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Depressive symptoms are associated with a poor orientation toward the past during future self-projection

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This study examines the relationship between depressive symptoms (DS) and mental time travel (MTT), focusing on individuals' ability to orient and project themselves into past or future scenarios. Drawing on literature suggesting that depression disrupts prospection, we hypothesized that DS are primarily associated with alterations in future-related MTT. Forty-eight university students were divided into two groups based on the presence or absence of mild-to-severe DS. Participants were asked to judge whether various events were located in the past or future while mentally projecting themselves ten years into the past, in the present, or ten years into the future. Results showed that participants with DS were less accurate in judging the temporal location of past events when projecting themselves into the future, as compared with those without DS. This suggests that DS may reduce prospection by interfering with the ability to orient to the past when individuals need to represent themselves in possible futures. Clinical implications will be discussed on how focusing on future-related MTT may help counteract DS.

Keywords Depressive symptoms, Mental time travel, Future self-projection

Depression is a clinical condition characterized by low mood, low self-esteem, anhedonia, together with other manifestations[1]. It is a widespread mental health issue, necessitating further investigation into its underlying psychological mechanisms to develop more effective treatments[2]. Research suggests that depressive symptoms (DS) are often associated with dysfunctional prospection, that is the predominance of negative over positive content when representing possible future events[3–5]. It contributes to negative self-beliefs, hopelessness, difficulties in goal-setting and pursuing, and a reduction in adaptive behaviors[5]. However, the link between depression and prospection may extend beyond the valence, negative or positive, of the represented events. Prospection is part of mental time travel (MTT)[6,7], a cognitive function that enables individuals to orient to past and future events and to mentally navigate along the mental time line[8–11]. Yet, the nature of the relationship between MTT and DS is not completely understood.

MTT involves episodic memory (retrieving past personal events), autobiographical memory (semantic self-related memories), and executive functions (extraction and re-combination of episodic memories for the simulation of unexperienced scenarios)[7]. More specifically, MTT allows individuals to mentally represent events positioned at different timepoints in self-centred coordinates[12]. For instance, one can represent World War II as extremely distant in the past and the day of one's degree as closer to the current self-position. Symmetrically, one can represent the death of the sun as extremely far in the future and the day of one's retirement as nearer to the current self-position. Additionally, MTT allows individuals to project themselves along this mental time line, either backward into the past or forward into the future. For instance, one can represent oneself 20 years ago, 10 years ago, 10 years from now, or 20 years from now.

The representation of time from past to future, the ability to shift orientation to past and future events and to move oneself along this representation, serves several purposes for mental health. It contributes to self-continuity and the construction of personal identity[13]. It also enables individuals to envision events from different time

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perspectives in alignment with their current goals[12]. For example, individuals might mentally represent the final day of elementary school either from the perspective of a recent graduate, feeling affection toward their younger self, or from the perspective of a newly retired individual, feeling nostalgia, with different influences on the current behavior. Most importantly for the present study, mental travel into unexperienced scenarios located at different timepoints is crucial for the representation of possible future events, which is the basis of prospection[5,14].

In summary, MTT is linked to prospection in ways that may be partially independent of the valence positive or negative — of represented events. This raises a crucial question: do individuals with DS struggle solely with representing future events with positive content, or do they face broader difficulties in orienting to and navigating through future time? If the latter is true, then depression may be linked to a poor ability in forming effective mental maps of the future. Such poor ability could undermine planning and the capacity to envision oneself in future scenarios. Addressing this question could guide research on interventions that manipulate time representation as a means to counteract DS.

Research indicates that manipulating the representation of time can promote psychological well-being and adaptive behavior in non-clinical populations[15,16]. For instance, Suksasilp and colleagues[17] asked students to project themselves in the present, near-future, or far-future with respect to a stressful event. Students who projected themselves in the far-future reported lower stress levels related to the event compared to other projections. Similarly, Bruehlman-Senecal et al.[18] evaluated the ability of non-clinical participants to project themselves far in the future concerning specific events. Participants with a high ability to engage in such projection reported lower levels of psychological symptoms and higher levels of adaptive coping strategies compared to participants with limited projection ability.

