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Clinical factors predicting impaired executive functions in eating disorders: The role of illness duration

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ABSTRACT

Poor performance in executive functions is observed in individuals with eating disorders (EDs). These impairments have usually been associated with the presence of comorbid psychopathology or with higher severity of EDs. However, few studies have explored the interaction between illness duration and deficits in executive functions. The present study investigates the association between ED duration and performance in decision-making, inhibitory control, and cognitive flexibility in the anorexia nervosa restrictive subtype (AN-R), bulimic/purging subtype (AN-BP), and binge spectrum disorders (BSDs) (namely, bulimia nervosa and binge eating disorder) among 116 women with EDs compared with 123 women healthy controls (HCs). Using cumulative survival analysis, we estimated the risk of deficits related to illness duration. Predictors of executive dysfunctions were assessed by regression analysis, including as potential predictors illness duration, severity of general psychopathology, and ED symptomatology. Results showed poor decision-making and cognitive flexibility in participants with EDs compared with HCs. ED duration was associated with poor inhibitory control in the AN-BP group and poor cognitive flexibility in the BSD group. The illness duration increased the risk of presenting early deficits in executive function. In decision-making and inhibitory control, the AN-R group showed the earliest deficits, whereas in cognitive flexibility it was the BSD group. ED duration predicted impaired cognitive flexibility in the BSD group and impaired inhibitory control in the AN-BP group, whereas the severity of general psychopathological symptoms was a predictor of impaired cognitive flexibility in individuals with AN-R. These results highlight the relevance of illness duration in executive dysfunctions in EDs.

1. Introduction

Executive functions are a set of mental processes that facilitate controlling and adapting goal-directed behaviors to internal states and environmental context (Diamond, 2013). They consist of several subdomains that include decision-making, set-shifting, planning, working memory, cognitive function, and inhibition, as well as other cognitive domains important for the functioning of human behavior. For this reason, executive dysfunctions can involve difficulties at the cognitive, behavioral, and emotional levels, exerting substantive problems on individuals' everyday life activities (Rabinovici et al., 2015).

In the case of eating disorders (EDs), previous studies have reported dysfunctions in different executive processes, such as cognitive flexibility (Wu et al., 2014), decision-making (Guillaume et al., 2015), and inhibitory control (Bartholdy et al., 2016), suggesting that executive dysfunctions play a key role in problems related to maladaptive eating behaviors. Consistent with this hypothesis, a recent study detected that poor cognitive functioning in childhood was also associated with the risk of developing EDs in adolescence (Schaumberg et al., 2020). Likewise, a recent review suggested that impaired cognitive functions can

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contribute to the etiology and maintenance of the disorder (Smith et al., 2018). However, to date, it remains unclear whether executive dysfunctions are a vulnerability factor for ED symptoms or whether ED symptoms are influencing executive deficits (Hirst et al., 2017).

Cognitive flexibility, understood as the ability to shift thoughts or actions according to situational demands, is frequently impaired in EDs (Tchanturia et al., 2012; Wu et al., 2014). In individuals with anorexia nervosa restrictive subtype (AN-R), it is observed a lack of cognitive flexibility associated with rigid behaviors and habits, contributing to increased severity of ED symptomatology, such as intake restriction (Abbate-Daga et al., 2014; Roberts et al., 2010). But on the other hand, a recent review has recently been described that the recovery of normal weight in these individuals can improve cognitive flexibility in children and adolescents with AN (Hemmingsen et al., 2020). In the case of individuals within the bulimic-binge spectrum of eating disorders (BSDs) — namely, bulimia nervosa (BN) and binge eating disorder (BED) — poor cognitive flexibility is frequently linked to the inability to cut off compulsive overeating (Wu et al., 2014).

Similarly, deficits in decision-making have been widely described in individuals with EDs (Guillaume et al., 2015). Decision-making involves several processes that require the evaluation and selection of stimuli to execute a planned behavior based on preferences formation (Ernst and Paulus, 2005). Interestingly, studies in AN-R have described how poor decision-making is positively associated with an acute phase of the disorder (Lindner et al., 2012; Tchanturia et al., 2007) that improves when there is remission of ED symptomatology in these individuals, displaying similar performance to healthy controls (Lindner et al., 2012; Steward et al., 2016; Tchanturia et al., 2007). Accordingly, Guillaume and collaborators (2015) suggested that these observed deficits in decision-making can be a state rather than a trait impairment in AN and BN. In the case of individuals with BED, it has been observed a predisposition to make decisions that provide immediate but negative results, disregarding options that provide long-term benefits (Steward et al., 2019). Deficits in decision-making in BED are also associated with problems in attentional skills and low adaptability to change according to the context (Aloi et al., 2015).

Regarding inhibitory control, understood as the ability to suppress or interrupt behavioral or cognitive responses (Bari and Robbins, 2013), several studies have described an altered performance in each ED subtype (Howard et al., 2020; Smith et al., 2018; Wierenga et al., 2014). In the case of AN-R, an exacerbated inhibitory control over intake can lead to dietary restraint despite negative health consequences (Howard et al., 2020; Wierenga et al., 2014), whereas in individuals within the BSD, inhibitory control deficits are associated with impulsivity and emotional regulation difficulties that can lead to binge episodes (Kittel et al., 2015).

