negative urgency and positive urgency) and to a lesser degree (if any) with sensation-seeking; (ii) IA will be more closely related to lack of perseveration and lack of premeditation. For the subcomponents of ODD, we hypothesized that (i) ODD anger/irritable would be related to

negative urgency; (ii) ODD argumentative/defiant behavior (comprised of arguing with adults, purposefully annoying others, disobedience, and blaming others for one's own mistakes) is also likely to be related to lack of premeditation; and (iii) as ODD vindictiveness reflects spiteful/meanness pertaining to relational aggression and antisocial attitude (based on face validity), it will be largely unrelated to UPPS-P subcomponents of impulsivity.

2. Method

2.1. Participants

The sample in the study was a convenient Australian general community sample of 324 (men = 78, women = 246), comprised of emerging adults. The mean (*SD*) for the entire sample was 23.12 years (3.762 years). The mean (standard deviation) age for women was 23.06 (3.793), and for men, it was 23.31 (3.680). The groups did not differ for age, *t* (*df* = 322), = 0.573, *p* = .614). Twelve (3.7%) participants reported that they had been diagnosed with either ADHD or ODD. Supplementary Table S1 also shows that the majority of participants were either university students or in full-time employment, had completed higher education (university education), were located in regional Australia, and were in some sort of relationship. Supplementary Table 2 provides descriptive scores (including the mean and SD) of the variables represented in the network model.

2.2. Measures

All participants completed a questionnaire on demographic information, including age, gender, education, employment and relationship status, and previous diagnosis of ADHD and ODD. In addition, participants completed the Current Symptom Scale (CSS; Barkley and Murphy, 1998) and the Short-Urgency-Premeditation-Perseverance-Sensation Seeking- Positive Urgency (S-UPPS-P; Cyders et al., 2014).

2.2.1. Current Symptom Scale (CSS; Barkley and Murphy, 1998)

The Current Symptom Scale (CSS; Barkley and Murphy, 1998) was used to obtain ratings for the ADHD and ODD symptoms, comparable to diagnostic symptoms for these disorders in the DSM-IV/DSM-IV-TR and DSM-5. CCS included 18 ADHD symptoms and 8 ODD symptoms. Examples of IA and HY/IM symptoms are "Fail to give close attention to details or make careless mistakes in my work" and "Blurt out answers before questions have been completed", respectively. Participants indicate the frequency of symptoms over the previous six months on a four-point Likert scale: 0 = "never or rarely", 1 = "sometimes", 2 = "often", and 3 = "very often". Thus, higher scores represented greater severity. The CSS was scored to yield the following five dimensions: IA, HY/IM, ODD-anger, ODD-defiant behavior, and ODD-vindictiveness. In the present study, the Cronbach's alpha values for the first four of these scales were 89, .75, .80, and .73, respectively. This value for ODD vindictiveness is not reported as it comprises only one item.

2.2.2. Short-Urgency-Premeditation-Perseverance-Sensation Seeking-Positive Urgency (S-UPPS-P; Cyders et al., 2014)

The Short-Urgency-Premeditation-Perseverance-Sensation Seeking-Positive Urgency (S-UPPS-P; Cyders et al., 2014) measured the five dimensions of impulsivity, including sensation seeking (e.g., "From time to time, I like doing things that are a bit frightening."), lack of premeditation (e.g., "Before doing something, I think about it a lot."), lack of perseverance ("I usually prefer to finish what I've started."), negative urgency (When I'm in a bad mood, I act without thinking"."), and positive urgency ("When I'm really happy, I do not necessarily think about the consequences of my actions.) in the UPPS-P model. The S-UPPS-P has 20 items, with four items for each of the five impulsivity dimensions. Each item is rated based on how the act/incident described applies to them during the last six months. The ratings ranged from 1 ("agree strongly")

to 4 ("disagree strongly"), with higher scores indicating more impulsivity. In the present study, the Cronbach's alpha values for negative urgency, positive urgency, sensation seeking, lack of perseverance, and lack of premeditation, were .85, .75, .84, .89, and .84, respectively.