However, literature examining temporal manipulation in individuals with DS have yielded inconclusive results. Hollar and Siegel[19] examined whether envisioning either the current-self or a future-ideal-self would influence help-seeking attitudes for depression. Participants with DS who imagined their future-ideal-self reported more positive attitudes toward seeking help compared to those who focused on their current-self. While these findings suggest that temporal manipulation may effectively affect help-seeking, they do not clarify whether representing a future-self or an ideal (positive)-self, specifically drives this effect.

This highlights the need for further research into how individuals with DS engage in MTT, particularly in contexts that do not explicitly require to focus on positive or negative content. To address this, we asked students with and without DS to perform an MTT task[12,20], which required them to judge whether a series of events were located in the past or future while projecting themselves in the past, present or future. This task assessed participants' ability to orient attention toward the past or the future and to place events in the past or future based on their self-position in time. Importantly, the task did not require a detailed retrieval or elaboration of events, nor did it depended on the subjective experience elicited by the stimuli (see Supplementary Materials – SM - for details on personal relevance and emotional valence of the stimuli). Participants responded as quickly and accurately as possible using mouse buttons, and we recorded reaction times (RTs) and accuracy (percentage of correct responses).

RTs and accuracy are widely used behavioral indices in MTT tasks[11,12]. RTs reflect the cognitive load required in shifting temporal orientation or one's self-position along the mental time line[12]. Accuracy, reflects the quality of temporal orientation, specifically, the ability to discriminate between past and future events, which depends on decision-making efficacy[21]. In simpler terms, the better individuals are at distinguishing between past and future, the more efficiently they can decide where to place events along the appropriate temporal frame, which in turn leads to higher accuracy. RTs and accuracy index rely on distinct cognitive mechanisms. Therefore, we analyzed them separately. This distinction is particularly relevant in individuals with DS. Previous research has shown that RTs may be preserved or only mildly slowed in individual with DS, whereas accuracy tends to be consistently lower - especially in tasks requiring complex decision-making[22,23].

Aim, hypotheses and expected results

The aim of this study was to explore whether the presence of DS is associated with poor MTT. Following existing evidence linking DS to dysfunctional prospection, our main hypothesis is that DS are associated with poor orientation to (Hp1a) and poor self-projection into (Hp2a) the future. Given the lack of prior evidence using paradigms similar to the one used in this study, we formulated exploratory hypotheses regarding whether DS are associated with orientation to (Hp1b) and self-projection into (Hp2b) the past. In terms of performance indicators, we examined whether poor MTT manifests as increased cognitive load – i.e. slower reaction times –and/or as reduced response quality – i.e. lower accuracy. Based on previous literature, we hypothesize that DS are more likely to be associated with reduced response quality than increased cognitive load.

Hp1a. If DS are associated with poor orientation to the future, then participants with DS should, at the group level, exhibit slower RTs and/or lower accuracy in judging future events compared to those without DS, regardless of their self-projection.

Hp1b. If DS are associated with poor orientation to the past, then participants with DS should, at the group level, exhibit slower RTs and/or lower accuracy in judging past events compared to those without DS, regardless of their self-projection.

Hp2a. If DS are associated with poor self-projection into the future, then participants with DS should, at the group level, exhibit slower RTs and/or lower accuracy in judging past and/or future events, compared to those without DS, when projecting themselves into the future.

Hp2b. If DS are associated with poor self-projection into the past, then participants with DS should, at the group level, exhibit slower RTs and/or lower accuracy in judging past and/or future events, compared to those without DS, when projecting themselves into the past.

Materials and methods

Screening measure for DS

The DSM-5 Level 2 - Depression – adult[24] (Fossati et al., 2015) questionnaire is an 8-item self-report measure. Individuals respond on a 5-point Likert scale (1 = "never"; 5 = "always"). The sum of single items gives a total raw score. Scores ≥ 17, corresponding to a T-score ≥ 55.3, indicates mild-to-severe DS.