In the same way that executive functions interact with ED symptomatology, some studies point out a reciprocal association between executive function deficits and the presence of comorbid symptomatology with other psychiatric disorders (Billingsley-Marshall et al., 2013; Matsumoto et al., 2015). For instance, it has been observed that anxiety and depressive symptoms can predict poor performance on executive functions in AN-R, anorexia binge/purging (AN-BP), specified feeding or eating disorder (OSFED) (Billingsley-Marshall et al., 2013), and BN (Matsumoto et al., 2015). The presence of comorbid psychopathology has been associated with a worse prognosis of EDs, hampering recovery and a good treatment outcome (Forrest et al., 2018) thereby extending illness duration (Ambwani et al., 2020; Fernández-Aranda et al., 2021; Flynn et al., 2020).

Overall, illness duration in psychiatric disorders has been associated with poor cognitive performance (Galimberti et al., 2020). In EDs, the role of illness duration has been widely studied because it is closely connected with nonresponders to treatment and therefore, with chronicity (Fernández-Aranda et al., 2021). Although this finding is inconsistent with other studies that found no relationship between ED duration and treatment outcome (Radunz et al., 2020). Results in this area are still unclear, reinforcing the need to explore the impact of ED duration on treatment outcome. Concerning cognition, a longer ED duration could be expected to have an adverse effect on executive functions, according to previous evidence (Galimberti et al., 2020). However, the literature on the impact of disease duration on executive function is contradictory and requires further research. For instance, a study in individuals with AN and BN observed how longer illness duration and severity in ED symptomatology were associated with executive dysfunctions (Grau et al., 2019; Roberts et al., 2010) whereas other studies did not find significant associations (Cavedini et al., 2004; Galimberti et al., 2012).

In light of the above, there is a lack of studies addressing how ED duration affects each ED subtype differently. Given the impact of illness duration on individuals with eating disorders (Fernández-Aranda et al., 2021), and the role of executive functions on the treatment outcome (Billingsley-Marshall et al., 2013; Juarascio et al., 2015), the present study investigates performance in executive functions within three main cognitive domains: cognitive flexibility, decision-making, and inhibitory control in women with AN-R, AN-BP, and BSD (i.e., BED, BN), compared to a healthy control group. To explore the impact of illness duration on executive dysfunction in each ED subtype, we explored whether illness duration was associated with decision-making, cognitive flexibility, and inhibitory control performance within each ED subtype. Furthermore, we sought to identify the point estimate throughout the EDs where there is an associated risk for executive dysfunction. Finally, to explore the potential factors contributing to executive dysfunctions, we also assessed the predictive role of ED duration, ED symptomatology, and general psychopathology in observed deficits within these executive subdomains for each ED subtype.

Based on prior literature, we would expect poorer executive function performance across all ED subtypes compared to healthy controls. Regarding illness duration, we hypothesized a negative association between illness duration and executive function performance among ED subtypes. Finally, we postulated that longer ED duration, higher ED symptomatology, and more severe general psychopathology would distinctively predict executive dysfunctions in each ED subtype.

2. Methods

2.1. Participants

The present study recruited 239 female participants. A total of 116 individuals had a diagnosis of ED and 123 belonged to the healthy control (HC) group. The ED groups were classified according to three ED subtypes: AN-R (n = 59), AN-BP (n = 27), and BSD (n = 30) based on the DSM-5 diagnostic criteria (APA, 2013). The current diagnosis of ED was considered irrespective of whether patients had another ED subtype during their lifetime. All participants of the ED groups were previously admitted to the EDs Unit of the Bellvitge University Hospital (Barcelona, Spain). Patients were asked to voluntarily participate in the study and were assessed by experienced clinicians using a semi-structured interview based on the SCID-5 (First et al., 2015). During the clinical interview, individuals with EDs reported onset and duration of problematic eating. It should be noted that this study did not generate the illness duration as the difference between age and onset, but rather both onset and duration were self-reported.

Neuropsychological and clinical assessments were conducted in the first week of treatment. Women in the control group were recruited from the same hospital catchment area. The exclusion criteria applied in this study were as follows: (1) being male; (2) individuals with a history of chronic medical illness or neurological condition that might affect cognitive function; (3) individuals with head trauma with a loss of consciousness for more than 2 min, learning disability or intellectual disability; and (4) individuals age under 18 or over 60 years of age.

Written informed consent was obtained from all participants before they took part in the study. The study procedures were carried out in

accordance with the Declaration of Helsinki as revised in 1989, and the Clinical Research Ethics Committee of Bellvitge University Hospital (PR146/14) approved the study.

2.2. Procedures

Participants underwent two separate sessions: the first session consisted of a psychological assessment, and the subsequent session consisted of an executive function assessment.

2.2.1. Psychological assessment

Temperament and Character Inventory-Revised (TCI-R). This 240-item questionnaire is a self-report instrument that assesses temperament and character traits on a 5-point Likert scale (Cloninger et al., 1993). Temperamental dimensions are novelty-seeking, harm avoidance, reward dependence, and persistence, whereas character dimensions are self-directedness, cooperativeness, and self-transcendence. The current study used the validated Spanish version of the questionnaire, which demonstrated a Cronbach's alpha of 0.87 (Gutiérrez-Zotes et al., 2004).

