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Dialectical behavior therapy in autistic adults: effects on ecological subjective and physiological measures of emotion dysregulation

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Abstract

Background Although Ecological Momentary Assessment (EMA) and physiological measurements provide a valuable opportunity to evaluate therapeutic interventions in real time, no study has used this approach to assess Dialectical Behavior Therapy (DBT) in autistic adults with high levels of emotion dysregulation (ED).

Methods In this study, 26 autistic adults were evaluated before and after participating in a standard 5-month DBT program, using Ecological Momentary Assessment (EMA). The EMA included: (1) twelve evaluations per day over a 7-day period, measuring alexithymia, emotional states, subjective arousal and emotion control; (2) continuous physiological monitoring with a wristband to record heart-rate (HR), heart-rate variability (HRV) and skin conductance levels (SCL).

Results Following DBT, no significant differences were found with respect to negative emotions and higher conflicting emotions, but increased rates of identified emotions, positive emotions and emotion control were found. Baseline autonomic responses remained unchanged, whereas subjective arousal was found to correlate positively with HRV. Overall, these results suggest that participants showed enhanced emotion awareness and emotion regulation capabilities following DBT.

Conclusion Our study adds to previous research showing that DBT is efficient in treating ED in autistic adults, using real-time measurements of subjective and physiological markers collected through EMA. Specifically, alexithymia measures decreased post-DBT while positive emotions and emotion control increased. Randomized controlled trials should consider using these methods to improve the assessment of the impact of DBT in the daily life of autistic individuals with ED and/or suicidal behavior.

Keywords Ecological momentary assessment, Autism spectrum condition, Emotion dysregulation, Alexithymia, Dialectical behavior therapy

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Introduction

Dialectical Behavior Therapy (DBT) is widely acknowledged as the leading intervention for emotion dysregulation (ED) [1–5]. DBT guides individuals to remain present, recognise and accept emotions as they arise, and act in alignment with their values and goals, through the use of mindfulness and emotion regulation strategies [6, 7]. In addition to its efficacy in targeting ED and suicidal behavior in various psychiatric and neurodevelopmental disorders (e.g., borderline personality disorder (BPD), attention-deficit/hyperactivity disorder (ADHD)) [5], recent studies have validated the feasibility, acceptability and efficacy of DBT in treating ED in autistic individuals [8–12].

The surge in research examining ED interventions for Autism Spectrum Condition (ASC) can be attributed to the growing acknowledgement of the emotional challenges encountered by this population [13–17]. For instance, the biosocial model for ASC, adapted from that for BPD, posits that ED in autistic adults may also result from an interaction between biological vulnerabilities (i.e., hypersensitivity, hyperreactivity, slow return to baseline and impulsivity) and an invalidating environment (e.g., neglect, abuse) [18–20]. Apart from the biosocial correlates shared with individuals with BPD, autistic individuals often display atypical responses to sensory information and are particularly sensitive to changes in their environment [21]. These sensory and adaptive differences can increase emotional reactivity and lability, contributing to distinctive regulatory strategies [22, 23]. For instance, self-soothing behaviors (e.g., rocking, hand-flapping) are common among autistic individuals and may function as protective mechanisms to regulate emotional arousal [24]. However, reliance on other strategies, such as avoidance or rumination, can perpetuate dysregulation [25–27]. In some cases, as it is also observed in individuals with BPD, maladaptive behaviors may escalate to include uncontrolled outbursts, aggression [28, 29], and even self-injury and suicidal behaviors [30, 31].

Notably, autistic adults are at a significantly elevated risk of suicidal behaviors [32], with suicidal attempts rates ranging from 7 to 47%, and suicidal ideation occurring in up to 72% of cases [33]. The relationship between suicidal behavior and ED has been linked to the intensity and the physiology of negative emotions [34–37]. For instance, in people with BPD [34] and adolescents seeking treatment for various psychiatric conditions (e.g., post-traumatic stress disorder, ADHD) [35], research has highlighted that higher levels of negative emotions and lower positive affectivity predicted suicidal risk, with negative emotions decreasing after suicidal behavior [38, 39]. Physiological markers also play a critical role in understanding these dynamics. For example, heart rate variability (HRV), defined as the variation in time intervals between consecutive heartbeats, and heart rate (HR), defined as the number of heart beats per minute, have been observed to change in response to stress and emotional states [40, 41]. Specifically, a reduction in HRV and a slower return to resting HR (i.e., higher HR levels) have been noted in individuals with suicidal ideation and a history of suicide attempts [36, 42].

This complex interplay between negative emotions and suicidal behavior may also be linked to alexithymia, a condition particularly prevalent in ASC [43]. Alexithymia refers to the difficulty in identifying, describing and distinguishing emotions from bodily sensations, as well a tendency to orient thoughts towards external rather than internal stimuli [44]. Alexithymia can hinder effective emotion regulation [45, 46], as it is challenging to control emotions that one cannot clearly identify [19]. Indeed, most studies have reported that, to reduce negative internal states, alexithymic individuals tend to rely mainly on avoidant coping mechanisms, such as experiential avoidance (i.e., avoidance of aversive internal experiences) [47, 48]. Given their increased use of dysfunctional emotion regulation strategies, negative emotions may prove challenging to soothe once they have been aroused [49], explaining the association of alexithymia with the increased risk of suicidal behavior [50]. In the field of physiological research, the evidence at baseline or in response to stressful stimuli suggests that some autistic individuals, especially those presenting with co-occurring ED, are physiologically hyper-aroused [51, 52]. This often includes elevated HR, reduced HRV, and elevated electrical conductance of the skin based on sweat gland activity (i.e., skin conductance levels; SCL) [51]. Chronic hyperarousal has been linked to a reduction in social-reciprocity and the emergence of maladaptive and aggressive behaviors, both towards oneself and others [53, 54]. Yet, whereas some studies have suggested that alexithymia is associated with hyperarousal [55–57], others suggest that individuals with high levels of alexithymia show discrepancies between physiological responses and subjective self-reported experiences [58, 59]. This phenomenon is known as the decoupling hypothesis, and its explanations are related to the presence of poorly differentiated emotional responses and difficulties accurately interpreting bodily signals (i.e., impaired interoception). Although such discrepancies have been studied in populations with alexithymia, they remain underexplored in autistic individuals. Considering the high prevalence of alexithymia in ASC [43], it is possible that similar patterns of decoupling may occur in autistic individuals, potentially contributing to ED [60–62].