2.3. Procedure

Approval for the study was provided by the Human Research Ethics Committee of Federation University. The study was advertised widely on noticeboards around Federation University, Facebook, the Australian Psychology Society's website, and general community areas such as bus stops. The recruitment of participants was online for over two months. No inclusion or exclusion criteria, including restrictions based on demographic characteristics, were applied for participation in the study. Survey Monkey was used for data collection. Participants had to click the survey link that led them to the questionnaires that were presented randomly across participants. Proceeding with the survey was taken as providing implicit informed consent. Participants from the Federation University psychology participant pool received research participation credit, and all others were not offered any incentive to participate.

2.4. Statistical network analyses

The network model included the five ADHD and ODD dimensions (IA, HY/IM, ODD-anger, ODD-defiance, and ODD-vindictiveness) and the five impulsivity subcomponents in the S-UPPS-P (negative urgency, positive urgency, sensation seeking, lack of perseverance, and lack of premeditation). As UPPS-P scores are known to be higher among men than women (Loeber and Hay, 1997; Moffitt and Caspi, 2001), and as there are sex differences for externalizing behavior, gender was also included in the network. In network analysis, the number of participants must exceed the number of estimated parameter variables (Epskamp and Fried, 2018). In the current network model, with gender included, there were 11 variables. The total number of estimated parameters in our model was [(11) + (11 × 10/2) = 66] (Leme et al., 2020). Thus, our sample size (*N* = 324) provided ample statistical power, exceeding the minimum requirement for the network analysis.

For the current study, we used the network module provided in Jeffreys' Amazing Statistics Program (JASP) version 0.14.1.0 statistical software (JASP Team, 2020) to conduct the network analysis. This module uses the botnet (Epskamp et al., 2018) and the qgraph (Epskamp et al., 2012) (Epskamp et al., 2012) packages from R to conduct network analyses and network graphs, respectively. A regularized partial correlation approach was used for our network analysis (i.e., Least Absolute Shrinkage and Selection Operator or g-lasso; Tibshirani, 1996). Lasso shrinks small partial correlations to zero, resulting in a sparse network, and showing only the most important relationships, thereby making the network easier to interpret. The EBICglasso produces the optimal degree of shrinkage according to an EBIC and a hyperparameter. The hyperparameter in the study was set at 0.5 since it is suggested to produce networks that balance specificity and interpretability with sensitivity (Foygel and Drton, 2010; Epskamp and Fried, 2018). For the network analysis, missing data were handled using the "exclude pairwise method."

Network analysis provides a graph that is a visualization of the data structure that is easy to interpret. In these network graphs, the variables are referred to as nodes, and the connections between variables are referred to as edges. The strength of the relationship between nodes (i.e., number of connections) is indicated in terms of edge weights. Apart from visualization of the network graph, a number of statistical parameters are reported for a network analysis. The more common ones include edge weights and the centrality of the nodes (Borgatti, 2005). Centrality refers to the relative importance of the individual nodes in the network. A central node is one that is highly connected to other nodes, and its activation can be expected to spread to other nodes.

Given the study's aims (i.e., to examine the associations of the ADHD and ODD dimensions with the S-UPPS-P dimensions), the findings in the results and discussion sections will focus primarily on edge weights. Centrality is not relevant in this context and is therefore not considered further. For the edge weights, a minimum absolute value of 0.03 was considered worthy of interpretation (Isvoranu et al., 2017). Additionally, Christensen and Golino's (2021) guidelines for network effect sizes were used to facilitate the interpretation of the magnitude of our network edge weight findings (small = 0.15, moderate = 0.25, and large = 0.35). Although values between 0.03 and 0.15 were considered worthy of interpretation, they were interpreted as negatable effect sizes. A network must also be evaluated for its accuracy and stability. Network accuracy and stability refer to the likelihood that the network results will be replicated. The accuracy of edge weights can be evaluated using bootstrap 95% non-parametric confidence intervals (CIs), with narrower CIs suggesting a more precise estimation of the edge (Epskamp et al., 2018). The study used these procedures, with 1000 bootstraps, to evaluate the edge weight accuracy.