Symptom Checklist-Revised (SCL-90-R). This 90-item questionnaire is a self-report instrument that measures perceived psychopathological symptoms on a 5-point Likert scale (Derogatis and Savitz, 1999). Items are subdivided into nine dimensions: somatization, obsessive-compulsive, interpersonal sensitivity, depression, anxiety, hostility, phobic anxiety, paranoid ideation, and psychoticism. These dimensions enable the determination of the Global Severity Index (GSI). The current study used the validated Spanish version of the questionnaire, which has demonstrated a Cronbach's alpha of 0.75 (Derogatis, 2002).

Eating Disorders Inventory-2 (EDI-2). ED symptomatology was assessed via a validated Spanish version of the Eating Disorders Inventory-2 (Garner, 1991). The EDI-2 is a self-report instrument to screen symptomatology related to eating disorders on a six-point Likert scale. The EDI-2 consists of 91 items and provides scores on 11 subscales: drive for thinness, body dissatisfaction, bulimia, ineffectiveness, perfectionism, interpersonal distrust, interoceptive awareness, maturity fears, asceticism, impulse regulation, and social insecurity. The sum of all subscales provides an eating disorder measure, which is considered a global scale of ED severity. The EDI-2 has been validated in the Spanish population, showing a Cronbach's alpha of 0.63 (Garner, 1998).

2.2.2. Executive function assessment

Executive function performance was evaluated considering three subdomains: cognitive flexibility, inhibitory control, and decision-making. Deficits in executive functions were established when individuals' scored below the 16th percentile based on normative values regarding age and education according to previous studies examining cognitive performance (Reitan, 2004; Tanner-Eggen et al., 2015).

Wisconsin Card Sorting Test (WCST) (Heaton and Staff, 1990). Cognitive flexibility was evaluated using the computerized WCST (version 4). The WCST consists of matching stimulus cards within one of three available categories: color, shape, or number. For a correct match, participants must identify the sorting rule, receiving the feedback of "Right" or "Wrong" after each sort. Following 10 consecutive correct matches, the rule is changed and then a new sorting rule must be identified. There are up to six attempts to detect the sorting rule and five rule shifts during the task. Each rule attainment is referred to as "category completed". Participants do not know the correct rules or changes. The test continues until 128 cards are sorted. Two types of errors exist: perseverative errors (i.e., the number of errors when continuously responding to an incorrect rule) and nonperseverative errors (i.e., the number of errors when changing a rule). Both are summarized in terms of total errors as an index of cognitive flexibility.

IOWA Gambling Task (IGT) (Bechara et al., 1997). Decision-making was assessed using a computerized version of the IGT. This task consists of selecting 100 cards distributed in four decks (A, B, C, and D). Participants have five blocks (20 cards in each trial). There are two advantageous decks (C and D) providing overall gains, whereas the disadvantageous decks (A and B) provide overall losses. Participants are instructed to choose cards to obtain as much money as possible with minimal losses. Higher scores involve advantageous decks (better performance), whereas lower scores involve a persistent choice of disadvantageous decks (poor performance). Scores from five blocks facilitate obtaining a learning curve and total IGT score, which are the sum of the five blocks.

Stroop Color-Word Test (SCWT) (Golden, 1978). Cognitive inhibitory control was evaluated using the SCWT. This paper-and-pencil test is composed of three different trials. In the first trial, participants read the color names displayed on a page. Next, participants must indicate the color in which an "X" is printed. Finally, there is a trial involving the names of colors printed in an incongruent color (e.g., the word "blue" printed in red). Participants must complete each trial in 45 s. Collectively, these results enable the determination of the "interference score", where a high interference score indicates good cognitive inhibitory control.

2.3. Statistical analysis

Statistical analysis was carried out with Stata16 for Windows (StataCorp, 2019). First, comparisons between the groups were based on chi-square tests for categorical measures and the analysis of variance (ANOVA) for quantitative variables.

Second, Cox regression analysis estimated the survival function between the duration of the ED in years and the presence of a deficit in the cognitive measures of the study. This methodology is a statistical procedure commonly used to explore changes over time for a specific event with censored data. Third, separate survival functions were used to assess the relationship between the EDs and the risk of presenting impaired cognitive functioning, as well as the potential moderator/interaction role in each ED subtype.

Finally, stepwise logistic regressions explored the main contributors to the presence of impaired performance in decision-making, cognitive flexibility, and inhibitory control. These models implemented the duration of eating-related symptoms, ED severity (EDI-2 total), and global psychopathological distress (SCL-90R GSI) as potential predictive variables. Impaired performance was identified when participants scored below the 16th percentile (Reitan, 2004; Tanner-Eggen et al., 2015) according to the normative data published in the manuals of each test. Concretely, scores below the 16th percentile in the IGT total score were considered to indicate impaired decision-making, and scores below the 16th percentile in perseverative errors, nonperseverative errors, and numbers of categories completed were considered to indicate impaired cognitive flexibility. Likewise, impaired inhibitory control was assigned to participants scoring below the 16th percentile on the Stroop interference scale. Goodness-of-fit was valued with Hosmer-Lemeshow test ($p > 0.5$ was considered for adequate fitting) and the global prediction capacity with the Nagelkerke's pseudo-R^2 coefficient.