Given the relevance of alexithymia and ED in the context of ASC, interventions such as DBT are of paramount importance, as DBT has the potential to enhance individuals' awareness of their physiological sensations and internal

emotional states [63]. Adaptations of DBT for autistic functioning, such as the use of visual aids to elucidate abstract concepts [8, 10], have fostered accessibility and efficacy within this population. For instance, a recent randomised control trial (RCT) showed that DBT was associated with a reduction in suicidal behaviors and depression in autistic adults in comparison with treatment as usual [9]. However, at the 6-month follow-up, only the reduction in depression remained significant, suggesting that while DBT shows promise, its long-term efficacy warrants further investigation. It is noteworthy that, to the best of our knowledge, this study is the sole RCT published on DBT in ASC. However, it did not evaluate ED or alexithymia. This lacuna is to some extent addressed by a recent systematic review across various clinical groups with ED, including in autistic adults, which indicated that DBT-based interventions may be associated with self-reported improvements in the identification of emotional states [64]. Nevertheless, it is important to highlight that few studies have assessed the afficacy of DBT in ASC, and they have relyied on retrospective measurements. Although informative, such methods may be particularly problematic for individuals with alexithymia, as their difficulty in recognizing and interpreting emotions can lead to biases in retrospective self-reports [65, 66]. Furthermore, this approach lacks ecological validity, as they fail to capture the real-time emotional challenges autistic individuals experience [67, 68].

One potential solution to this issue is the measurement of affective, contextual, and physiological experiences as individuals engage in their usual daily activities [69]. This approach is known as experience sampling, or Ecological Momentary Assessment (EMA) [67], and has already been employed to assess the impact of DBT among individuals with different psychiatric disorders who engage in non-suicidal self-injury [70–72]. Given that previous studies have reported minimal to moderate correspondences between retrospective self-reports and EMA [73], there is a need for more ecological studies to track intervention effects. Nevertheless, to date, no EMA study has evaluated the effect of DBT in ASC. To this purpose, our study aims at gaining a better understanding of the effects of DBT on everyday subjective and physiological functioning of emotions in autistic adults with ED. To this end, over the course of a one-week period prior and after treatment (i.e., pre- and post-18-week standard DBT), 27 autistic individuals responded to 12 notifications per day, to evaluate the nature, the intensity and the control they exerted over their emotions. Concomitantly, physiological parameters such as HR, HRV, and SCL were measured through a wearable device designed for real-time data collection.

Given the established link between DBT and decreased levels alexithymia [64], we hypothesize that it will result in (1a) a reduction of EMA measures of alexithymia (i.e., "I have no emotion" and "I have an emotion I cannot identify"), (1b) a reduction in negative emotions, particularly anxiety and sadness, as well as (1c) fewer conflicting emotions (i.e., the presence of at least two emotions with different valences, such as concomitant "anger" and "joy"), reflective of diminished self-reported psychological distress [74]. Additionally, we hypothesize that, post-DBT, autistic individuals will present (2a) lower physiological sympathetic activity, as measured through SCL, and changes in sympathovagal balance, indicated by variations in HR and HRV and (2b) less pronounced discrepancies between subjective and physiological arousal. Specifically, we expect a more consistent alignment between subjective reports of emotional arousal and physiological measures; for instance, high subjective emotional arousal is frequently observed to be positively correlated with increased HR, although it should be noted that increased HR can also be the result of other factors. Finally, given that DBT strives to help individuals build "a life worth living" [6], we expect that, following DBT, autistic individuals will report (3a) enhanced emotion control, (3b) and higher rates of positive emotions.

Methods

Participants

In the current research, we aimed to explore pre- and post-DBT differences in terms of subjective and physiological EMA-related emotional functioning. Initially, a total of 29 autistic adults participated in DBT from May 2022 to July 2023 and completed EMA assessments before therapy. Three participants dropped out of therapy, resulting in a total of 26 individuals with pre- and post-DBT EMA. Participants received monetary compensation for their participation (€200). The regional ethics committee for the East of France approved this study (Reference: SI 21.01.21.41923). Before participating, all subjects provided written informed consent. This study is part of a larger project, which has been registered in clinicaltrials.gov (Registration Number: NCT04737707). The larger project involved (a) a RCT on the efficacy of DBT in autistic individuals with high ED, self-injury and/or suicidal behaviors, and (b) an EMA study tackling ED in ASC [75]. Specifically, the registered RCT was designed to investigate the efficacy of DBT using retrospective measures, with a waiting list control group and follow-up assessments. In contrast, the present study aims to examine the feasibility and preliminary effects of DBT using EMA as a complement to the findings of the RCT, which included retrospective assessments and targeted measures of self-harm and suicidal behaviors. Due to the constraints of feasibility, the EMA approach was unable to include a waiting list group our follow-up assessments, and prioritised real-time assessments of emotional functioning (e.g., emotion control and alexithymia).

Therefore, these results are presented as preliminary. For the RCT, the main outcome was the DERS total score. Hence, the minimal sample size was estimated based on assumptions on distribution of DERS scores reported in Bemmouna et al.'s pilot study [8]. Assumptions included a margin of error set at 0.05 and a minimal statistical power of 90%. A sample of at least 48 participants was required to demonstrate a reduction of at least 10 points in the DERS mean score at mid-therapy (T1) compared to baseline (T0) with a power of 95%. Additionally, the study aimed to demonstrate a reduction of at least 15 points at post-therapy (T2) and six-month follow-up (T3) compared to baseline, with a statistical power of 91%. To account for potential dropouts, 16 additional patients were included, representing approximately one-third of the required sample.

