Personality and Individual Differences 204 (2023) 112041



Contents lists available at ScienceDirect

Personality and Individual Differences

journal homepage: www.elsevier.com/locate/paid





Reward sensitivity across the lifespan in males and females and its associations with psychopathology

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ARTICLE INFO

Keywords:
Rewards
Mental disorders
Transdiagnostic
Lifespan
Nonlinear models

ABSTRACT

Most studies on the relationship between reward sensitivity and psychopathology have focused on one condition at a time and have not considered potential sex or lifespan differences. Using nonlinear modeling, we explored reward sensitivity normative patterns across the lifespan (age range: 4–91; $N = 37{,}727$) for men and women, and subsequently studied its sex-specific associations with psychopathology problems (inattention, hyperactivity, autism spectrum, reactive aggression, depression, anxiety, smoking, and alcohol, soft and hard drug use). Findings indicated a nonlinear trend for reward sensitivity across the lifespan: within childhood, adolescence, middle-age adulthood, and older adulthood, older individuals scored lower compared to younger ones, with no age differences beyond age 70. Across young adulthood, older males scored higher and females presented no age differences. Reward sensitivity was positively associated with all psychopathology problem domains studied and associations were clustered into three groups: neurodevelopmental, with stronger associations in young age and more lifespan similarity in males; internalizing, with stronger associations in young and middle adulthood and in females; and substance use, with mostly similar associations across the lifespan and virtually no sex differences. In conclusion, reward sensitivity is transdiagnostically relevant for psychopathology, with specific lifespan and sex patterns within the neurodevelopmental, internalizing, and substance use problems.

1. Introduction

Our instinct to seek out and attain rewards guarantees our survival (e.g., eating and drinking water). Rewards are also fundamental for emotional experiences, motivation, and learning processes (Wise, 2002). However, individuals differ greatly in their sensitivity to rewards. One way of conceptualizing reward sensitivity is based on Gray's reinforcement sensitivity model of personality, which describes the Behavioral Activation System (BAS) as the system that regulates our approach motivation to attain rewards (Gray, 1981). Extreme scores on questionnaires measuring BAS are associated with a wide range of psychopathology domains. For instance, there is evidence of high reward sensitivity in conditions like attention deficit/hyperactivity disorder (ADHD), oppositional defiant disorder (ODD), substance use disorders (SUD), and anxiety disorders (Barker et al., 2019; Bruin, 2011; Cardoso Melo, Groen, & Hartman, 2022; Franken et al., 2006; Loxton & Dawe, 2001; Mitchell & Nelson-Gray, 2006). On the other hand, low reward sensitivity has been observed in individuals with major depressive disorder (MDD), although no association was found when considering only self-report measures (Katz et al., 2020). Even though research on reward sensitivity measured by questionnaires in autism spectrum disorder (ASD) is scarce, low reward sensitivity in ASD has been described (Larson et al., 2010; Schiltz et al., 2018). Taken together, the literature suggests that individuals with extreme reward sensitivity tend to be more vulnerable to psychopathology.

Despite numerous observations that extreme levels of reward sensitivity are linked to multiple forms of psychopathology, the literature is fragmentary. Most studies have focused on only one disorder or psychopathology domain at a time. As a result, methodological differences (e.g., design, sample characteristics, statistical approach) complicate comparisons of findings across studies. Hence, there is a need to carefully map individual differences in reward sensitivity to various psychopathology domains to study overlap and differences. Our recent work in a cohort of adolescents followed up into young adulthood

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https://doi.org/10.1016/j.paid.2022.112041
Received 9 November 2022; Received in revised form 3 December 2022; Accepted 5 December 2022
Available online 15 December 2022
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showed that high reward sensitivity is shared across psychopathology domains and predicts their future course (Cardoso Melo, Groen, & Hartman, 2022). However, most studies on the relationship between reward sensitivity and psychopathology, including ours, have focused on specific age ranges. Even though reward sensitivity has been shown to decrease throughout life (Espinoza Oyarce et al., 2021; Jorm et al., 1998; Windsor et al., 2012), no studies have documented normative lifespan trends from childhood to old age. As for psychopathology, the course over the lifespan differs across domains (e.g., there is a higher remission rate of ADHD than ASD (Daniels et al., 2011; Faraone et al., 2006)). Therefore, age-related differences in reward sensitivity and psychopathology may influence how they are associated with each other across the lifespan.

Besides age, research suggests that sex might influence reward sensitivity. Both behavioral and neuroimaging studies have shown higher reward sensitivity in males than females (Eneva et al., 2017; Georgiou et al., 2018; Soutschek et al., 2017). However, not all studies support this (Colder & O'Connor, 2004; Scheres & Sanfey, 2006). It is possible that potential sex-related differences in reward sensitivity may translate to well-known sex differences in prevalence rates of certain conditions (e.g., ADHD is more common in males, while anxiety disorders and MDD are more common in adult females (Hartung & Lefler, 2019)). Yet, it is currently unknown whether males and females differ in the association between reward sensitivity and psychopathology.

In this study, we used cross-sectional data spanning ages 4–91 (N = 37,727) to investigate the normative patterns of reward sensitivity across the lifespan in males and females and the associations with different psychopathology problem domains (i.e., attention problems, hyperactivity, autism spectrum problems, reactive aggression problems, mood problems, anxiety problems, alcohol use, smoking, soft drug use, and hard drug use).

2. Methods

2.1. Sample and design

We used data from the Comorbid Conditions of Attention deficit/hyperactivity disorder (CoCA) add-on study within the Lifelines Cohort Study. Lifelines is a prospective population-based cohort study examining the health and health-related behaviors of 167,729 persons living in the North of the Netherlands. First, an index population between 25 and 50 years old was recruited. Subsequently, their family members, such as partners, parents, parents-in-law, and children were invited to participate in Lifelines. Thus, individuals between 25 and 50 years old are overrepresented in the sample. Additionally, adults could self-register online. More information about Lifelines can be found elsewhere (Scholtens et al., 2015). For CoCA, all Lifelines participants were invited and approximately 22.5 % of all participants (N = 37,727, age 4–91 years) participated, which involved completing digital surveys. The surveys measured psychopathology, reward sensitivity, sleep problems, and circadian rhythm (sleep problems and circadian rhythm are not part of the current study). The University Medical Center Groningen ethics committee approved Lifelines and CoCA, and informed consent was obtained from the participants or their parents.