Analyses involving executive functions were adjusted for age and education levels, and the BMI as confounding variables. The effect size for the mean differences in the ANOVA was estimated with Cohen's d coefficient (poor effect size was considered for $|d|>0.20$, mild-moderate for $|d|>0.50$, and high-large for $|d|>0.80$) (Cohen, 1988; Granero et al., 2020; Kelley and Preacher, 2012). For the correlation estimates, the effect size was considered mild-moderate for $|R|>0.24$ and high-large for $|R|>0.37$ (these thresholds correspond to Cohen's $d = 0.50$ and $d = 0.80$, respectively) (Rosnow and Rosenthal, 1996). Finally, Finner correction was also used to control for Type-I error due to multiple statistical comparisons (Finner and Roters, 2001). This correction carries out by adjusting the rejection criteria for each hypothesis fixing the familywise error rate no higher than a certain prespecified significance level. The procedure starts sorting into order lowest-to-highest the p(unadjusted)-values p1, …, pk obtained in

k-independent null-hypothesis tests and then applying the next algorithm: p(adjusted) = (1 – (1-p(non-adjusted)) ^ (total tests/position within the ordered tests). This study applied the Finner method separately for each Table/procedure.

3. Results

3.1. Description of the sample

Table 1 describes the clinical groups (AN-BP, AN-R, BSD) and the healthy controls, including age, body mass index (BMI), age at the onset of ED, and the duration of the ED (in years). Both onset and duration were directly reported by individuals with EDs. Significant differences between groups were found in age, the duration of the ED, and BMI. The age of onset of the disorder did not differ between ED subtypes.

The first block of Table 2 shows the clinical measures and neurocognitive performance, including the frequency distribution of the former: the severity of the ED symptoms (EDI-2 total) and global psychopathological distress (SCL-90R GSI). Differences between the groups appeared, except for the comparison between BSD and AN-BP.

3.2. Differences between ED subtypes and healthy controls in executive function performance

The second block of Table 2 contains the comparison between groups (adjusted by the covariates age and education, and BMI) for the mean scores obtained in each executive function. All clinical groups showed poor decision-making scores compared to controls; lower cognitive flexibility was detected for individuals with AN-BP and BSD than for controls. The AN-R group obtained better performance in decision-making and cognitive flexibility than the AN-BP and BSD groups. No differences were found between the BSD and AN-BP groups. Finally, as to inhibitory control, no differences were observed between any of the ED groups and HCs or between clinical groups.

Fig. 1 includes the neurocognitive profile of executive subdomains in the study: the first line graph represents the prevalence of participants within the deficit condition, and the second line graph represents the z-standardized means (standardized values within the sample).

Likewise, deficits in executive functions were mainly represented by the BSD group. Considering the cutoff point for identifying impaired performance (i.e., scores below the 16th percentile), 66% of individuals with BDS exhibited deficits in decision-making, whereas 48.1% and 40.7% of individuals in the AN-BP and AN-R groups, respectively, exhibited deficits in decision-making. Deficits in cognitive flexibility were observed in 33% of the BSD and AN-BP groups and 18.6% in the AN-R group. The smallest deficit gaps were observed in inhibitory control. In the BSD group, 33% of participants demonstrated deficits in inhibitory control, whereas 22% and 18.6% of participants in the AN-BP and AN-R groups, respectively, demonstrated deficits in inhibitory control. There was a lower proportion of individuals with deficits in the control group than in the clinical groups (Fig. 1).

3.3. Associations between ED duration and executive function performance among ED subtypes

Table 3 includes the correlation matrix between ED duration and performance on the executive functions (partial correlations adjusted by age and education, and BMI were calculated). For the AN-BP group, ED duration was negatively correlated with Stroop interference. For the BSD group, ED duration was negatively correlated with the WCST number of categories completed. Also, ED duration was positively correlated with the number of WCST errors and perseverant errors, in this group.

3.4. Association between ED duration and the risk of deficits in executive function

The risk associated with executive impairment is represented in Fig. 2, which contains the survival functions (adjusted by age and education level, and BMI) obtained for each executive domain: the ED duration is plotted on the X-axis and the cumulative proportion of participants "surviving" without the presence of impaired executive function is plotted on the Y-axis (functional deficits were assigned to individuals with performance scores below the 16th percentile based on normative data). Each graphic includes a horizontal dashed line drawn on the value 0.75 for the Y-axis (representing the probability of *surviving* without cognitive deficit, corresponding to the 75th percentile) and three vertical dashed lines for the cutoff of the 75th percentile, with the cumulate curves estimated for each diagnostic subtype. Dashed lines within each plot identify the duration of the disorder associated with a high risk of impaired cognitive performance (at least 25% of risk).

Therefore, an ED duration of 3 years among AN-R demonstrated at least a 25% risk of deficits in decision-making (that is, at least 25% of AN-R experienced impaired decision-making after an ED duration of 3 years). For BSD, ED duration of 7 years was associated with at least a 25% probability of reporting impaired decision-making while, for AN-BP, ED duration of 8 years was associated with a 25% or higher risk of impaired decision-making. As to cognitive flexibility, BSD duration of 8 years, AN-R duration of 9 years, and AN-BP duration of 11 years were the thresholds for a 25% or more risk of achieving impaired levels. For the inhibitory control domain, the risk of impaired performance was 25% or greater after a duration of 5 years for AN-R, 12 years for AN-BP, and 15 years for BSD.