Table 1 Sociodemographic characteristics of autistic adults

	n	%
Sex		
Female	15	58
Male	11	42
Gender identity		
Cisgender women	13	50
Cisgender men	11	42
Nonbinary	2	8
Relationship status		
Single	13	50
In a relationship	8	31
Married	3	11
Divorced	2	8
Highest educational level		
High school	9	35
Bachelor's Degree	8	31
Master's Degree	8	31
Doctoral Degree	1	4
Employment		
Student	7	27
Unemployed	7	27
Employed	11	42
Retired	1	4
Co-occurrent diagnoses		
Anxiety Disorders	10	45
MDD	11	50
Bipolar Disorder	1	4
OCD	1	4
Eating Disorders	2	9
ADHD	8	36
Psychotropic medication		
Anxiolytic	8	35
Antidepressant	16	70
Neuroleptic	4	17
Psychostimulant	6	26
Antipsychotic	8	35

n = 26

ADHD Attention deficit/hyperactivity disorder, *OCD* obsessive-compulsive disorder, *MDD* Major depressive disorder

Participants (15 female and 11 male) had an average age of 28.5 (SD = 10.3, range = 18–67). The diagnosis of ASC without intellectual disabilities was established through the Autism Diagnostic Interview-Revised [76] and the Autism Diagnostic Observation Schedule-2 [77], with all participants undergoing a comprehensive DSM-5 evaluation for co-occurring psychiatric disorders [21]. This assessment revealed that 85% ($n = 22$) had a co-occurring condition, with the most prevalent being depression (50%), anxiety disorders (45%), and ADHD (36%) – see Table 1. Given the presence of co-occurrent disorders, psychotropic medication was observed in 88% of autistic individuals. Because some medication have significant anticholinergic effects which can influence physiological parameters [78], we employed an anticholinergic scale – The Anticholinergic Impregnation Scale [79] - to account for their effects in our statistical analysis. The scale ranged from 0 (no medication or medication with low anticholinergic effect) to 5 (multiple medications with very strong anticholinergic effect). Furthermore, all participants completed The Difficulties in Emotion Regulation Scale - DERS [80] and the Eight-item General Alexithymia Factor Score – GAFS-8 [81] at two time points: before (pre-) and after (post-) DBT. The baseline (pre-) scores were employed to describe the sample, which was selected on the basis of elevated levels of ED, while the post- scores were analysed to assess changes in ED and alexithymia following treatment.

DBT intervention

Participants engaged in a standard DBT program for 5 months. Standard DBT comprises the four modes of treatment developed by Linehan [6]: (i) weekly individual sessions, (ii) weekly 2-hours and 15-minute skills training groups, (iii) phone coaching, and (iv) consultation team. The therapy was delivered by three clinical psychologists extensively trained in DBT. Weekly supervision sessions were provided by LW, professor of clinical psychology. In order to adapt DBT to the needs of autistic adults, several modifications were implemented. These included maintaining a stable therapy environment, addressing sensory sensitivities, simplifying materials, and incorporating visual tools (e.g., an emotional thermometer). Further details on these adaptations are discussed by Bemmouna et al. [8] ([76], p. 4340].

Self-reported EMA surveys

To evaluate the subjective self-reported effects of DBT, all participants responded to real-time mobile phone notifications delivered 12 times per day, for a period of 7 days, both before and after the therapy. Using Qualtrics

(Qualtrics, Provo, UT) and the Textra app on a Samsung Galaxy XCover 5 device, the notifications were sent between 7 am and 11 pm, tailored to each participant's chronotype. The average interval between each survey was 65 min, ranging from 43 to 84 min. Participants were also encouraged to complete the assessment if they were experiencing an intense emotion outside of scheduled notifications.

At each EMA survey, participants were required to respond to six questions, as described in [75]. Firstly, they selected one or more options from a list of 12 emotional categories to characterise their current emotional state: joy, anxiety, anger, interest, shame, disgust, calm, sadness, surprise, guilt, I have an emotion that I cannot name, and I have no emotion. Participants had the possibility to choose multiple emotions at a time, as previous EMA studies have shown that, compared to control individuals, participants with ED overreport conflicting emotions (i.e., the presence of at least two emotions with different valences, such as concomitant "anger" and "joy") [74, 75]. Secondly, participants rated the intensity of their selected emotions (i.e., subjective arousal) on a Likert scale ranging from 0 (i.e., no intensity) to 10 (i.e., high intensity). Thirdly, they evaluated their perceived level of control over emotions (i.e., emotion control) on a similar single-item scale, from 0 to 10, with higher scores indicating greater perceived control. Next, participants indicated their preference for emotion regulation by selecting one of three options: (a) 'I would prefer to maintain my current emotional state'; (b) 'I would prefer to increase my current emotional state'; and (c) 'I would prefer to decrease my current emotional state'. Furthermore, they evaluated their level of fatigue on a scale from 0 (i.e., no fatigue) to 10 (i.e., severe fatigue). Finally, to assess contextual factors, participants reported on their physical activity and social interactions during the 15 min preceding the survey. For physical activity, they indicated whether they had engaged in (a) no activity; (b) light activity; or (c) intense physical activity. For social interactions, they selected from six predefined categories: (a) 'I had no interactions; I was alone in a closed environment'; (b) 'I had no interactions; I was alone in an open environment'; (c) 'I had no interactions; other people were present in the same environment'; (d) 'I had a direct social interaction'; (e) 'I had a virtual social interaction (e.g., an online meeting)'; and (f) 'I had an indirect social interaction (e.g., text messages)'.