2.2. Measurements

For a full description of the measurements, please refer to Supplement 1.

Reward sensitivity was assessed with the Sensitivity to Reward (SR) scale of the parent-reported and self-reported Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ) in individuals under and over 18 years old, respectively (Colder & O'Connor, 2004; Torrubia et al., 2001). Although the SPSRQ measures both sensitivity to punishment and reward, only the reward sensitivity subscale was administered in CoCA within Lifelines.

Attention problems and hyperactivity were assessed with the Self-Report Questionnaire on Attention Problems and Hyperactivity in individuals over 18 years old and with the parent-reported version in those under 18 years old (Kooij et al., 2008; Kooij & Buitelaar, 1997).

Autism spectrum problems were assessed with the Children's Social Behavior Questionnaire (CSBQ) and the Adult Social Behavior Questionnaire (ASBQ) in individuals under and over 18 years old, respectively (Hartman et al., 2006; Horwitz et al., 2016).

Reactive aggression problems were assessed with the aggressive behavior syndrome scale of the parent-reported Child Behavior Checklist (CBCL) and the Adult Self-Report (ASR) in individuals under and over 18 years old, respectively (Achenbach & Rescorla, 2001; Achenbach & Rescorla, 2003).

Mood and anxiety problems were assessed with the parent-reported CBCL and the self-reported Youth Self-Report (YSR) in individuals under 13 years old and individuals between 13 and 17 years old, respectively (Achenbach & Rescorla, 2001). For those over 18 years old, we used the Dutch version of the self-reported Mini International Neuropsychiatric Interview (MINI; Overbeek et al., 1999).

2.2.1. Substance use

We assessed alcohol use, smoking, soft drug use, and hard drug use with a parent- or self-reported survey developed for Lifelines.

2.2.2. Covariates

Age was measured in years. We used education years as a proxy for socioeconomic status (SES), measured as parental education years (i.e., average of both parents) for individuals up to 24 years old and as own education years for those over 24. Finally, sex was coded dichotomously.

2.3. Missing data

Online survey administration resulted in less than 5 % of individuals with incomplete data. Still, we used corrected item mean imputation for individuals with at least 50 % of the items filled in per scale. See Supplement S2 for details. After imputation, less than 0.5 % of individuals had missing values.

2.4. Statistical analyses

First, we explored the normative trends of reward sensitivity across the lifespan using descriptive statistics. Next, we analyzed the association between reward sensitivity and psychopathology problem domains across the lifespan and, if applicable, by sex using generalized additive models (GAMs; Wood, 2017). GAMs are flexible regression models that allow linear and nonlinear relationships between the independent (reward sensitivity and age) and dependent variables (psychopathology problems). Each psychopathology problem domain was modeled separately. All continuous variables were standardized to enhance results interpretability and allow cross-domain comparability. For substance use domains, the only dichotomous outcomes, we fitted logistic GAMs.

In each model, we predicted psychopathology problems by smooth (nonlinear) terms for reward sensitivity and age while adjusting for SES. We added a tensor product interaction term to test whether the association between reward sensitivity and psychopathology problems varied across the lifespan. Finally, to test whether these associations differed by sex, we modeled difference smooths for sex. If there was a statistically significant difference between males and females, we allowed the estimation of independent smooths by sex to fully capture these differences.

3. Results

3.1. Descriptive statistics

A total of 37,727 individuals were included in the study, of whom 57.6 % were females (Table S1). Participants ranged from 4 to 91 years

old with a mean age (SD) of 48.9 (15.9) years. Sample demographics are provided in Tables S1-S3. Correlations between reward sensitivity and psychopathology problems are presented in Tables S4-S6.

3.2. Normative patterns of reward sensitivity across the lifespan

Fig. 1 shows reward sensitivity scores for males and females at each age. Reward sensitivity showed a nonlinear trend across the lifespan. Within childhood, adolescence, middle-age adulthood, and older adulthood, older males and females scored lower than their younger counterparts, with no age differences after age 70. Across young adulthood, though, older males scored higher than younger ones and females presented no age differences. Furthermore, overall, males scored higher compared to females. See Figs. S1 and S2 for the lifespan patterns of psychopathology.

The contrasting patterns in reward sensitivity observed between adolescence and young adulthood coincides with the informant change from parent- to self-report. To examine if the informant change explained this shift, we estimated reward sensitivity scores for each informant separately (i.e., from age 4 to 17 for parent-report and from age 18 onwards for self-report; Fig. S3). The separate plots confirmed that the patterns observed in Fig. 1 hold despite the informant change. However, there is some difference in reward sensitivity levels between parent- and self-report that likely reflects cross-informant discrepancies as each informant has access to different information and may interpret that information differently.

3.3. Associations between reward sensitivity and psychopathology – GAMs

Reward sensitivity was significantly associated with all psychopathology problem domains tested (Table S6). To aid interpretation of the (non)linear associations, Figs. 2 and 3 display the estimated level or probability of psychopathology problems for individuals with low, average, and high reward sensitivity. Note that to observe whether the association between reward sensitivity and psychopathology problems differed across the lifespan, one should focus on the differences between the lines depicting the three levels of reward sensitivity. When the association of reward sensitivity with psychopathology problems is similar across the lifespan, all lines follow the same change pattern (e.g., alcohol use, males). In contrast, when the change patterns among the three lines diverge, association differs across the lifespan (e.g., reactive aggression problems, females).