3.5. Predictors of deficits in executive functions

The results of the logistic regressions exploring whether ED duration, among other clinical indexes, was a predictor of executive dysfunctions among ED subtypes are included in Table 4. For the AN-R group, psychopathological distress was associated with a higher likelihood of deficits in cognitive flexibility. For the AN-BP group, a higher likelihood of deficits in inhibitory control was related to longer ED duration. Finally, in the BSD group, increased odds of impaired flexibility were also related to longer ED duration.

Table 1
Descriptive of the sample.

	Control *(N = 123)*		AN-R *(N = 59)*		AN-BP *(N = 27)*		BSD *(N = 30)*		
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*p*
Chronological age (years-old)	26.21	7.91	26.36	8.50	28.67	8.91	35.63	10.28	**<.001***
Onset of disorder (years-old)	–	–	20.88	8.14	21.00	8.06	23.17	9.86	.469
Duration of disorder (years)	–	–	5.22	6.07	8.41	4.89	9.98	7.80	**.003***
Body mass index (BMI,kg/m^2)	21.66	2.68	16.10	1.50	16.74	1.95	30.80	9.17	**<.001***
Frequency of binges/week	–	–	–	–	2.30	3.24	6.40	4.48	**<.001***
Frequency of vomits/week	–	–	–	–	5.74	5.55	3.53	5.08	.123

Note. AN-R: anorexia nervosa restrictive. AN-BP: anorexia nervosa bulimic purgative. BSD: binge spectrum disorder.
SD: standard deviation. *Bold: significant comparison (0.05 level). — Not applicable.

Table 2
Comparison for clinical measures and neurocognitive performance.

	Control		AN-R		AN-BP		BSD		Factor group		AN-R vs Control		AN-BP vs Control		BSD vs Control		AN-BP vs AN-R		BSD vs AN-R		BSD vs AN-BP	
	N = 123		*N = 59*		*N = 27*		*N = 30*															
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*p*	*power*	*p*	|*d*|	*p*	|*d*|	*p*	|*d*|	*p*	|*d*|	*p*	|*d*|	*p*	|*d*|
Clinical measures																						
EDI-2 Total score	26.4	20.8	63.5	38.9	101.2	38.4	112.3	43.3	**.001***	1.00	**.001***	**1.19**†	**.001***	**2.42**†	**.001***	**2.53**†	**.001***	**0.98**†	**.001***	**1.18**†	.188	0.27
SCL-90R GSI	0.58	0.42	1.30	0.72	1.88	0.62	1.86	0.83	**.001***	1.00	**.001***	**1.21**†	**.001***	**2.45**†	**.001***	**1.94**†	**.001***	**0.87**†	**.001***	**0.72**†	.890	0.03
[a]**Executive functions**																						
Decision making																						
IGT Trail-1	−1.54	7.16	−3.05	4.36	−2.35	4.81	−1.98	3.87	.585	.185	.184	0.26	.561	0.13	.774	0.08	.619	0.15	.595	0.26	.862	0.09
IGT Trail-2	3.19	8.22	−1.25	4.59	−1.85	4.34	−1.55	6.27	**.001***	.994	**.001***	**0.67**†	**.001***	**0.77**†	**.006***	**0.65**†	.701	0.13	.892	0.05	.901	0.05
IGT Trail-3	5.45	8.43	1.18	5.35	−1.73	5.32	−1.32	4.26	**.001***	1.000	**.001***	**0.60**†	**.001***	**1.02**†	**.001***	**1.01**†	.072	**0.55**†	.281	**0.52**†	.868	0.08
IGT Trail-4	5.60	9.68	2.59	7.39	−1.78	5.36	−0.52	7.12	**.001***	.988	.058	0.35	**.001***	**0.94**†	**.005***	**0.72**†	**.026***	**0.68**†	.268	0.43	.671	0.20
IGT Trail-5	4.24	10.48	3.17	8.94	−3.36	6.57	−1.59	6.16	**.001***	.969	.538	0.11	**.001***	**0.87**†	**.015***	**0.68**†	**.003***	**0.83**†	.124	**0.62**†	.589	0.28
IGT Total	16.95	29.82	2.64	21.96	−11.08	17.48	−6.97	17.41	**.001***	1.000	**.003***	**0.55**†	**.001***	**1.15**†	**.001***	**0.98**†	**.019***	**0.69**†	.250	**0.51**†	.643	0.24
Cognitive flexibility																						
WCST Total errors	19.07	15.90	18.98	18.73	33.43	32.52	28.78	26.25	**.002***	.914	.983	0.00	**.002***	**0.56**†	.060	0.45	**.002***	**0.54**†	.141	0.43	.510	0.16
WCST Persever.errors	9.98	7.17	8.33	8.61	14.49	19.59	17.67	16.38	**.004**	.885	.410	0.21	.070	0.31	**.005***	**0.61**†	**.013***	0.41	**.009***	**0.71**†	.399	0.18
WCST Categ.compl.	5.58	1.24	5.57	1.38	4.55	2.41	4.92	2.10	**.007**	.850	.996	0.00	**.005***	**0.54**†	.103	0.38	**.004***	**0.52**†	.207	0.37	.488	0.17
Inhibitory control																						
STROOP Interference	6.25	9.23	5.52	8.02	5.16	9.94	6.77	9.02	.944	.073	.658	0.08	.592	0.11	.821	0.06	.858	0.04	.670	0.15	.604	0.17

Note. SD: standard deviation. AN-R: anorexia nervosa restrictive. AN-BP: anorexia nervosa bulimic purgative. BSD: binge spectrum disorder.
IGT: Iowa Gambling Test. WCST: Wisconsin Card Scoring Test. [a] Comparison between the groups (ANCOVA, adjusted by age, education and BMI).
*Bold: significant comparison (0.05 level). †Bold: effect size into ranges mild-moderate (|d|>0.50) to high-large (|d|>0.80).