Physiological parameter monitoring

To measure real-time physiological responses in relation to emotions, participants wore the Empatica E4 wristband for 7 days, alongside subjective EMA pre- and post-DBT participation [82]. The device recorded SC and PPG signals for 12 h each day. In light of the EMA question concerning physical activity, which specified a 15-minute timeframe, we analyzed the segments of physiological signals recorded during the 15 min preceding each questionnaire. These segments were selected based on two criteria: firstly, the availability of the data, which was dependent on whether the subject was wearing the device during the relevant period; and secondly, the signal quality. Any segments affected by motion artifacts were excluded.

The SC signal is modulated by the sweat gland activity, which is controlled by the sympathetic nervous system activity. The SC signal can be divided into a tonic component, known as skin conductance level (SCL), which indicates overall arousal state and varies slowly, and a superimposed phasic component, known as skin conductance response (SCR), which reflects faster stimulus-related reactions. In this study, we focused on the SCL to monitor the overall state of the subject, as no specific protocol was administered. The SCL was obtained by applying a low-pass filter with a cutoff frequency of 0.05 Hz, to isolate the tonic component of the skin conductance. Hereinafter, we define SCL as the mean value of the tonic component, averaged within non-overlapping 30-second time windows across the entire segments of analyzed data.

The Empatica provides the average heat rate values computed in spans of 10 s, derived from the blood volume pulse (BVP). We computed the average within non-overlapping 5-minute time windows across the segments of analyzed data to obtain the heart rate (HR) mean. Finally, from the BVP, the Empatica provides also the interbeat interval (IBI) series. Therefore, we extracted the HRV as the standard deviation of the IBI within non-overlapping 5-minute time windows across the selected segments of data. Participants were instructed to upload the data via the Empatica Manager App at the end of each day. This allowed the processing of the data and the extraction of the SCL, HR and HRV.

Statistical analyses

Statistical analyses were performed using Jamovi [83]. To assess changes in self-reported emotions (Hypotheses 1a, 1b, 1c and 3b) before and after therapy, we conducted paired samples t-tests for normally distributed data (Shapiro-Wilk test; $p > .05$) and Wilcoxon signed-rank tests (Shapiro-Wilk test, $p < .05$) for nonparametric data. Cohen' s d effect sizes and rank biserial correlations were calculated for all comparisons. As for Hypotheses 1a, 1b and 3b, based on the normality test, we conducted either paired samples t-tests or Wilcoxon signed-rank tests and reported effect sizes.

Differences in emotion control, physiological arousal, and discordances between physiological and subjective arousal were analysed using Multilevel Model Analysis

(MLM), a suitable tool for analysing repeated measures [84]. In this study, we employed a restricted maximum likelihood estimation method [85], and the hierarchical structure of MLM allowed us to explore variations in outcome variables (i.e., emotion control, HR, HRV and SCL) across different levels: observations within a day, days within a person, and among different persons. The final MLM aimed to predict the outcome variables as described in Eq. 1. Specifically, we accounted for variability in intercepts (random intercepts) for the 12 EMA evaluations per day (1/Q), the 26 participants (1/ID), and the seven days (1/Day). To control for variables potentially influencing subjective emotion control and physiological responses, we included age, sex, medication, the presence of anxiety disorders, and EMA of social interactions and physical activity in the 15 min prior to each evaluation. To test hypothesis 2b (diminished discrepancy between physiological and subjective emotional arousal post-therapy), and hypothesis 3a (post-DBT enhanced emotion control, independently of emotional intensity), we added the variable "Subjective Arousal" and its interaction with time (Subjective Arousal: Time) to the models. Slopes for EMA variables varied across the 12 evaluations (1 + Social Interaction + Physical Activity + Subjective Arousal / Q), while fixed slopes were used for demographic data and the pre-post DBT condition (Time). To facilitate interpretation and comparison of predictors, and to reduce multicollinearity in the analysis, all continuous variables (i.e., Emotion Control, HR, HRV, SCL, Age, Subjective Arousal) were standardised using z-scores (i.e., each value was transformed to represent the number of standard deviations from the variable's mean). Categorical variables were not centered [86].

Equation 1

a). Hypothesis 2b

$$\begin{aligned} Physiological\,Variable\ (HR;\ HRV;\ SCL) \sim\ & 1 + Age + Sex \\ & + Medication + Anxiety\,Disorders \\ & + Social\,Interaction + Physical\,Activity \\ & + Time + Subjective\,Arousal \\ & + Subjective\,Arousal : Time + (1|Q) + (1|ID) \\ & + (1|Day) + (1 + Social\,Interaction \\ & + Physical\,Activity + Subjective\,Arousal\ |\ Q) \end{aligned}$$

b). Hypothesis 3a

$$\begin{aligned} Emotion\,Control \sim\ & 1 + Age + Sex + Medication \\ & + Anxiety\,Disorders + Social\,Interaction \\ & + Physical\,Activity + Time \\ & + Subjective\,Arousal \\ & + Subjective\,Arousal : Time + (1|Q) \\ & + (1|ID) + (1|Day) + (1 + Social\,Interaction \\ & + Physical\,Activity + Subjective\,Arousal\ |\ Q) \end{aligned}$$

Results

EMA surveys description

Participants completed a total of 4.072 EMA evaluations across the pre-post DBT phases (EMA_{pre}=2046; EMA_{post}=2026). There were no significant differences in the number of responses between the two phases ($p = .757$). Specifically, each participant completed an average of 78.7 EMA (SD = 9.23, range: 44–89) before DBT, and 77.9 EMA (SD = 8.62; range: 46–87) after DBT. The compliance rate, defined as the percentage of answered prompts relative to the total number of prompts sent, was 92.3% (SD = 10.7; range: 50–100) before DBT and 92.2% (SD = 10.5; range: 51.2–100) after DBT.