Participants

Forty-eight (computed by an a priori power analysis carried out using G*power 3.1[25] estimated minimum-medium effect size f = 0.25, correlations among repeated measure, $r = 0.5$, number of groups = 2, number of measurements = 3, powered at 90%) University students (16 males; age Mean = 23.21 years, age SD = 2.57 years; IQR = 21.75–25.00 years; education Mean = 14.21 years, education SD = 2.32) participated in the study. Participants with psychiatric, neurological, or neurodevelopmental diagnoses were excluded from the study.

Included participants were grouped according to the level of DS measured by the screening measure in the "with DS" (mild-to-severe DS, $N = 24$, 6 males; age Mean = 22.83 years, age SD = 2.71 years; IQR = 21.00–24.25; education Mean = 13.71 years, education SD = 2.54) and the "without DS" group (no symptoms, $N = 24$, participants, 10 males; age Mean = 23.58 years, age SD = 2.41 years; IQR = 22.00–25.00; education Mean = 14.71 years, education SD = 2.01).

Informed consent was obtained from all subjects and/or their legal guardian(s).

The study was approved by the Ethics Board of the University of Parma (protocol number 0254671). All procedures were in agreement with the Declaration of Helsinki.

Mental time travel task

Participants sat about 60 cm in front of a PC running E-Prime 3.0 (Psychology Software Tools). They heard brief vocal descriptions of personal (e.g. one's last day of elementary school) or impersonal events (e.g. dominance of artificial intelligence; for a similar procedure[11]. Participants had to press the "P" button on the mouse, with their right index finger, if they judged the event as already happened (past event) or "F" as yet to happen (future event). Events could belong to personal history (personal events) or not (impersonal events). Participants were instructed to judge the events as either past or future without being required to provide any details, estimate a specific date or time range, and regardless of whether the events had been personally experienced or not. We recorded RTs (milliseconds, ms) of correct responses and the accuracy as the percentage of correct responses (%). To avoid an effect of lateralized associated responses (left-past; right-future[26], the mouse was positioned centrally and horizontally, the finger movement was kept vertical (up-down or down-up), and the mouse was rotated at 180° in a counterbalanced order across items and participants. To familiarize with the apparatus, participants underwent a training phase of 8 events. The task was the same for three self-projections: past (judge the event as you were placed 10 years ago, i.e. in 2014), present (judge the event as you were placed now, 2024), and future (judge the event as you were placed in 10 years, 2034). For each self-projection, we presented a total of 24 events (6 for each combination: past-personal, past-impersonal, future-personal, future-impersonal). To make participants familiarizing with the task, the present self-projection, was always administered first[20], while the past and the future self-projections were administered in a counterbalanced order across participants (see SM for detailed description and graphical representation of stimuli – Fig. 1S, estimation of their temporal placement in time – table 1S, comparisons to assess emotional intensity and salience – Fig. 2S, and inherent difficulty of kind of stimuli across self-projection conditions – Fig. 3S and 4 S).