Across all psychopathology domains tested, higher reward sensitivity related to higher levels of psychopathology problems. Additionally, the association between reward sensitivity and psychopathology problems differed across the lifespan for attention problems, hyperactivity, autism spectrum problems (only in females), reactive aggression problems, mood problems, anxiety problems, alcohol use, and smoking (Table S6). Specifically, Fig. 2 shows that the association between reward sensitivity and neurodevelopmental problems (i.e., attention, hyperactivity, autism spectrum, and reactive aggression) was stronger for younger people than older people. In contrast, this association was strongest for young and

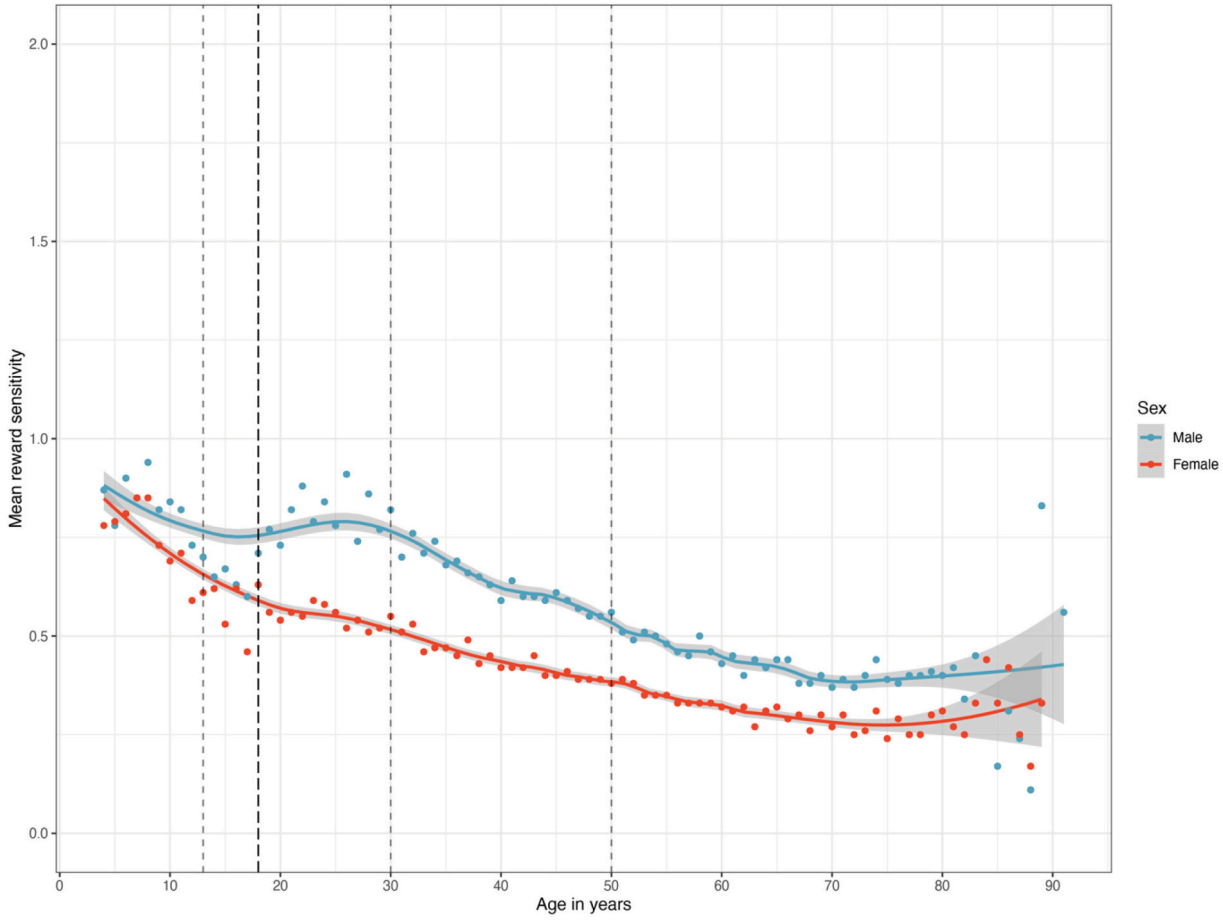

Fig. 1. Reward sensitivity scores across the lifespan for males and females.
Note. The data points represent the mean score for all individuals at each age in years. Lines and shaded area represent loess fit lines and their credible interval, respectively. Vertical dotted lines represent the cutoff points for the different age groups (up to 12 years old 'childhood'; 13–17 'adolescence'; 18–29 'young adulthood'; 30–49 'middle-age adulthood'; above 50 'older adulthood'). Age groups are plotted solely for reference. Age was a continuous measure in all analyses. The bold vertical dotted line represents the informant change from parent- to self-report.