4. Discussion

The present study initially set out to examine cognitive flexibility, inhibitory control, and decision-making across individuals with ED subtypes (i.e., AN-R, AN-BP, and BSD) compared to controls. In addition, the study explored the association between executive dysfunctions and ED duration. We found that ED subtypes showed poorer decision-making and cognitive flexibility than the HC group, whereas we observed similar executive functioning performance between the AN-BP and BSD groups. Concerning ED duration, our results showed that ED duration was specifically associated with poor inhibitory control in individuals with AN-BP and poor cognitive flexibility in the BSD group (i.e., BN and BED). By contrast, in the AN-R group, we were not able to find a significant association. Cumulative survival analysis found that illness duration increased the risk of presenting early deficits in decision-making and inhibitory control in the AN-R group, whereas the BSD group was the first to exhibit deficits in cognitive flexibility. Likewise, ED duration predicted the executive impairment in the BSD and AN-BP groups, whereas the severity of general psychopathological symptoms predicted executive impairment in the AN-R group.

The comparative analysis of the performance in executive functioning showed, as expected, poorer performance in the ED groups than in the HC group in terms of cognitive flexibility and decision-making, in accordance with previous studies (Aloi et al., 2015; Guillaume et al., 2010; Tamiya et al., 2018). However, no significant differences were reported in inhibitory control. There were pronounced deficits in decision-making in the BSD and AN-BP groups compared to the AN-R and HC groups according to previous literature (Guillaume et al., 2015; Hirst et al., 2017), whereas the AN-R group showed poor decision-making compared to the HC group. The IGT evaluates risky decision-making based on monetary gain or losses, where participants must decide between four decks that offer an immediate reward, aiming to obtain as much money as possible. Individuals with BSD tend to prefer risky immediate rewards over future and safe gains, disregarding long-term outcomes (Steward et al., 2017). These individuals reported greater risk-seeking and inflexible choices irrespective of changes in context, as reflected in binge episodes (Voon, 2015). Performance in cognitive flexibility was remarkably dysfunctional in the AN-BP and the BSD groups, displaying increased total errors and perseverative errors. Although cognitive rigidity has been often associated with AN-R, most of the studies did not clearly distinguish between the subtypes of AN (Roberts et al., 2010; Wu et al., 2014). In the case of inhibitory control, previous studies have focused on adopting tasks using disorder-relevant stimuli (e.g., food or weight-/shape-related), proposing that problems in inhibition are more related to food stimuli than unrelated stimuli (Bartholdy et al., 2016; Wu et al., 2013). Therefore, the lack of significant differences between groups in our study could be due to the stimuli used in the Stroop task. Overall, it is remarkable that the AN-BP group shared more similarities with the BSD group, as reported previously (Mandelli et al., 2019; Reichenberger et al., 2021). Both groups presented a severe clinical profile in comparison to the AN-R group.

ED duration was associated with executive function performance in the AN-BP and BSD groups. Our results showed a negative association between the duration of BSD and cognitive flexibility. Binge eating episodes, characterized by frequent excessive food intake and a sense of a loss of control (APA, 2013), can underlie a behavioral inflexibility in these individuals reflected in an inability to change their response despite the context. Likewise, illness duration in the AN-BP group displayed a negative association with inhibitory control. The AN-BP group has been consistently differentiated from the AN-R group difficulties in control over intake, increasing complications to regulate a normal weight, and becoming gradually worse as EDs progress (Berkowitz et al., 2016; Lantz et al., 2017), in addition to higher impulsivity and emotional dysregulation (Culbert et al., 2016; Mallorquí- Bagu é et al., 2020; Vervaet et al., 2021). This might also explain why individuals with AN-BP, over the years, are at risk of conversion to BN (Monteleone et al.,