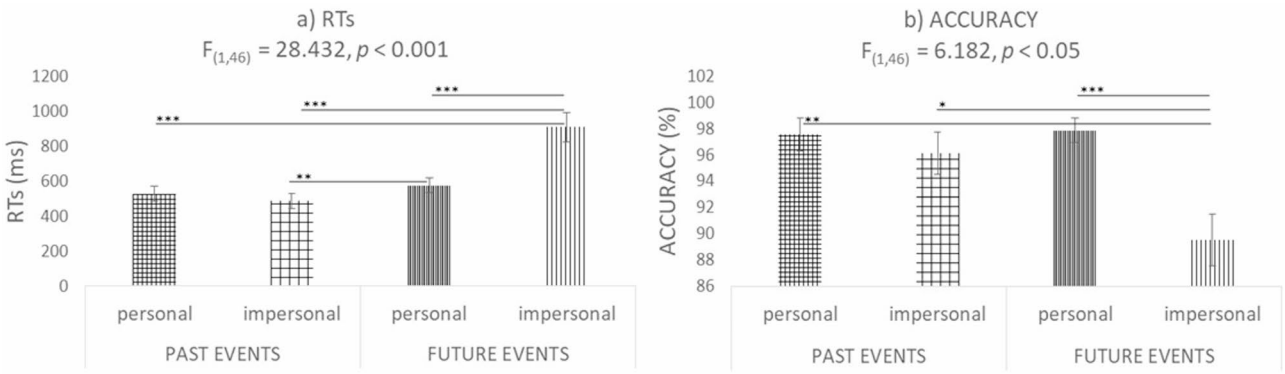

Fig.1. The graph depicts the means of (**a**) RTs (milliseconds, ms) of correct responses and (**b**) accuracy (%) of judging past or future events (time) according to whether they were personal or impersonal (type) in the future self-projection. Error bars indicate standard errors of means. ** and *** symbols indicate $p < 0.01$ and $p < 0.001$, respectively.

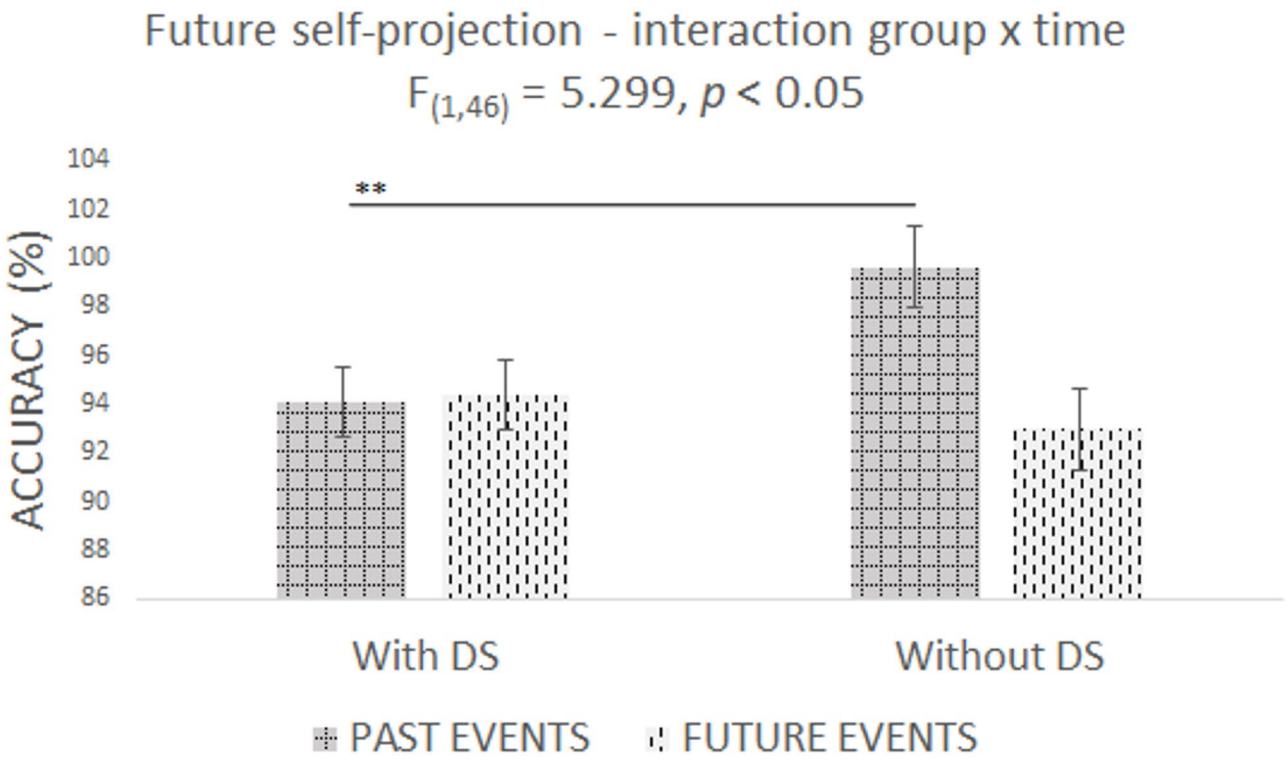

Fig. 2. The graph depicts the means of accuracy (%) of judging past or future events (time) according to the presence (with DS) or the absence (without DS) of depressive symptoms in the future self-projection. Error bars indicate standard errors of means. ** symbol indicates $p < 0.01$.