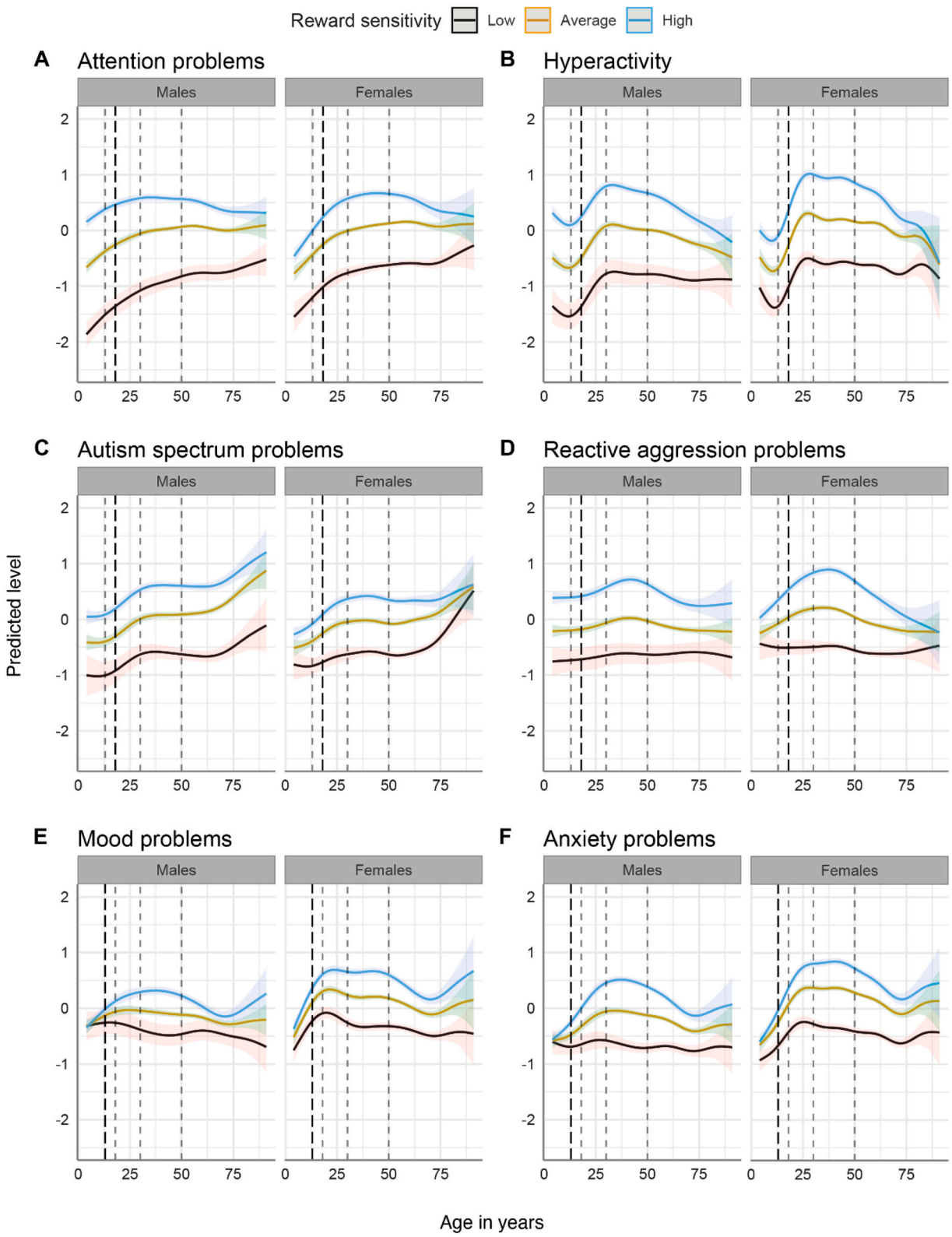

Fig. 2. Estimated level of psychopathology problems across the lifespan for males and females with varying reward sensitivity levels.
Note. The figures display the predicted level of psychopathology (standardized) based on the main effect of reward sensitivity and its effect in interaction with age, for males and females, adjusted for SES. For mood and anxiety problems, although plotted separately, males and females did not significantly differ in the interaction effect between reward sensitivity and age. The different lines show different reward sensitivity levels and their associated credible intervals. To account for males scoring higher on reward sensitivity than females (Fig. 1), extreme levels were set to 2 and 1.5 SD above and below the mean, respectively, which corresponds to comparable high and low reward sensitivity scores for males and females in the plots. The vertical dotted lines represent the cutoff points for the different age groups (up to 12 years old 'childhood'; 13–17 'adolescence'; 18–29 'young adulthood'; 30–49 'middle-age adulthood'; above 50 'older adulthood'). Age groups are plotted solely for reference. Age was a continuous measure in all analyses. The bold vertical dotted line represents the informant change from parent- to self-report, which is earlier for mood and anxiety than for the other domains of psychopathology.