Pre- and post-DBT differences in terms of emotional frequencies: hypotheses 1a, 1b, and 3b

Descriptive statistics and paired sample comparisons are detailed in Table 2. In line with our first hypothesis (1a), paired samples t-tests and Wilcoxon signed-rank tests revealed that the rates of "I have an emotion I cannot name" were three times lower post-therapy compared to pre-therapy [pre_{DBT}= 9.3%, M(SD) = 7.35 (10.54); $post_{DBT}$= 3.5%, M(SD) = 2.77 (3.8); $p = .015$)]. However, contrary to our expectations, no significant differences were found between the pre- and post-therapy conditions for the option, "I have no emotion" ($p = .165$), nor for other negative emotions (e.g., sadness, anxiety; Hypothesis 1b) – see Table 2. When testing our hypothesis regarding the effects of DBT on the presence of positive emotions (3b), results revealed that, post-intervention, autistic individuals reported higher rates of joy [pre_{DBT}= 12.5%, M(SD) = 9.85 (7.32); $post_{DBT}$= 18.7%, M(SD) = 14.62 (11.48); $p = .008$], calm [pre_{DBT}= 25.5%, M(SD) = 20.1 (19.9); $post_{DBT}$= 34.2%, M(SD) = 26.7 (22.3); $p = .026$], and interest [pre_{DBT}= 8.3%, M(SD) = 6.5 (8.48); $post_{DBT}$= 15.8%, M(SD) = 12.3 (16.51); $p = .025$].

Pre- and post-DBT differences in terms of multiple - conflicting emotions, and need for emotion regulation: hypothesis 1c

Analyses revealed that compared to the pre_{DBT} phase, $post_{DBT,}$ autistic individuals had higher rates of multiple emotions (i.e., more than one emotion at a time) [pre_{DBT}=22.4%, M(SD) = 17.7(15.8); $post_{DBT}$=32.4%, M(SD) 25.3 (20.1); $p = .020$]. Moreover, among these multiple concomitant emotional states, conflicting emotions represented 28.3% of choices in pre_{DBT} [M(SD) = 5(5.29)] and 41.1% in $post_{DBT}$ [M(SD) = 10.38 (12.67)], with significant increase between the two conditions ($p = .004$). With regards to the self-reported need for emotion regulation, no statistical differences were found in the pre- and post-DBT comparisons [need to decrease ($p = .162$); need to maintain ($p = .476$); need to increase ($p = .082$)] (Table 2).

Table 2 Descriptive statistics,paired samples t-test and Wilcoxon signed-rank test results for emotion selections and need for emotion regulation

	Pre DBT		Post DBT				
	n	%	*n*	%	Paired t-test / Wilcoxon W	*p*-value	Effect size (Cohen's d/ Rank biserial correlations)
Joy	256	12.5	380	18.7	68.5	**0.008**	−0.57
Calm	522	25.5	693	34.2	79.5	**0.026**	−0.46
Interest	169	8.3	320	15.8	50.5	**0.025**	−0.56
Anxiety	530	25.9	516	25.5	167	0.814	0.05
Anger	190	9.3	268	13.2	82.5	0.094	−0.40
Shame	61	3.0	69	3.4	107	0.716	−0.07
Disgust	33	1.6	18	0.9	90	0.079	0.50
Sadness	267	13.0	279	13.8	147	0.796	0.06
Guilt	80	3.9	107	5.3	59	0.257	−0.31
Surprise	26	1.3	48	2.4	38.5	0.377	−0.27
I have an emotion I cannot name	191	9.3	72	3.5	129	**0.015**	0.68
I have no emotion	339	16.6	274	13.5	184	0.165	0.33
Multiple Emotions	459	22.4	657	32.4	79	**0.020**	−0.49
Conflicting emotions	130	28.3	270	41.1	38.5	**0.004**	−0.70
Need for emotion regulation							
Need to decrease	879	43.4	798	39.4	231	0.401	0.17
Need to maintain	913	45.1	970	47.9	136	0.601	−0.10
Need to increase	253	12.5	361	17.8	65	0.082	−0.44

Frequencies were computed by summing the number of times each participant selected a specific emotion (e.g., joy) before and after DBT. These sums were then divided by the total number of EMA for all emotions (EMA_{pre}=2046; EMA_{post}=2026) and multiplied by 100 to obtain percentages. Thus, method assumes that every participant selected each emotion at least once

Table 3 $Post_{DBT}$ effects on emotion control, HR, HRV, and SCL

	Emotion control	HR	HRV	SCL
	β (SE)	β (SE)	β (SE)	β (SE)
Intercept	0.11 (0.12)	0.46 (0.08)***	0.38 (0.08)***	0.39 (0.07)***
Age	0.11 (0.12)	−0.13 (0.06)*	−0.00 (0.07)	−0.00 (0.02)
Sex	−0.04 (0.24)	0.01 (0.13)	0.14 (0.15)	0.06 (0.03)
Medication	−0.07 (0.11)	0.21 (0.06)**	0.18 (0.14)	−0.00 (0.01)
Co-occurring anxiety disorders	0.12 (0.24)	−0.20 (0.12)	−0.03 (0.07)	0.01 (0.03)
Physical activity	0.03 (0.03)	1.40 (0.16)***	0.85 (0.09)***	1.23 (0.18)***
Social interaction	0.06 (0.03)	0.16 (0.03)***	0.22 (0.03)***	0.05 (0.03)
Time ($post_{DBT}$ versus pre_{DBT})	0.70 (0.05)***	−0.03 (0.03)	0.04 (0.03)	−0.01 (0.03)
Subjective Arousal	−0.08 (0.01)***	0.01 (0.02)	0.06 (0.02)**	0.03 (0.02)
Subjective Arousal * Time	−0.02 (0.02)	−0.04 (0.03)	0.03 (0.03)	−0.00 (0.03)

*p <.05

**p <.01

***p <.001

Pre- and post-DBT differences in terms of emotion control: hypothesis 3a

When evaluating the effects of therapy on emotion control, MLM analyses revealed that time ($post_{DBT}$) was a significant positive predictor [post-hoc difference (SE) = 0.70 (0.05); p <.001] –see Table 3. This effect persisted despite high levels of subjective arousal, which were negatively associated with emotion control [b (SE) =−0.08 (0.01); p <.001] in both conditions (i.e., the interaction between time and arousal revealed no significant association; p = .389) (Fig. 1). Among control predictors, only intense physical activity (compared to no physical activity) was associated with increased levels of emotion control [post-hoc difference (SE) = 0.19 (0.01); p = .035].