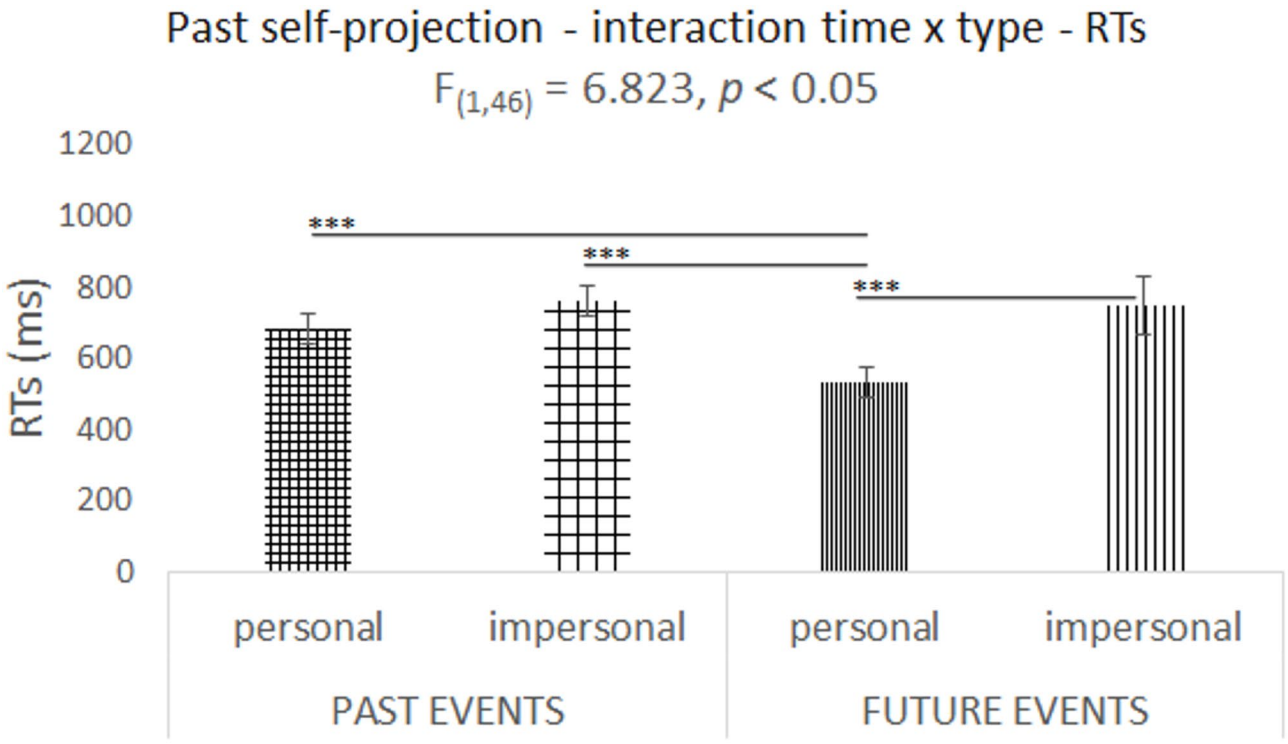

Fig. 3.. The graph depicts the means of RTs (milliseconds, ms) of correct responses of judging past or future events (time) according to whether they were personal or impersonal (type) in the past self-projection. Error bars indicate standard errors of means. *** symbol indicates $p < 0.001$.

Analysis

Preliminary analysis

Groups balance and differences

We first conducted preliminary analyses to ensure the two groups (with and without DS) were balanced for age and education using two-tailed independent samples t-tests, and for sex using a chi-square test. Furthermore, we confirmed that participants classified in the with DS group exhibited significantly higher levels of depressive symptomatology than those in the without DS group by an independent samples t-test.