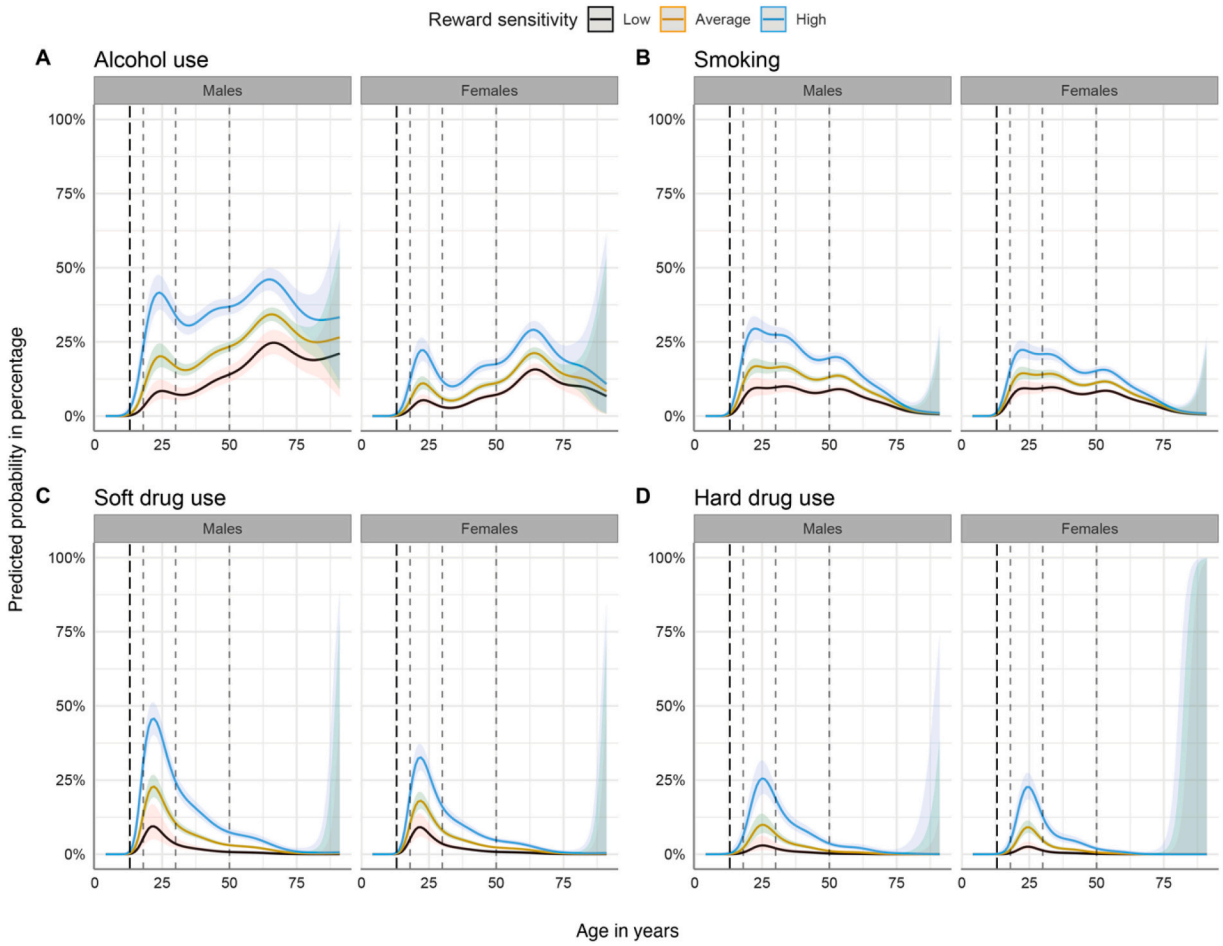

Fig. 3. Estimated probability of substance use across the lifespan for males and females with varying reward sensitivity levels.
Note. The figures display the predicted probability of substance use based on the main effect of reward sensitivity and its effect in interaction with age for males and females, adjusted for SES. Except for hard drug use, although plotted separately, males and females did not significantly differ in the main effect of reward sensitivity and its effect in interaction with age. The different lines show different reward sensitivity levels and their associated credible intervals. To account for males scoring higher on reward sensitivity than females (Fig. 1), extreme levels were set to 2 and 1.5 SD above and below the mean, respectively, which corresponds to comparable high and low reward sensitivity scores for males and females in the plots. The vertical dotted lines represent the cutoff points for the different age groups (up to 12 years old 'childhood'; 13–17 'adolescence'; 18–29 'young adulthood'; 30–49 'middle-age adulthood'; above 50 'older adulthood'). Age groups are plotted solely for reference. Age was a continuous measure in all analyses. The bold vertical dotted line represents the informant change from parent- to self-report.

middle-aged adults for internalizing problems (i.e., mood and anxiety). For alcohol use and smoking, the association with reward sensitivity was strongest in adulthood (Fig. 3). In contrast, the association was not significantly different across the lifespan for soft and hard drugs.

The associations between reward sensitivity and psychopathology problems differed by sex in most cases (Table S8). First, the associations with neurodevelopmental problems were more similar across the lifespan for males than females. As shown in Fig. 2, while relevant across the lifespan for males, reward sensitivity was less relevant for females in childhood and old age compared to other life phases. The associations with internalizing problems were slightly more similar across the lifespan for females, compared to males. Fig. 2 shows that while relevant across the lifespan for females, reward sensitivity was less relevant for males in childhood compared to other life phases. For hard drugs, statistical testing indicated that the association differed by sex. Fig. 3 indicates, however, highly similar associations for both sexes indicating that statistical testing picked up on very subtle differences. In contrast, the associations with alcohol use, smoking, and soft drug use did not differ across sexes.

4. Discussion

Our results yielded four key findings. First, reward sensitivity followed a nonlinear trend across the lifespan: within childhood and adolescence, older individuals scored higher than younger ones; within young adulthood, older males scored higher and females presented no age differences; within middle-age and older adulthood, older individuals scored lower than younger ones, with no age differences beyond age 70. Second, higher reward sensitivity related to more psychopathology problems. Third, this association between reward sensitivity and psychopathology problems was strongest in young age for neurodevelopmental problems and between young and middle-age adulthood for internalizing problems. In contrast, this association was mostly similar across the lifespan for substance use problems. Fourth, we found sex differences across the lifespan in the association between reward sensitivity and neurodevelopmental problems (more similar in males) and internalizing problems (more similar in females).

We identified a nonlinear normative trend in reward sensitivity across the lifespan. Although we used cross-sectional data of different persons as a proxy for development, thus we cannot determine whether the observed age differences do reflect aging, our findings support, as well as refine, previous findings. For instance, a decreasing trend in

reward sensitivity has been already described in childhood (Assari, 2020) and adulthood (Dierickx et al., 2022; Espinoza Oyarce et al., 2021; Jorm et al., 1998), suggesting that reward sensitivity decreases over the lifespan. We found similar trends and extend previous findings by applying non-linear modeling which suggested discontinuities in young adulthood and old age. Specifically, during young adulthood, older males scored higher than their younger counterparts and females scored similarly regardless of age. An increase in reward sensitivity in young adulthood has been previously reported (Pagliaccio et al., 2016; Schreuders et al., 2018; Urosevic et al., 2012; Windsor et al., 2012). However, given that we stratified by sex, this only held for males, which may be driven by the peak in testosterone level in males during young adulthood (Harden et al., 2018). Furthermore, nonlinear modeling suggested that reward sensitivity stabilizes from age 70 onwards, which had not been previously reported. This stabilization could be explained by a so-called goal orientation shift, in which individuals' motivation to explore external and novel rewards, as measured in our questionnaire, shifts towards the maintenance and exploitation of well-known rewards already at one's disposal (Ebner et al., 2006; Spreng & Turner, 2021).

Generally, higher reward sensitivity related to more psychopathology problems. This association varied between three domains of psychopathology problems: neurodevelopmental, internalizing, and substance use. For neurodevelopmental problems, we observed the strongest associations in childhood, which is also when neurodevelopmental conditions have their onset (Thapar et al., 2017). For internalizing problems, the strongest associations were in young and middle-age adulthood, which is again the peak onset period for internalizing disorders (Kessler et al., 2005). For substance use, the association between reward sensitivity and alcohol use and smoking statistically differed across the lifespan, while it was similar for soft and hard drug use. However, the plots for alcohol use and smoking indicated hardly any differences in form across the lifespan between low and high reward sensitivity. Most likely, given the higher frequency of drinking and smoking than soft and hard drug use across the lifespan, we had a higher chance to identify (subtle) lifespan differences (i.e., a low frequency may attenuate an association). We conclude that the associations of any type of substance use with reward sensitivity were roughly similar across the lifespan.