3. Results

3.1. Missing values

There was no missing value in the data set.

3.2. Stability of the centrality strength index and accuracy of edge weights

Concerning the accuracy of the edge weights (estimated using bootstrap 95% non-parametric CIs), as shown in Supplementary Figure S1, almost all of the 95% CI of the edges included zero. The CIs around the estimated edge weights were relatively small, indicating no significant differences. This suggests that the interpretation of the order of edges in the network is not problematic.

3.3. Results of the network analysis

With 11 nodes, the maximum number of edges in this network was 55. However, the EBICglasso estimation used in the analysis reduced the number of edges estimated to 32. Figure 1 shows a visualization of the relationship of nodes (i.e., gender, ADHD dimensions, ODD dimensions, and S-UPPS-P dimensions) in the network model. Table 1 shows the weight matrix between these nodes.

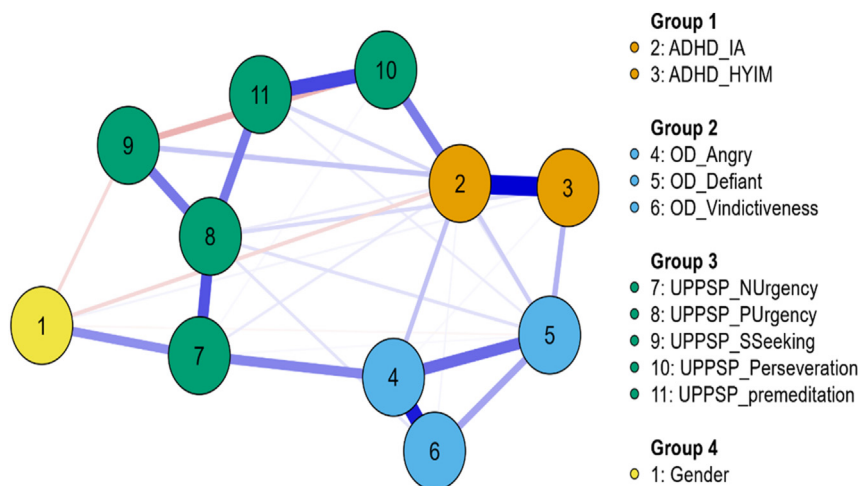### 3.3.1. Associations of the ADHD and ODD dimensions with the S-UPPS-P impulsivity dimensions

As shown in Figure 1 and Table 1, there were noticeable (≥.03) and positive relations for IA connecting with negative urgency, positive urgency, lack of perseveration, and lack of premedition. As shown in Table 1, for these associations, the association involving lack of perseveration was the strongest, with a medium effect size. There were also noticeable and positive relations for HY/IM with positive urgency and sensation seeking, and they were both of negatable effect sizes. There were noticeable and positive relations for ODD-anger with negative urgency, with this association being very close to medium effect size. ODD-defiance had noticeable and positive relations with positive urgency, lack of perseveration, and lack of premeditation. All these associations were of negatable effect sizes. ODD-vindictiveness also had noticeable and positive relations with positive urgency, and this association was of negatable effect size.

3.3.2. Associations of the ADHD and ODD dimensions in the network

As shown in Table 1 and Figure 1, all ADHD and ODD dimensions were associated positively (blue edges) with one another. Notably, the nodes of ADHD (2 and 3), ODD (4, 5, and 6), and S-UPPS-P (7, 8, 9, 10, and 11) dimensions clustered together in different sections of the network. Also, there were noticeable and stronger edge connections within the ADHD and ODD dimensions than between the ADHD and ODD dimensions. The edge weight connections between the ODD and ADHD dimensions were relatively low (ranging from .00 to .17). There were no or minimal edge weight connections (≤.03) for IA (2) with ODD-vindictiveness (6), HY/IM (3) with ODD-anger (4), and ODD-vindictiveness (6). There was a high effect size connection between IA (2) and HY/IM (3), and a high effect size connection between ODD-anger (5) and ODD-Vindictiveness (6).