Hypotheses testing

To test *Hp1a*, we conducted a repeated measures ANOVA on both RTs and accuracy means for judging *future events*, with group as a between-groups variable and type as a within-subjects variable, collapsing the self-projection variable.

To test *Hp1b*, we performed the same ANOVA on RTs and accuracy means for judging *past events*.

To test *Hp2a*, we conducted a repeated measures ANOVA on both RTs and accuracy means obtained in the *future self-projection*, with group as a between-groups variable and time and type as within-subjects variables.

To test *Hp2b*, we conducted the same ANOVA on RTs and accuracy means obtained in the *past self-projection*.

In cases of interaction between group and other variables, we conducted two-tailed independent samples t-tests to compare the two groups. In cases of interaction between variables other than group we conducted paired sample t-tests. For each F we applied the Bonferroni correction and we reported the size effect as partial eta square, while for each t we reported the size effect as Cohen's d estimated point. Dispersion is expressed as standard errors (SE) of means. All analyses were performed using SPSS version 26.

Results

Preliminary analyses

Groups balance and differences

The two groups (participants with and without DS) were balanced for age [$t_{(46)} = 1.012$; $p = 0.158$; $d = 0.292$], education [$t_{(46)} = 1.511$; $p = 0.069$; $d = 0.436$], and sex [$\chi^2_{(1,48)} = 1.500$; $p = 0.221$]. As expected, the DS group showed higher levels of depressive symptomatology (mean = 21.792, SE = 0.897) compared to the non-DS group (mean = 11.208, SE = 0.370) [$t_{(46)} = -10.900$; $p < 0.001$; $d = -3.150$].

Hypotheses testing

Hp1a. judging future events

RTs. No significant effect of group [$F_{(1,46)} = 0.346$, $p = 0.559$, $\eta p2 = 0.007$] or group × type interaction [$F_{(1,46)} = 0.058$, $p = 0.811$, $\eta p2 = 0.001$] was found, indicating similar RTs for both groups when judging future events, regardless of whether events were personal or impersonal. However, a significant effect of type [$F_{(1,46)} = 83.126$, $p < 0.001$, $\eta p2 = 0.644$] showed that all participants were faster in judging personal future events (mean = 553.938 ms, SE = 41.151 ms) than impersonal ones (mean = 823.521 ms, SE = 61.109 ms).

Accuracy. No significant effect of group [$F_{(1,46)} = 0.213$, $p = 0.647$, $\eta p2 = 0.005$] or group × interaction [$F_{(1,46)} = 0.053$, $p = 0.819$, $\eta p2 = 0.001$] was found. The effect of type was significant [$F_{(1,46)} = 21.688$, $p < 0.001$, $\eta p2 = 0.320$], with higher accuracy for personal future events (mean = 98.67%, SE = 0.43%) than impersonal ones (mean = 93.19%, SE = 1.17%).

Hp1b. Judging past events

RTs. The effect of group [$F_{(1,46)} = 0.769$, $p = 0.385$, $\eta p2 = 0.016$] and its interaction with type [$F_{(1,46)} = 0.078$, $p = 0.781$, $\eta p2 = 0.002$] was not significant indicating that both groups show similar RTs when judging past events, regardless of they were personal or impersonal. However, the effect of type [$F_{(1,46)} = 4.374$, $p < 0.05$, $\eta p2 = 0.087$] was significant indicating that all participants were faster in judging past events when they were personal (mean = 577.958 ms, SE = 39.236 ms) than impersonal (mean = 624.604 ms, SE = 40.795 ms).

Accuracy. The effect of group [$F_{(1,46)} = 0.842$, $p = 0.364$, $\eta p2 = 0.018$], of type [$F_{(1,46)} = 1.362$, $p = 0.249$, $\eta p2 = 0.029$] and their interaction [$F_{(1,46)} = 0.195$, $p = 0.661$, $\eta p2 = 0.004$] was not significant indicating that all participants showed similar accuracy when judging personal and impersonal past events.