The associations between reward sensitivity and neurodevelopmental problems were more similar across the lifespan for males than females. While relevant across the whole lifespan for males, reward sensitivity was less relevant in females in childhood and old age. In contrast, the associations with internalizing problems were more similar across the lifespan for females, compared to males for whom the association was less prominent in childhood. Lastly, we found no sex differences in the association between reward sensitivity and most substance use indicators. Hard drug use was an exception and males and females statistically differed. However, the plots indicated hardly any sex differences in the association between reward sensitivity and hard drug use. Therefore, across the full lifespan, we conclude that while males and females with high reward sensitivity are equally likely to report substance use, males are more likely to report neurodevelopmental problems, and females internalizing problems.

Our study is the first to investigate the normative patterns of reward sensitivity across the lifespan by sex and its associations with psychopathology. We analyzed a general population sample of over 37,000 individuals aged 4 to 91 years. Additionally, our data are characterized by broad measurement of psychopathology problems, which allowed us to bridge the current fragmentary literature that focuses on one psychopathology problem domain at a time. Thus, we could provide a comprehensive overview of cross-domain similarities and differences per life phase and sex.

Nonetheless, we must acknowledge that we used cross-sectional data as a proxy for developmental change and cross-sectional data might be confounded by cohort effects. One example is the alcohol use increase in older adulthood, which can potentially be explained by the higher rates of substance use of baby boomers relative to previous cohorts (Cleary et al., 2017). Even though studies like the current are important to chart developmental trends, further longitudinal work, feasible when focused on specific parts of the lifespan, is needed. Another potential limitation is that our findings cannot be directly translated to clinical psychiatric conditions as we used dimensional measures of psychopathology. Still, our work is highly relevant for extending the knowledge on the role of reward sensitivity in psychopathology and may be used as a basis for future clinically-oriented studies.

Another point that merits further discussion is that the SR scale from the SPSRQ is only one way to measure reward sensitivity. The SR scale was originally conceptualized as a broad construct of reward sensitivity to reflect the BAS. However, recent studies have proposed that the BAS is better reflected by four subdimensions (i.e., *wanting, incentive motivation, striving, and liking*) and the SR scale tends to load on the *wanting* subdimension, which is described as a form of impulsivity that reflects the ambition and readiness to obtain or consume rewards (Krupić et al., 2016; Krupić & Corr, 2017). Consequently, it might be that the associations found here are driven by this specific subdimension rather than the broad construct of reward sensitivity. This raises a question as to whether our findings can be generalized to broad reward sensitivity or other subdimensions of reward sensitivity. Therefore, we would like to see confirmation of our findings based on different instruments that distinguish these proposed subdimensions of reward sensitivity, such as the Reinforcement Sensitivity Theory of Personality Questionnaire (RST-PQ; Corr & Cooper, 2016). While this was not the purpose of this study, a final note is that cause and effect cannot be teased out by our data. We modeled reward sensitivity as the predictor, in line with theory, but it may additionally be the case that psychopathology alters reward sensitivity. Alternatively, both extreme reward sensitivity and psychopathology may have a (partly) common cause, such as a shared genetic disposition.

In conclusion, our study showed how reward sensitivity differs across the lifespan and how it is associated with psychopathology problems while highlighting age, sex, and cross-domain differences. This way, our work adds substantially to the characterization of the relationship between reward sensitivity and psychopathology. We have shown that reward sensitivity is of transdiagnostic relevance for psychopathology and has specific lifespan and sex patterns within the neurodevelopmental, internalizing, and substance use domains.

CRediT authorship contribution statement

Raniere Dener Cardoso Melo: Conceptualization, Methodology, Formal analysis, Data Curation, Writing Original-Draft Preparation, Visualization; **Marieke J. Schreuder**: Methodology, Writing - Reviewing and Editing; **Robin N. Groen**: Conceptualization, Writing - Reviewing and Editing; **Dina Sarsembayeva**: Methodology, Writing - Reviewing and Editing; **Catharina A. Hartman**: Conceptualization, Methodology, Writing - Reviewing and Editing, Supervision.

Funding

This study used data from the ADHD add-on study of the Lifelines initiative. The Lifelines initiative has been made possible by a subsidy from the Dutch Ministry of Health, Welfare, and Sport, the Dutch Ministry of Economic Affairs, the University Medical Center Groningen (UMCG), the University of Groningen, and the Provinces in the North of the Netherlands (Drenthe, Friesland, Groningen). The ADHD add-on study has been funded by the European Community's Horizon 2020 Programme under grant agreement number 667302 (CoCA). However, the funders had no role in the study design; in the collection, analysis, and interpretation of data; in the writing of the report; and in the decision to submit the article for publication.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.paid.2022.112041.

References

Achenbach, T. M., & Rescorla, L. A. (2001). *Manual for the ASEBA school-age forms & profiles*. University of Vermont, Research Center for Children, Youth, & Families.

Achenbach, T. M., & Rescorla, L. A. (2003). *Manual for the ASEBA adult forms & profiles*. University of Vermont, Research Center for Children, Youth, & Families.

Assari, S. (2020). Age-related decline in children's reward sensitivity: Blacks' diminished returns (Issue 1) *Research in Health Science, 5*(3), 112 https://www.ncbi.nlm.nih.gov/pubmed/33274304.

Barker, T. V., Buzzell, G. A., & Fox, N. A. (2019). Approach, avoidance, and the detection of conflict in the development of behavioral inhibition. *New Ideas in Psychology, 53*, 2–12. https://doi.org/10.1016/j.newideapsych.2018.07.001

Bruin, N. H. (2011). *Reward- and punishment sensitivity in reactive andproactive aggression* [Master Thesis, University of Leiden]. Student Repository at the University of Leiden https://hdl.handle.net/1887/18102.