Pre- and post-DBT differences in terms of physiological manifestations: hypotheses 2a and 2b

Contrary to our hypothesis 2a, no significant differences were found between the pre_{DBT} and $post_{DBT}$ conditions in HR (p = .339), HRV (p = .305), and SCL (p = .756)

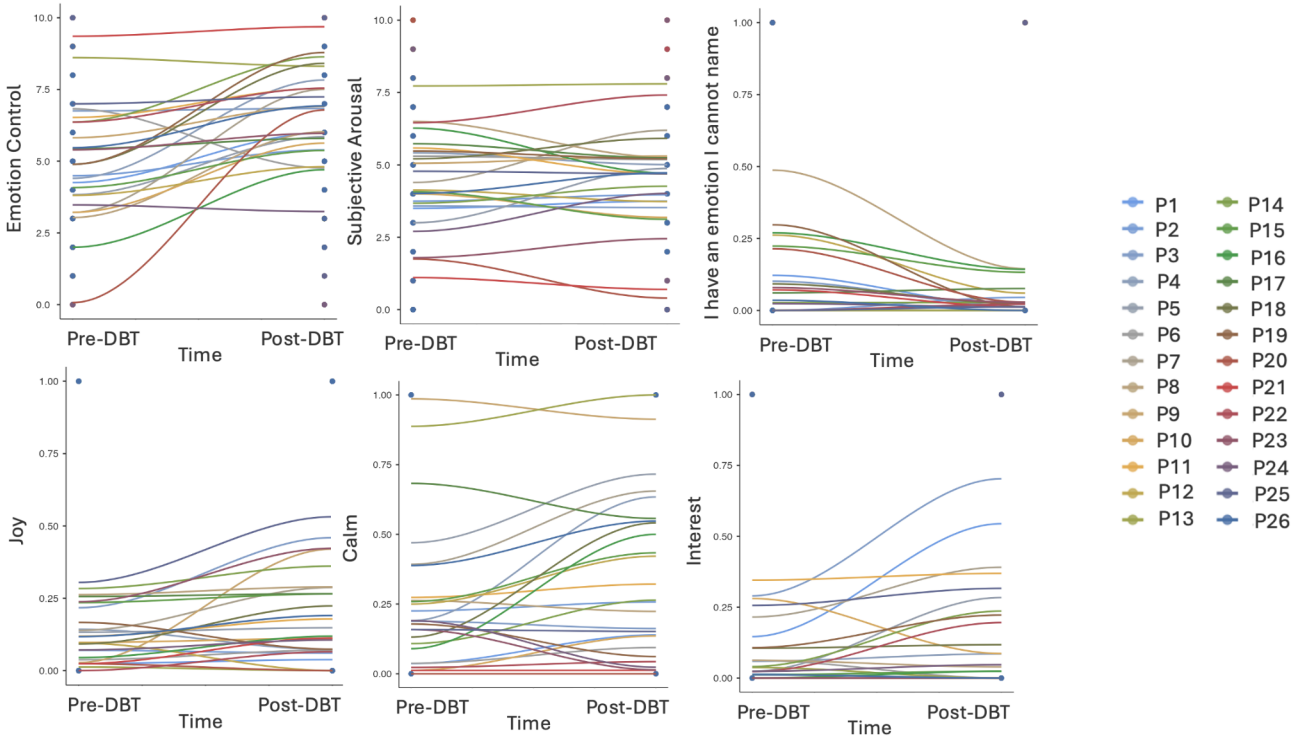

Fig. 1 Participant-level emotional changes pre- and post- DBT

Table 4 Paired sample t-Test for retrospective measures of emotion dysregulation and alexithymia

	Pre DBT		Post DBT			
	M	SD	M	SD	Paired t-test	*p*-value
DERS	132.0	29.3	83.2	22.5	11.6	<.001
Non-Acceptance	21.7	7.2	12.5	5.2	8.3	<.001
Goals	21.6	4.8	16.5	4.7	5.8	<.001
Impulse	21.2	6.3	12.0	3.9	9.4	<.001
Awareness	20.1	5.3	12.5	4.5	8.6	<.001
Strategies	30.8	7.0	18.6	5.7	9.5	<.001
Clarity	17.0	4.7	11.4	3.7	7.2	<.001
GAFS-8[a]	31.4	7.5	21.4	4.6	10.7	<.001

DERS Difficulties in Emotion Regulation Scale scores, *GAFS-8* The General Alexithymia Factor Score, *M* mean, *SD* standard deviation

[a] data missing for two participants

(Table 3). When evaluating hypothesis 2b, results showed that subjective arousal was positively associated with HRV [b(SE) = 0.06 (0.02); $p = .003$]. However, it was not a significant predictor of HR ($p = .485$), SCL ($p = .103$), and no interaction with time was found (pre_{DBT} versus $post_{DBT}$). Among all variables included in the models, the only positive predictor of the three physiological measures was intense physical activity ($p < .001$). The presence of social interactions was positively associated with HR [b(SE) = 1.40 (0.16); $p < .001$], and HRV [b(SE) = 0.22 (0.03); $p < .001$], but not with SCL ($p = .143$). Moreover, for HR, age and medication intake were also significant predictors, with older age being associated with decreased HR [b(SE) = – 0.13 (0.06); $p = .044$] and medication intake with increased HR levels [b(SE) = 0.21 (0.06); $p = .002$].