Hp2a. future self-projection

RTs. The effect of group [$F_{(1,46)} = 0.188$, $p = 0.667$, $\eta p2 = 0.004$] and of interaction with time [$F_{(1,46)} = 0.105$, $p = 0.747$, $\eta p2 = 0.002$], type [$F_{(1,46)} = 1.830$, $p = 0.183$, $\eta p2 = 0.038$] and with time x type [$F_{(1,46)} = 0.113$, $p = 0.738$, $\eta p2 = 0.002$] was not significant. This indicates that both groups, when projecting themselves into the future, showed similar RTs when judging past and future events regardless of whether they were personal or impersonal. However, the effect of time [$F_{(1,46)} = 64.679$, $p < 0.001$, $\eta p2 = 0.584$] was significant indicating that all participants, when projecting themselves into the future, were faster in judging past (mean = 507.417 ms, SE = 38.955 ms) than future (mean = 743.385 ms, SE = 59.556 ms) events. The effect of type [$F_{(1,46)} = 20.648$, $p < 0.001$, $\eta p2 = 0.310$] was also significant indicating that all participants were faster in judging personal (mean = 551.833 ms, SE = 39.925 ms) than impersonal (mean = 698.969 ms, SE = 59.701 ms) events. Finally, the interaction time x type [$F_{(1,46)} = 28.432$, $p < 0.001$, $\eta p2 = 0.382$] was significant indicating that all participants, when projecting themselves into the future, were slower in judging future impersonal than future personal [$t_{(47)} = -5.710$; $p < 0.001$; $d = -0.825$], past impersonal [$t_{(47)} = -7.460$; $p < 0.001$; $d = -1.080$] and past personal [$t_{(47)} = -6.870$; $p < 0.001$; $d = -0.991$] events. Moreover, participants were slower in judging future personal than past impersonal events [$t_{(47)} = -3.340$ $p < 0.01$; $d = -0.481$] ($p > 0.106$ for all other comparisons, see Fig. 1A for all values).

Accuracy. The effect of group [$F_{(1,46)} = 1.711$, $p = 0.197$, $\eta p2 = 0.036$] and of its interaction with type [$F_{(1,46)} = 0.062$, $p = 0.804$, $\eta p2 = 0.001$] and with time x type [$F_{(1,46)} = 0.570$, $p = 0.454$, $\eta p2 = 0.012$] was not significant. However, the interaction group x time [$F_{(1,46)} = 5.299$, $p < 0.05$, $\eta p2 = 0.103$] was significant. Independent samples t-test showed that, when projecting themselves into the future, participants with DS (mean = 94.08%, SE = 1.42%) were less accurate [$t_{(46)} = 2.770$; $p < 0.01$; $d = 0.799$] than those without DS (mean = 99.65%, SE = 1.42%) in judging past events, and not [$t_{(46)} = -0.544$; $p = 0.589$; $d = -0.157$] in judging future events (with DS mean = 94.40%, SE = 1.68%, without DS mean = 93.00%, SE = 1.68%, Fig. 2).

The effect of time [$F_{(1,46)} = 4.390$, $p < 0.05$, $\eta p2 = 0.087$] was significant. Similarly to RTs results, all participants, when projecting themselves into the future, were more accurate in judging past (mean = 96.87%, SE = 1.00%) than future (mean = 93.70%, SE = 1.19%) events. The effect of type [$F_{(1,46)} = 10.623$, $p < 0.01$, $\eta p2 = 0.188$] was also significant. Similarly to RTs results, all participants were more accurate in judging personal (mean = 97.73%, SE = 0.88%) than impersonal (mean = 92.83%, SE = 1.27%) events. Finally, the interaction time x type [$F_{(1,46)} = 6.182$, $p < 0.05$, $\eta p2 = 0.118$] was significant. Again, the results were similar to those of RTs: all participants, when projecting themselves into the future, were less accurate in judging future impersonal than future personal [$t_{(47)} = 4.220$; $p < 0.001$; $d = 0.609$], past impersonal events [$t_{(47)} = 2.550$; $p < 0.05$; $d = 0.368$] and past personal [$t_{(47)} = 3.470$; $p < 0.01$; $d = 0.501$] events ($p > 0.393$ for all other comparisons, see Fig. 1B for all values).