Cardoso Melo, R. D., Groen, R. N., & Hartman, C. A. (2022). Reward sensitivity at age 13 predicts the future course of psychopathology symptoms. *Frontiers in Psychiatry, 13*, 818047. https://doi.org/10.3389/fpsyt.2022.818047

Cleary, M., Sayers, J., Bramble, M., Jackson, D., & Lopez, V. (2017). Overview of substance use and mental health among the "baby boomers" generation. *Issues in Mental Health Nursing, 38*(1), 61–65. https://doi.org/10.1080/01612840.2016.1243177

Colder, C. R., & O'Connor, R. M. (2004). Gray's reinforcement sensitivity model and child psychopathology: Laboratory and questionnaire assessment of the BAS and BIS. *Journal of Abnormal Child Psychology, 32*(4), 435–451. JACP.0000030296.54122.b6.

Corr, P. J., & Cooper, A. J. (2016). The Reinforcement Sensitivity Theory of Personality Questionnaire (RST-PQ): Development and validation. *Psychological Assessment, 28*(11), 1427–1440. https://doi.org/10.1037/pas0000273

Daniels, A., Daniels, A., Rosenberg, R., Rosenberg, R., Law, J., Law, J., Lord, C., Lord, C., Kaufmann, W., Kaufmann, W., Law, P., & Law, P. (2011). Stability of initial autism spectrum disorder diagnoses in community settings. *Journal of Autism and Developmental Disorders, 41*(1), 110–121. https://doi.org/10.1007/s10803-010-1031-x

Dierickx, S., Dierckx, E., Claes, L., & Rossi, G. (2022). Measuring behavioral inhibition and behavioral activation in older adults: Construct validity of the Dutch BIS/BAS scales. *Assessment (Odessa, Fla.), 29*(5), 1061–1074. https://doi.org/10.1177/10731911211000123

Ebner, N. C., Freund, A. M., & Baltes, P. B. (2006). Developmental changes in personal goal orientation from young to late adulthood. *Psychology and Aging, 21*(4), 664–678. https://doi.org/10.1037/0882-7974.21.4.664

Eneva, K. T., Murray, S., O'Garro-Moore, J., Yiu, A., Alloy, L. B., Avena, N. M., & Chen, E. Y. (2017). Reward and punishment sensitivity and disordered eating behaviors in men and women. *Journal of Eating Disorders, 5*(1), 6. https://doi.org/10.1186/s40337-017-0138-2

Espinoza Oyarce, D. A., Burns, R., Butterworth, P., & Cherbuin, N. (2021). Bridging classical and revised reinforcement sensitivity theory research: A longitudinal analysis of a large population study. *Frontiers in Psychology, 12*, Article 737117. https://doi.org/10.3389/fpsyg.2021.737117

Faraone, S. V., Biederman, J., & Mick, E. (2006). The age-dependent decline of attention deficit hyperactivity disorder: A meta-analysis of follow-up studies. *Psychological Medicine, 36*(2), 159–165. https://doi.org/10.1017/S003329170500471X

Franken, I. H. A., Muris, P., & Georgieva, I. (2006). Gray's model of personality and addiction. *Addictive Behaviors, 31*(3), 399–403. https://doi.org/10.1016/j.addbeh.2005.05.022

Georgiou, P., Zanos, P., Bhat, S., Tracy, J. K., Merchenthaler, I. J., McCarthy, M. M., & Gould, T. D. (2018). Dopamine and stress system modulation of sex differences in decision making. *Neuropsychopharmacology: Official Publication of the American College of Neuropsychopharmacology, 43*(2), 313–324. https://doi.org/10.1038/npp.2017.161

Gray, J. A. (1981). In *A critique of Eysenck's theory of personality. A model for personality* (pp. 246–276). Springer.

Harden, K. P., Mann, F. D., Grotzinger, A. D., Patterson, M. W., Steinberg, L., Tackett, J. L., & Tucker-Drob, E. M. (2018). Developmental differences in reward sensitivity and sensation seeking in adolescence: Testing sex-specific associations with gonadal hormones and pubertal development. *Journal of Personality and Social Psychology, 115*(1), 161–178. https://doi.org/10.1037/pspp0000172

Hartman, C. A., Luteijn, E., Serra, M., & Minderaa, R. (2006). Refinement of the Children's Social Behavior Questionnaire (CSBQ): An instrument that describes the diverse problems seen in milder forms of PDD. *Journal of Autism and Developmental Disorders, 36*(3), 325–342. https://doi.org/10.1007/s10803-005-0072-z [doi].

Hartung, C. M., & Lefler, E. K. (2019). Sex and gender in psychopathology: DSM-5 and beyond. *Psychological Bulletin, 145*(4), 390–409. https://doi.org/10.1037/bul0000183

Horwitz, E. H., Schoevers, R. A., Ketelaars, C. E. J., Kan, C. C., van Lammeren, A. M. D. N., Meesters, Y., Spek, A. A., Wouters, S., Teunisse, J. P., Cuppen, L., Bartels, A. A. J., Schuringa, E., Moorlag, H., Raven, D., Wiersma, D., Minderaa, R. B., & Hartman, C. A. (2016). Clinical assessment of ASD in adults using self- and other-report: Psychometric properties and validity of the Adult Social Behavior Questionnaire (ASBQ). *Research in Autism Spectrum Disorders, 24*, 17–28. https://doi.org/10.1016/j.rasd.2016.01.003

Jorm, A. F., Christensen, H., Henderson, A. S., Jacomb, P. A., Korten, A. E., & Rodgers, B. (1998). Using the BIS/BAS scales to measure behavioural inhibition and behavioural activation: Factor structure, validity and norms in a large community sample. *Personality and Individual Differences, 26*(1), 49–58. https://doi.org/10.1016/S0191-8869(98)00143-3

Katz, B. A., Matanky, K., Aviram, G., & Yovel, I. (2020). Reinforcement sensitivity, depression and anxiety: A meta-analysis and meta-analytic structural equation model. *Clinical Psychology Review, 77*, Article 101842. https://doi.org/10.1016/j.cpr.2020.101842

Kessler, R. C., Berglund, P., Demler, O., Jin, R., Merikangas, K. R., & Walters, E. E. (2005). Lifetime prevalence and age-of-onset distributions of DSM-IV disorders in the National Comorbidity Survey Replication. *Archives of General Psychiatry, 62*(6), 593–602. https://doi.org/10.1001/archpsyc.62.6.593

Kooij, J. J., Boonstra, A. M., Swinkels, S. H. N., Bekker, E. M., Noord, I. D., & Buitelaar, J. K. (2008). Reliability, validity, and utility of instruments for self-report and informant report concerning symptoms of ADHD in adult patients. *Journal of Attention Disorders, 11*(4), 445–458. https://doi.org/10.1177/1087054707299367

Kooij, J. J. S., & Buitelaar, J. K. (1997). *Self-report questionnaire on attention problems and hyperactivity*.