Pre- and post-DBT differences in terms of retrospective measures of ED and alexithymia

In addition to the prospective subjective and physiological measures, pre- and post- DBT comparisons of retrospective measures were conducted to evaluate changes in ED and alexithymia (see Table 4). Paired sample t-tests demonstrated statistically significant reductions in the total DERS scores ($p < .001$) and in all six DERS subscales, including Non-Acceptance ($p < .001$), Goals ($p < .001$), Impulse ($p < .001$), Awareness ($p < .001$)], Strategies ($p < .001$)], and Clarity ($p < .001$)]. Additionally, significant reductions were observed in the GAFS-8 scores ($p < .001$)].

Discussion

To the best of our knowledge, this is the first pilot study to explore EMA of subjective and physiological emotional functioning, both pre- and post-DBT, in autistic adults presenting with ED, self-injury and/or suicidal behavior. While preliminary, our findings suggest that, following their participation in a five-month standard DBT, autistic individuals reported a reduction in difficulties associated with identifying emotions (i.e., decreased frequencies of "I have an emotion I cannot name"). Additionally, they reported an increase in positive emotions, including joy, calm, and interest, as well as an enhanced feeling of emotion control in their daily lives. No significant differences were identified in the baseline physiological parameters (i.e., HR, HRV, and SCL), or with respect to negative emotions between the pre- and post-DBT. Contrary to our predictions, an increased prevalence of conflicting emotions was found post-DBT, probably due to reduced alexithymia. Nevertheless, despite the absence of an increase in baseline autonomic resilience following DBT, subjective arousal was found to predict higher HRV. This result may indicate that the participants' physiological systems showed enhanced capacity to adapt to intense emotional states, as evidenced by changes in HRV.

Contrary to our expectations, rates of multiple emotions, including conflicting (i.e., simultaneous positive and negative) ones, were significantly higher post-therapy. We argue that this unexpected finding may be attributed to the fact that participants reported fewer unidentified emotions (i.e., "I have an emotion I cannot name"), which likely led to the identification of a broader and more complex range of emotions, particularly an increase in the frequency positive emotions. Importantly, this increase in emotion labelling post-DBT is one of the primary outcomes of our study. This improvement aligns with the goals of DBT, which specifically teaches individuals to observe and identify their current emotions, thoughts and physical sensations, through mindfulness and emotion regulation skills [87]. Furthermore, since the potential risks associated with heightened emotional awareness are addressed by DBT modules of distress tolerance (e.g., using self-soothing techniques), it can be argued that the increase in conflicting emotions reflects greater emotional diversity and the emergence of positive emotions rather than a purely maladaptive response. Nevertheless, we recommend future studies further explore this relationship to better understand its implications.

Notably, no significant differences were found in the measure of "I have no emotion" between the pre- and post-therapy assessments. This indicates that, although participants showed an improved ability to identify specific emotions, the overall experience of lacking emotions remained unchanged following DBT. These results are consistent with prior research indicating that DBT effectively addresses certain aspects of alexithymia, such as the ability to identify emotions [64, 70]. The findings presented here contribute to the ongoing discussion regarding the potential of DBT to enhance emotion identification, while also suggesting that the experience of having no emotions, which has been linked to alexithymia in past studies [62, 88], might remain unchanged following DBT in autistic people. Rather than being related to the identification of emotions per se, the latter may be associated with the dimensions of alexithymia that pertain to the differentiation between emotions and physical sensations, as well as the presence of externally oriented thoughts [44, 89].

In addition to the decreased rates of alexithymia-related EMA responses, our study revealed a significant increase post-DBT in EMA responses relative to emotion control and positive emotions. This is consistent with the primary aim of DBT, i.e., to build a life worth living by focusing on ED [6]. Indeed, participants reported elevated rates of positive emotions, including joy, calm, and interest, post-therapy. This outcome is consistent with prior research demonstrating DBT's efficacy in enhancing quality of life [5] and, in certain instances, in reducing depressive symptoms, anger, aggressive and self-destructive behaviors [4, 9, 90]. However, substantial effects on anger, depression and suicidal ideation are typically observed following extended DBT programmes (i.e., lasting from 4 to 14 months) [91]. It is therefore possible that our 5-month DBT programme may have been too short to significantly reduce the experience of negative emotions. Interestingly, our results suggested that, although the rates of negative emotions remained unchanged over time, participants reported increased emotion control following DBT. This indicates that, irrespective of their valence, the ability to control emotions matters more than their mere presence. This finding is consistent with the therapy's focus on enhancing emotion experience and emotion regulation, rather than reducing negative or conflicting emotions. Interestingly, enhanced emotion regulation may allow individuals to experience negative and conflicting emotions without increased distress, emphasizing the importance of emotion control in psychological well-being [92]. Overall, our EMA results are therefore congruent with recent research showing reduced suicidal behavior linked to intense self-reported ED following DBT in autistic adults [9], and our own results showing a decrease of ED, measured by the DERS, post-therapy. Importantly, while DBT's effects on the reduction of suicidal behaviors are well-documented [91], evidence of its effects on ED is less robust [93]. This discrepancy may be attributable to the use of self-report retrospective questionnaires of ED, which are based on various models of ED and are liable to memory biases

and alexithymia [65]. The use of EMA methodology may therefore circumvent these problems and offer a more accurate reflection of emotional dynamics and emotion regulation in everyday life [66, 94]. Moreover, the combined use of subjective EMA responses and the measurement of physiological parameters might improve the understanding of mechanisms of change of DBT [66].