3.3.3. Association of the S-UPPS-P dimensions in the network

As shown in Table 1 and Figure 1, For the S-UPPS-P nodes, negative urgency and positive urgency were positively connected; positive urgency was associated positively with sensation seeking and lack of premeditation; sensation seeking was associated negatively with lack of perseveration; lack of perseveration and lack of premeditation was associated positively with each other. Table 1 shows that there was a high effect size connection between lack of perseveration (10) and lack of premeditation (11). Another notable edge (at least medium sizes) was between positive urgency (8) and sensation seeking (9). However, not all the S-UPPS-P impulsivity dimensions were interconnected.

Group 1
- 2: ADHD_IA
- 3: ADHD_HYIM

Group 2
- 4: OD_Angry
- 5: OD_Defiant
- 6: OD_Vindictiveness

Group 3
- 7: UPPSP_NUrgency
- 8: UPPSP_PUrgency
- 9: UPPSP_SSeeking
- 10: UPPSP_Perseveration
- 11: UPPSP_premedition

Group 4
- 1: Gender

Figure 1. Network of Relationships Between Gender, and ADHD, ODD and S-UPPS-P Dimensions. *Note.* Blue lines represent positive associations and red lines negative associations. The thickness and brightness of an edge indicate the association strength. The layout is based on the Fruchterman–Reingold algorithm that places the nodes with stronger and/or more connections closer together and the most central nodes into the center.

Table 1. Edge weights between gender, ADHD, ODD and S-UPPS-P dimensions.

Variable	1	2	3	4	5	6	7	8	9	10	11
Gender (1)	0.00	-0.08	0.02	0.00	-0.02	0.00	0.22	0.00	-0.07	0.00	0.00
ADHD Inattention (2)		0.00	0.50	0.12	0.10	0.02	0.04	0.04	0.00	0.25	0.08
ADHD Hyperactivity/Impulsivity (3)			0.00	0.01	0.15	0.00	0.00	0.07	0.11	0.00	0.00
ODD-Anger (4)				0.00	0.29	0.45	0.24	0.00	0.00	0.00	0.00
ODD-Defiance (5)					0.00	0.18	0.01	0.06	0.00	0.04	0.04
ODD-Vindictiveness (6)						0.00	0.00	0.05	0.00	0.00	0.00
UPPSP Negative Urgency (7)							0.00	0.34	0.00	0.01	0.00
UPPSP Positive Urgency (8)								0.00	0.26	0.00	0.26
UPPSP Sensation Seeking (9)									0.00	-0.15	0.00
UPPSP Perseveration (10)										0.00	0.36
UPPSP Premeditation (11)											0.00

Negative urgency had no noticeable associations (≤.03) with sensation seeking, lack of perseverance, and lack of premeditation. Positive urgency had no association with lack of perseverance, and sensation seeking had no association with lack of premeditation.

4. Discussion

Our primary goal was to examine the associations of the ADHD and ODD dimensions with the S-UPPS-P impulsivity dimensions and thereby contribute new information to inform further development of the trait impulsivity hypothesis. To this end, the present study discusses the implications of the findings in terms of (1) the trait impulsivity hypothesis; (2) associations between ADHD and ODD dimensions; (3) the UPPS-P model; and (4) dual processing ADHD models. Additionally, treatment implications will be discussed. However, prior to this discussion, a brief summary of the key findings will be provided to allow the reader to follow our discussion of these issues more closely.

4.1. Summary of key findings

In summary, related to our primary goal, our key findings were that there were noticeable (and positive) relations for (1) IA with negative urgency, positive urgency, lack of premeditation, and lack of perseveration, with the latter being relatively stronger; (2) HY/IM with positive urgency and sensation-seeking; (3) ODD-anger with negative urgency; (4) ODD-defiant with positive urgency, lack of perseverance, and lack of premeditation; and (5) ODD-vindictiveness with positive urgency (see Table 2 for a summary of these findings). Overall, our findings supported most of our predictions, and add new information that could potentially contribute to our understanding of the trait impulsivity theory from a multidimensional impulsivity perspective.