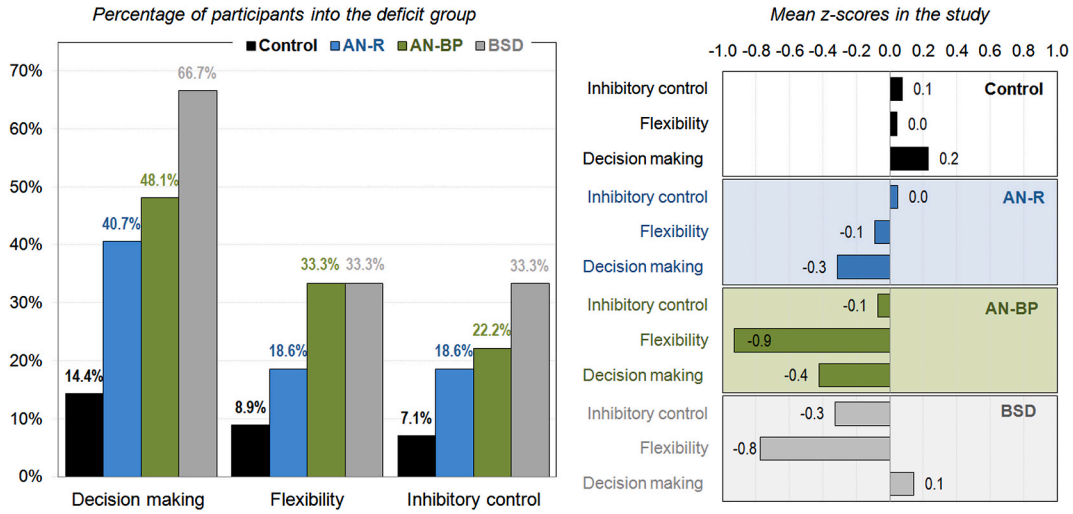

Fig. 1. Neurocognitive profile on executive function sub-domains in the study. *Note.* AN-R: anorexia nervosa restrictive. AN-BP: anorexia nervosa bulimic purgative. BSD: binge spectrum disorder.

Table 3
Association between the eating disorder duration and performance in executive function: partial correlations adjusted by age, education, and BMI.

	Total ED *N = 116*	AN-R *N = 59*	AN-BP *N = 27*	BSD *N = 30*
Decision making				
IGT Total	.001	.217	-.143	.008
Flexibility				
WCST Total errors	.092	-.048	-.052	**.275**[a]
WCST Perseverative errors	.118	-.079	-.051	**.333**[a]
WCST Categories completed	-.095	.086	-.021	**-.270**[a]
Inhibitory control				
STROOP Interference	-.113	-.120	**-.274**[†]	-.084

Note. IGT: Iowa Gambling Test. WCST: Wisconsin Card Scoring Test.
ED: eating disorder. AN-R: anorexia nervosa restrictive. AN-BP: anorexia nervosa bulimic purgative. BSD: binge spectrum disorder.
[a] Bold: effect size into ranges mild-moderate ($|R|>0.24$) to high-large ($|R|>0.37$).

2011). In this context, when further investigating the role of illness duration as a risk factor for executive dysfunctions, we modeled the time needed for 25% of individuals with ED to present deficits within each executive subdomain to identify a time point for a risk linked to illness duration. Using a cumulative survival model, our results showed that throughout the disorder there was an early risk of presenting deficits in decision-making as compared to other subdomains. Early risk of cognitive impairment was mainly observed in the AN-R and BSD groups in contrast to the AN-BP group. As the disorder progresses, our results show an increased risk of early cognitive impairment in decision-making in the AN-R group (up to 3 years of duration), followed by the BSD group (up to 7 years of duration) and the AN-R group (up to 8 years of duration). Concerning impaired cognitive flexibility, the BSD group showed an increased likelihood of early risk, closely followed by the AN-BP and AN-R groups. In inhibitory control, the AN-R group showed the earliest deficits (up to 5 years of duration) while in the AN-BP and BSD the time required to present deficits was 12 and 15 years, respectively. These results confirm an interaction between illness duration and cognitive functions (Galimberti et al., 2020) providing evidence on how executive dysfunctions are associated with a specific time point of duration for each ED subtype. Further studies focused on risk and maintenance models related to executive functions are required to confirm these findings.

ED duration had a consistently predictive role on executive dysfunction in the BSD and AN-BP groups, whereas greater general psychopathology predicted deficits in the AN-R group. Specifically, illness duration in the BSD group predicted deficits in cognitive flexibility, suggesting that individuals could increase their risk for exhibiting behavioral or/and cognitive rigidity at more advanced stages of the disorder. In individuals with AN-R, more severe psychopathology predicted deficits in cognitive flexibility. In general, there is consistent evidence that psychopathologic symptomatology can impact executive function, supporting the notion that other factors involve cognitive deficits (Abbate-Daga et al., 2014; Billingsley-Marshall et al., 2013; Dingemans et al., 2020; Kanakam et al., 2013). Studies in AN-R showed increased inflexibility in individuals with obsessive-compulsive (Kanakam et al., 2013), anxiety, and depression symptomatology

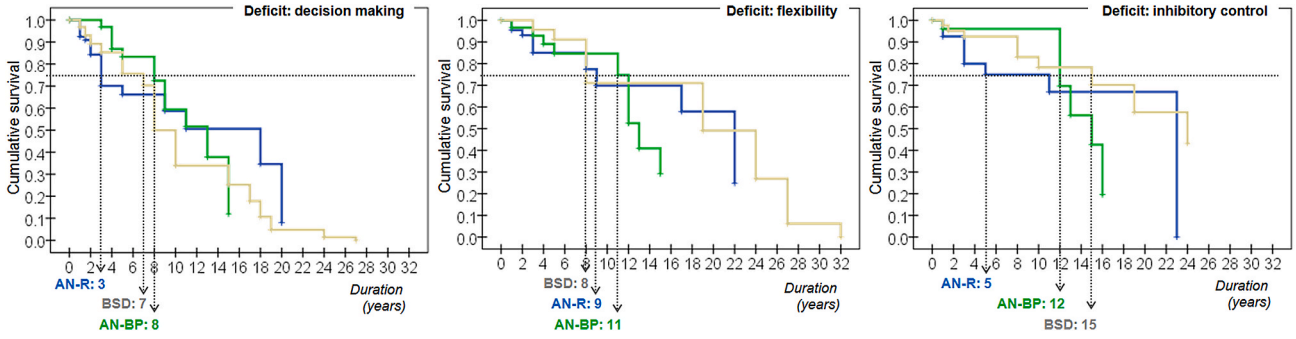

Fig. 2. Cumulate survival functions (adjusted by age, education, and BMI). *Note.* AN-R: anorexia nervosa restrictive. AN-BP: anorexia nervosa bulimic purgative. BSD: binge spectrum disorder.