While DBT might have been effective in enhancing positive emotions and emotion control, these changes did not directly translate into changes in physiological measures. One possible explanation is related to the absence of significant changes in negative emotions, e.g., anxiety and anger, as negative emotions are closely linked to SCL increase [95]. However, a positive correlation was found between subjective arousal and HRV. Given that HRV is a vagal index commonly associated with relaxation, emotion regulation and autonomic flexibility [96], it is generally linked to resting [97], thereby reduced subjective emotional arousal. One potential explanation relative to this unexpected finding is that the result reflects an increased emotional awareness and an enhanced capacity to adapt to intense emotional states. Consistently, in a prior study, it was demonstrated that elevated resting HRV was predictive of skills in facial emotional expression [98], suggesting that individuals experiencing higher subjective arousal may engage in more effective regulatory strategies (e.g., skills such as distraction, self-soothing, and radical acceptance).

Despite these encouraging findings, the absence of a significant interaction between time ($post_{DBT}$ versus pre_{DBT}) and subjective arousal in predicting HR, HRV, or SCL suggests that DBT may not have had a clear impact on physiological responses. This prompts the question of whether the observed relationship between HRV and emotional arousal is stable over time, and whether DBT interventions exert an influence on this relationship. One potential explanation may be related to the physiological measurement employed in this study. It is possible that the use of the wristband Empatica E4 to assess HRV and SCL may have limited sensitivity in terms of detecting subtle within-person changes over time. This is in comparison to more established methods of assessment such as electrocardiogram (i.e., ECG) or laboratory-based equipment used for measuring skin conductance. Although such devices are beneficial for obtaining data in real-world settings [82, 99], they may be more appropriate for identifying significant group-level differences than subtle individual variations.

Our research has some limitations. Firstly, the absence of a control group limits the ability to attribute observed changes specifically to DBT. However, given that similar results have been reported in populations other than ASC using self-reported questionnaires of ED in RCT designs [1, 100], we speculate that the emotion-related changes observed here are likely due to DBT rather than the mere passage of time or the effects of repeated measures. In addition, no prior study has explored DBT's effects using EMA, underscoring the innovative approach of our research. Secondly, the use of EMA items such as "I have no emotion" and "I have an emotion I cannot name" as measures of alexithymia and "emotion control" as a measure of ED may lack construct validity, as alexithymia and ED are complex constructs that might be only partially captured by these items. Precisely, we acknowledge the limitation of not being able to compute reliability coefficients (e.g., McDonald's omega) for single-item measures such as those pertaining to emotion control. Nevertheless, this single-item approach permitted precise and concise assessments throughout the intensive EMA protocol, thereby reducing participants' burden. Thirdly, although contextual information, e.g., physical activity and social interactions, was collected in this study, including more detailed behavioral variables, such as the use of emotion regulation strategies in real-life, might improve our understanding of the impact of DBT on physiological responses. Fourthly, psychophysiological measures were collected using Empatica E4 which may have had limited sensitivity when compared with gold-standard techniques such as ECG. This limitation may have contributed to the absence of significant physiological changes observed in the study. Furthermore, despite controlling for anticholinergic effects, the presence of psychotropic treatment in the sample introduces possible confounding variables. Additionally, the relatively small sample size of 26 participants limits the generalisability of the findings and the statistical power to detect significant effects. This study should therefore be considered preliminary, with results aimed at exploring the feasibility of employing EMA to examine therapy effects of DBT in autistic adults. Finally, the DSM-5 severity level ratings were not considered in our sample, and ASC-severity is likely to be heterogeneous. Yet, recent studies suggest that the DSM-5 severity specifier is influenced by factors unrelated to the ASC-severity (e.g., age, IQ), which limits its clinical utility [101]. Future studies should address these limitations by including control groups, using validated EMA measures of alexithymia and emotion control, gathering more detailed contextual and behavioral data, considering medication effects more comprehensively and including larger samples.

Conclusions

In conclusion, our EMA study contributes to the growing body of evidence supporting the adaptation and application of DBT for autistic adults. Specifically, our findings indicate that DBT shows promise in enhancing certain aspects of emotion regulation in this population, such as increased emotional awareness, as well as enhanced

everyday experience of positive emotions and emotion control. While these improvements were not linked to significant changes in physiological measures, it is essential to shift our focus towards the understanding of the real-life mechanisms that foster changes in ED post-DBT. To this aim, the combined use of EMA and real-time physiological monitoring might complement the use of traditional self-report questionnaires and provide valuable insight into the mechanisms of change of DBT.

Abbreviations

ADHD	Attention-deficit/hyperactivity disorder
BPD	Borderline personality disorder
BVP	Blood Volume Pulse
ECG	Electrocardiogram
ED	Emotion dysregulation
EMA	Ecological momentary assessment
DBT	Dialectical behavior therapy
HR	Heart rate
HRV	Heart-rate variability
MLM	Multilevel model analysis
NA	Negative affect
PA	Positive affect
PPG	Photoplethismographic signal
RCT	Randomised control trial
SC	Skin conductance
SCL	Skin conductance levels

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Authors' contributions
MEC: conceptualisation, methodology, project management, data collection, data curation, software, data analysis, writing – original draft, writing – review and editing; FG: software, data curation, data analysis; NV, AG: data curation, supervision; AC: conceptualisation, methodology, funding acquisition; SW & LW: conceptualisation, methodology, funding acquisition, data curation, supervision, writing – review and editing. All authors read and approved the final manuscript.

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Data availability
https://osf.io/hfpka/?view_only=9692ee9b65414b1f8a990a9afb213243.

Declarations

Ethics approval and consent to participate
The authors confirm that all procedures undertaken in the course of this research project comply with the ethical standards set out by the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. The Regional Ethics Committee of Eastern France approved this study as a preliminary step towards a randomised controlled trial of dialectical behavior therapy and emotion dysregulation (reference number: SI 21.01.21.41923). The study protocol has been registered on the clinicaltrials.gov (registration number: NCT04737707). Written informed consent was obtained from all participants prior to their involvement in the study.

Consent for publication
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Competing interests
The authors declare no competing interests.

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