4.2. Theoretical implications

4.2.1. Implications for trait impulsivity hypothesis

Based on the trait impulsivity hypothesis, it was expected that HY/IM and ODD dimensions would be more closely related to sensation-seeking, negative urgency, and positive urgency; IA will be more closely related to lack of perseverance and lack of premeditation; ODD anger/irritable would be related to negative urgency; ODD argumentative/defiant behavior is likely to be related to lack of premeditation. Thus, our findings for associations were in line with these predictions, regarding (1) HY/IM with positive urgency and sensation-seeking; (2) IA with lack of perseverance and lack of premeditation; (3) ODD angry with negative urgency; (4) ODD defiant with lack of premeditation; and (5) ODD vindictiveness with positive urgency. Although we did not predict associations for IA with negative urgency and positive urgency, these were found. One plausible explanation is that the negative and positive urgency dimensions could be linked to deficits in cognitive and attentional controls (i.e., top-down regulation processes), and consequently IA.

4.2.2. Implications for the associations between ADHD and ODD dimensions

The findings that the ADHD and ODD dimensions were associated positively with one another, with stronger connections within the ADHD and ODD dimensions than between the ADHD and ODD dimensions, as well as the findings that the ADHD dimensions and the ODD dimensions were clustered together in different sections of the network is consistent to the view that the ADHD and ODD dimensions represent different but related groups of dimensions. Given the developmental nature of the trait impulsivity hypothesis, it may be worth noting that this was established here for emerging adults.

4.2.3. Implications for the UPPS-P model

Theoretically, given that both sensation seeking and lack of perseveration are different types of impulsivity, a positive association between

Table 2. Relations Between ADHD, ODD and S-UPPS-P Dimensions with Correlation of at least 0.03.

Variable	Negative Urgency	Positive Urgency	Sensation Seeking	Perseveration	Premeditation
ADHD dimensions					
Inattention	+	+		+	+
Hyperactivity/Impulsivity		+	+		
ODD dimensions					
Anger	+				
Defiance		+		+	+
Vindictiveness		+			

Note. + = Correlation of at least 0.03 (considered worthy of interpretation; Isvoranu et al., 2017).
Bold + indicate effect size of moderate magnitude (Guidelines for network effect sizes interpretation: small = 0.15, moderate = 0.25, and large = 0.35; Christensen and Golino, 2021).

them was expected. Thus, our finding for a negative association between them was unexpected. However, such a relation has been reported in the literature (e.g., Donati et al., 2021; D'Orta et al., 2015; Mestre-Bach et al., 2020), and therefore, should not be interpreted as questioning the validity of the UPPS-P impulsivity model or the S-UPPS-P.

4.2.4. Implication for dual processing ADHD models

In the UPPS-P/S-UPPS-P, the positive and negative urgency factors are influenced by bottom-up processing, whereas the lack of premeditation and lack of perseverance factors are influenced by bottom-up processing (Cyders and Smith, 2008; Cyders et al., 2014; Martel and Nigg, 2006; Smith and Cyders, 2016). This distinction has relevance for ADHD, as dual-processing models of ADHD have implicated IA and HY primarily with top-down and bottom-up processing difficulties, respectively (Martel and Nigg, 2006).

As positive associations were found for IA with negative urgency, positive urgency, lack of premeditation, and lack of perseverance, it can be argued that IA is associated with both top-down and bottom-up processing difficulties. However, as the association for IA with lack of perseverance was much stronger than the other associations involving the impulsivity dimensions with IA, it could be speculated, consistent with dual-processing models, that IA is especially strongly associated with top-down processing difficulties. Also, as HY/IM was associated with positive urgency and sensation-seeking, it could be speculated that it is associated with bottom-up processing difficulties, as proposed in dual-processing models of ADHD.

In terms of the ODD dimensions, ODD-anger with positively with negative urgency, and vindictiveness was associated positively with positive urgency. Thus, both anger and vindictiveness are associated with bottom-up processing difficulties. In contrast, ODD-defiant was associated positively with positive urgency, lack of perseverance, and lack of premeditation. Thus, ODD-defiant is associated with both top-down and bottom-up processing difficulties, with the association with top-down being more pronounced.