Table 4
Contribution of age, ED duration, ED symptomatology (EDI-2 total), and general psychopathology (SCL-90R GSI) on executive dysfunction in each ED groups (logistic regression).

			Coefficients						Fitting statistics	
Group	Criteria	Predictors	B	SE	p	OR	95% CI OR		H-L	NR^2
AN-R *(n = 59)*	Deficits in decision making	*No significant predictors*								
	Deficits in flexibility	Psychopath. distress	0.935	0.472	.048	2.547	1.010	6.423	.125	.111
	Deficits in inhibitory control	*No significant predictors*								
AN-BP s*(n = 27)*	Deficits in decision making	*No significant predictors*								
	Deficits in flexibility	*No significant predictors*								
	Deficits in inhibitory control	Duration of ED (years)	0.183	0.109	.045	1.200	1.001	1.485	.333	.174
BSD *(n = 30)*	Deficits in decision making	*No significant predictors*								
	Deficits in flexibility	Duration of ED (years)	0.113	0.059	.045	1.120	1.001	1.257	.252	.194
	Deficits in inhibitory control	*No significant predictors*								

Note. ED: eating disorders. AN-R: anorexia nervosa restrictive. AN-BP: anorexia nervosa bulimic purgative. BSD: binge spectrum disorder.
H-L: Hosmer-Lemeshow test (p-value). N-R^2: Nagelkerke's pseudo-R^2 coefficient.
OR: odds ratio. List of predictors: ED duration, ED symptomatology (EDI-2 total) and psychopathological distress (SCL-90R GSI).

(Abbate-Daga et al., 2014), which, in turn, has been shown to negatively affect treatment outcomes, increasing the risk of a long-term disorder (Flynn et al., 2020).

Impaired executive functions could be related to the risk of developing and maintaining ED symptomatology and, at the same time, ED symptomatology can be affecting executive functions, presenting a reciprocal interaction between them. However, the results obtained do not allow a direct causal effect to be inferred. Therefore, longitudinal studies would be necessary to identify causality. A better understanding regarding the influence of top-down mechanisms in ED could facilitate efforts to develop suited interventions with respect to which factors play a direct role in treatment outcomes. Currently, interventional programs, such as cognitive remediation therapy oriented to improve executive functions, have been shown to be effective in EDs (Juarascio et al., 2015) and in severe and enduring patients (Dandil et al., 2020; Dingemans et al., 2013; Leppanen et al., 2018). Future studies should also consider ED duration and general psychopathology as main factors to be taken into consideration when fitting cognitive treatments to each ED subtype.

Although this study has its strengths, some limitations should be considered when interpreting these results. Inferences emerging from these results must be interpreted with caution due to the limited sample size: some statistical procedures could be underpowered with the consequence of missing real relationships in the population (Table 2 includes the power coefficient for the ANCOVA procedures). Likewise, our sample does not fully represent the general population with EDs because all participants were recruited from a hospital setting and were seeking treatment. Moreover, this study cannot be generalized to men with EDs, since only women were represented in the current sample. Further studies with larger samples are needed to confirm our findings. Finally, our study was not able to control the medication prescribed in individuals with EDs. Future studies should consider this aspect and verify if there is an impact on executive functions.

Other issues should also be considered when interpreting our results, such as the possible effect of other factors that the scientific literature has associated with cognitive functioning, mainly BMI. It should be outlined that we performed a statistical analysis stratified by the diagnostic subtype (separately for individuals with AN-R, AN-BP, and BSD, which also allowed obtaining the potential moderator-interaction role of this measures) and that BMI has been additionally included as a covariate to avoid confounding biases.

In conclusion, altered decision-making and poor cognitive flexibility were observed in individuals with EDs, highlighting similar neurocognitive profiles in the AN-BP and BSD groups. ED duration was associated with executive dysfunctions, showing different time points of increased risk of executive impairment within each ED subtype. The results confirmed our hypothesis predicting the role of ED duration in executive dysfunctions in individuals with BSD and AN-BP.

CRediT authorship contribution statement

Romina Miranda-Olivos: Conceptualization, Investigation, Methodology, Project administration, Data curation, Writing – original draft. **Giulia Testa:** Conceptualization, Investigation, Methodology, Project administration, Data curation, Writing – original draft. **Ignacio Lucas:** Conceptualization, Methodology, Writing – original draft. **Isabel Sánchez:** Data acquisition, Methodology. **Jessica Sánchez-González:** Data acquisition, Methodology. **Roser Granero:** Methodology, Formal analysis, Writing – original draft. **Susana Jiménez-Murcia:** Funding acquisition. **Fernando Fernández-Aranda:** Conceptualization, Investigation, Project administration, Funding acquisition, Writing – original draft.

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Declaration of competing interest

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