Krupić, D., & Corr, P. J. (2017). *Moving forward with the BAS: Towards a neurobiology of multidimensional model of approach motivation* (Issue 1). *26* https://dabar.srce.hr/islandora/object/ffos:2623.

Krupić, D., Corr, P. J., Ručević, S., Križanić, V., & Gračanin, A. (2016). Five reinforcement sensitivity theory (RST) of personality questionnaires: Comparison, validity and generalization. *Personality and Individual Differences, 97*, 19–24. https://doi.org/10.1016/j.paid.2016.03.012

Larson, M. J., South, M., Krauskopf, E., Clawson, A., & Crowley, M. J. (2010). Feedback and reward processing in high-functioning autism. *Psychiatry Research, 187*(1), 198–203. https://doi.org/10.1016/j.psychres.2010.11.006

Loxton, N. J., & Dawe, S. (2001). Alcohol abuse and dysfunctional eating in adolescent girls: The influence of individual differences in sensitivity to reward and punishment. *The International Journal of Eating Disorders, 29*(4), 455–462. https://doi.org/10.1002/eat.1042

Mitchell, J. T., & Nelson-Gray, R. O. (2006). Attention-deficit/hyperactivity disorder symptoms in adults: Relationship to gray's behavioral approach system. *Personality and Individual Differences, 40*(4), 749–760. https://doi.org/10.1016/j.paid.2005.08.011

Overbeek, T., Schruers, K., & Griez, E. (1999). *Mini international neuropsychiatric interview*. Maastricht: University of Maastricht.

Pagliaccio, D., Luking, K. R., Anokhin, A. P., Gotlib, I. H., Hayden, E. P., Olino, T. M., Peng, C., Hajcak, G., & Barch, D. M. (2016). Revising the BIS/BAS scale to study development: Measurement invariance and normative effects of age and sex from childhood through adulthood. *Psychological Assessment, 28*(4), 429–442. https://doi.org/10.1037/pas0000186

Scheres, A., & Sanfey, A. G. (2006). Individual differences in decision making: Drive and reward responsiveness affect strategic bargaining in economic games. *Behavioral and Brain Functions: BBF, 2*(1), 35. https://doi.org/10.1186/1744-9081-2-35

Schiltz, H. K., McVey, A. J., Barrington, A., Haendel, A. D., Dolan, B. K., Willar, K. S., Pleiss, S., Karst, J. S., Vogt, E., Murphy, C. C., Gonring, K., & Van Hecke, A. V. (2018). Behavioral inhibition and activation as a modifier process in autism spectrum disorder: Examination of self-reported BIS/BAS and alpha EEG asymmetry. *Autism Research, 11*(12), 1653–1666. https://doi.org/10.1002/aur.2016

Scholtens, S., Smidt, N., Swertz, M. A., Bakker, S. J. L., Dotinga, A., Vonk, J. M., van Dijk, F., van Zon, S. K. R., Wijmenga, C., Wolffenbuttel, B. H. R., & Stolk, R. P. (2015). Cohort profile: LifeLines, a three-generation cohort study and biobank. *International Journal of Epidemiology, 44*(4), 1172–1180. https://doi.org/10.1093/ije/dyu229

Schreuders, E., Braams, B. R., Blankenstein, N. E., Peper, J. S., Guroglu, B., & Crone, E. A. (2018). Contributions of reward sensitivity to ventral striatum activity across adolescence and early adulthood. *Child Development, 89*(3), 797–810. https://doi.org/10.1111/cdev.13056

Soutschek, A., Burke, C. J., Raja Beharelle, A., Schreiber, R., Weber, S. C., Karipidis, I. I., ten Velden, J., Weber, B., Haker, H., Kalenscher, T., & Tobler, P. N. (2017). The dopaminergic reward system underpins gender differences in social preferences. *Nature Human Behaviour, 1*(11), 819–827. https://doi.org/10.1038/s41562-017-0226-y

Spreng, R. N., & Turner, G. R. (2021). From exploration to exploitation: A shifting mental mode in late life development. *Trends in Cognitive Sciences, 25*(12), 1058–1071. https://doi.org/10.1016/j.tics.2021.09.001

Thapar, A., Cooper, M., & Rutter, M. (2017). Neurodevelopmental disorders. *The Lancet. Psychiatry, 4*(4), 339–346. https://doi.org/10.1016/S2215-0366(16)30376-5

Torrubia, R., Ávila, C., Moltó, J., & Caseras, X. (2001). The Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ) as a measure of Gray's anxiety and impulsivity dimensions. *Personality and Individual Differences, 31*(6), 837–862. https://doi.org/10.1016/S0191-8869(00)00183-5

Urosevic, S., Collins, P., Muetzel, R., Lim, K., & Luciana, M. (2012). Longitudinal changes in behavioral approach system sensitivity and brain structures involved in reward processing during adolescence. *Developmental Psychology, 48*(5), 1488–1500. https://doi.org/10.1037/a0027502

Windsor, T. D., Pearson, E. L., & Butterworth, P. (2012). Age group differences and longitudinal changes in approach–avoidance sensitivity: Findings from an 8-year longitudinal study. *Journal of Research in Personality, 46*(6), 646–654. https://doi.org/10.1016/j.jrp.2012.07.002

Wise, R. A. (2002). *Brain reward circuitry: Insights from unsensed incentives*. Elsevier Inc. https://doi.org/10.1016/S0896-6273(02)00965-0

Wood, S. N. (2017). *Generalized additive models: An introduction with R* (2nd ed.). CRC Press, Taylor & Francis Group. https://doi.org/10.1201/9781315370279