Although our findings are in part consistent with existing dual-processing theories of ADHD, they also provided a revised perspective in suggesting that IA is not only linked to top-down processing difficulties but also bottom-up processing. More importantly, our findings also showed that the different ODD dimensions are also linked to bottom-up and top-down processing. Indeed, in this respect, these findings for ODD are new.

4.3. Treatment implications

Although the proposed factor structure for UPPS-P/S-UPPS-P is a five-factor oblique model, there is also support for a hierarchical structure, with three factors: higher-order factors for urgency (with positive and negative urgency as lower-order factors) and lack of conscientiousness (with lack of premeditation and lack of perseverance as lower-order factors), and a primary factor for sensation seeking (Billieux et al., 2012; Cyders et al., 2014; D'Orta et al., 2015; Dugré et al., 2019). In terms of the content, the urgency dimension taps into emotional impulsivity (EI), and the conscientiousness dimension taps into cognitive impulsivity (CI). Thus, at a higher level, the UPPS-P model distinguishes between cognitive and emotional types of impulsivity.

Based on our findings for the associations for IA with the S UPPS-P dimensions, it can be argued that IA is associated with both cognitive and emotional impulsivity, However, the association for IA with lack of perseverance was much stronger than the other associations involving the impulsivity dimensions with IA, it could be speculated that IA is especially strongly associated with cognitive impulsivity. Also, as HY/IM with associated with positive urgency and sensation-seeking, it could be speculated that it is associated with emotional impulsivity. Concerning the ODD dimensions, our findings suggest that both anger and vindictiveness are associated with cognitive impulsivity. In contrast, ODD-defiant is associated with both cognitive and emotional

impulsivity, with the association with emotional impulsivity being more pronounced.

In a network, the presence of a connection between two symptoms implies that they are conditionally dependent on each other given the other symptoms in the network. Our edge weight findings linking the ADHD and ODD dimensions with different types of impulsivity have important treatment implications for ADHD, ODD, and comorbid ADHD/ODD. In this respect, the findings raise the possibility that directly focusing on emotionally and cognitively driven impulsivity can be an effective treatment for ADHD and/or ODD. They suggest that IA and ODD defiant symptoms can be reduced by reducing both cognitive and emotional impulsivity. Additionally, HY/IM, ODD-anger, and ODD-vindictiveness can be reduced by reducing emotional impulsivity.

To date, there has been no proven evidence-based treatment for impulsivity. Generally, treatment approaches recommended for impulsivity have been based on their efficacy for disorders closely associated with impulsivity (Moeller et al., 2001). Pharmaceutically, these include anticonvulsants, beta-adrenergic blockers or antagonists, lithium, antipsychotic agents, selective serotonin reuptake inhibitors (SSRIs), methylphenidate, dextroamphetamine, and pemoline (Neto and True, 2011). Major non-pharmaceutical treatments have included cognitive-behavioural therapy and dialectic behavior therapy (Neto and True, 2011). Siegel (2010) has also proposed a mediation-based intervention strategy that focuses on the regulation of emotion, intending to move from "being the emotion" to becoming a more distant observer of the emotion. It is assumed that with repeated practice of the strategies in this approach, the cortical connections necessary to regulate intense emotions will be built. As will be evident, Siegel's (2010) intervention can be seen as especially useful for treating emotional impulsivity.

4.4. Limitations and directions for further studies

Despite the novel findings reported in this study, the findings and interpretations made in the study must be viewed with several limitations in mind. Most importantly, the sample selection criteria could be considered as not sufficiently adequate to meet the objectives of the study. Secondly, although we used network analysis with partial regularized correction, "true" causality cannot be assumed as cross-sectional data was used. At best, we were able to eliminate spurious candidates for causal relations. Causality assessment would require longitudinal data collected repeatedly. Further studies may wish to minimize such concerns by using longitudinal network analysis. Thirdly, as the network analysis was conducted using a normative-community sample of emerging adults, the findings cannot be directly generalized to other samples, such as clinical groups, different age cohorts, or other groups of specific demographic characteristics. Relatedly, it is possible that uncollected demographic factors, such as the ethnicity of the participants, could have confounded the results (Wiesner et al., 2015). Additionally, the sample comprised of individuals mainly with non-pathological levels of ADHD and ODD symptoms. It is conceivable that the findings may not actually represent those with ADHD and/or ODD diagnoses. Also noteworthy is that other factors, such as psychiatric comorbidities and neurodevelopmental factors, may significantly influence the clinical picture of ODD and ADHD. These were not considered in the current study. Other limitations also need consideration. As self-report measures were used, the findings may be confounded with common method variance and may not be applicable to data collected via clinical interviews. Also, as our results are based on a single study, there is a need for more studies and replications before our findings can be generalized with confidence. Therefore, there is a need for more network studies of ADHD, ODD, and multidimensional impulsivity traits, which use longitudinal data, multiple sources, and methods on different racial and clinical groups. Despite these limitations, our findings offer new insights by reframing the trait impulsivity hypothesis using multidimensional measures of impulsivity concerning the externalizing trait spectrum.

5. Conclusions

Three major strengths of this study were (1) the use of network analysis to examine the interrelations of the ADHD and ODD dimensions with the five S-UPPS-P impulsivity dimensions; (2) parsing impulsivity into multidimensional dimensions; and (3) decomposing ODD into respective dimensions (ODD-anger, ODD-defiance, and ODD-vindictiveness). To our knowledge, this study is the first to address these relations in this manner. For the network analysis, we applied regularized partial correlation and therefore, the relations between the symptoms were estimated controlling for all other variables in the network. Consequently, the network findings can be interpreted in terms of a conditional independence structure, reflecting causal interactions between the symptoms in meaningful ways, resulting in the disorder (Borsboom and Cramer, 2013; von Klipstein et al., 2021).

As our study included HY/IM, IA, ODD dimensions (ODD-anger, ODD-defiance, and ODD-vindictiveness), and different types of impulsivity dimensions, our findings can be interpreted as indicating causal relations of the different dimensions of impulsivity with HY/IM, ODD dimensions, and IA. Although Martel et al. (2017) applied network analysis to a sample of children and adolescents with ADHD and ODD and demonstrated (consistent with the trait impulsivity theory) that impulsivity was the core dimension underlying these externalizing dimensions, our findings can be seen as extending the findings reported by Martel et al. as we showed that the externalizing spectrum dimensions were associated differentially with different types of impulsivity. More specifically, we were able to tease out the unique associations of the ADHD and ODD dimensions with different types of impulsivity. Our findings, therefore, provide new contributions to our understanding of the existing trait impulsivity theory.

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What this paper adds?

To our knowledge, this is the first study that applied network analysis to evaluate the Trait Impulsivity Hypothesis by parsing impulsivity into respective multidimensional components. It also decomposed ODD into respective dimensions (ODD-anger, ODD-defiance, and ODD-vindictiveness). By teasing out the unique associations of the ADHD and ODD subdimensions with different components of impulsivity, the present study identified critical links in symptom networks; and these provide novel insights into how symptoms influence each other in producing or maintaining the disorders. Consequently, the findings contribute to the existing trait impulsivity hypothesis by examining, for the first time, the inter-relationships of the ADHD (IA, HY/IM) and ODD (anger/irritable, vindictiveness, and argumentative/defiant behavior) dimensions with different observable aspects of impulsivity. An important feature of network analysis is that it will concurrently control all possible covariates. In contrast, existing studies have adapted the traditional latent variable approach to investigate trait impulsivity. Finally, emerging adulthood (18–25 years) represents an understudied transitional period in life, with increasing responsibility and independence but still undergoing brain development. The mismatch between life demands and brain maturity is exacerbated for those with impulsivity, which was the focus of the analyses among the emerging adult sample. The present study has, therefore, provided a substantive conceptual and methodological contribution to the literature.

Declarations

Author contribution statement

Rapson Gomez: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Shaun Watson: Performed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Taylor Brown: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Vasileios Stavropoulos: Conceived and designed the experiments; Analyzed and interpreted the data.

Wai Chen: Analyzed and interpreted the data; Wrote the paper.

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