Hp2b. past self-projection

RTs. The effect of group [$F_{(1,46)} = 2.535$, $p = 0.118$, $\eta p2 = 0.052$] and of its interaction with time [$F_{(1,46)} = 2.209$, $p = 0.144$, $\eta p2 = 0.046$], type [$F_{(1,46)} = 1.078$, $p = 0.305$, $\eta p2 = 0.023$] and with time x type [$F_{(1,46)} = 0.003$, $p = 0.957$, $\eta p2 = 0.000$] was not significant. This indicates that both groups, when projecting themselves into the past, showed similar RTs when judging past and future events regardless of they were personal or impersonal. However, the effect of time [$F_{(1,46)} = 7.947$, $p < 0.01$, $\eta p2 = 0.147$] was significant. Means indicate that, specularly to future self-projection, when projecting themselves into the past, all participants were faster in judging future (mean = 639.031 ms, SE = 45.746 ms) than past (mean = 722.792 ms, SE = 39.012 ms) events. The effect of type [$F_{(1,46)} = 27.915$, $p < 0.001$, $\eta p2 = 0.378$] was also significant. In this case, similarly to the future self-projection, means indicate that all participants were faster in judging personal (mean = 607.583 ms, SE = 37.654 ms) than impersonal (mean = 754.240 ms, SE = 46.267 ms) events. Finally, the interaction time x type [$F_{(1,46)} = 6.823$, $p < 0.05$, $\eta p2 = 0.129$] was significant. When projecting themselves into the past, all participants were faster in in judging future personal than future impersonal [$t_{(47)} = -6.600$; $p < 0.001$; $d = -0.952$], past personal [$t_{(47)} = 4.290$; $p < 0.001$; $d = 0.620$] and past impersonal [$t_{(47)} = 6.000$; $p < 0.001$; $d = 0.866$] events ($p > 0.088$ for all other comparisons, see Fig. 3 for all values).

Accuracy. The effect of group [$F_{(1,46)} = 0.009$, $p = 0.923$, $\eta p2 = 0.000$] and of its interaction with time [$F_{(1,46)} = 0.912$, $p = 0.344$, $\eta p2 = 0.019$], type [$F_{(1,46)} = 0.935$, $p = 0.339$, $\eta p2 = 0.020$] and with time x type [$F_{(1,46)} = 0.583$, $p = 0.449$, $\eta p2 = 0.013$] was not significant. Also, the effect of time [$F_{(1,46)} = 2.634$, $p = 0.111$, $\eta p2 = 0.054$], type [$F_{(1,46)} = 2.640$, $p = 0.111$, $\eta p2 = 0.054$] and the interaction time x type [$F_{(1,46)} = 0.321$, $p = 0.574$, $\eta p2 = 0.007$] was not significant. Means indicate that, when projecting themselves into the past, all participants were equally accurate in judging past and future events regardless of they were personal or impersonal.

Discussion

This study set out to clarify the relationship between DS and MTT, focusing on whether DS are linked to difficulties in temporal orientation and self-projection, independent of the valence, negative or positive, of represented events. While previous research has established that DS are associated with dysfunctional prospection - typically manifesting as a tendency to imagine negative rather than positive future scenarios[5] - the cognitive mechanisms underlying this association remain unclear. Our primary hypothesis was that DS would be specifically associated with a reduced ability to orient toward and project oneself into the future, even in the case of our experimental paradigm that did not require participants to focus on or modify the valence of their representations. To test this, participants with and without DS judged whether events (personal or impersonal) were located in the past or future, relative to their self-projection in the past, present, or future. We analyzed reaction times (RTs) and accuracy separately, as they reflect distinct cognitive processes: RTs index cognitive load, while accuracy reflects the quality of temporal orientation.

Contrary to expectations, results for Hp1a revealed that DS were not associated with increased cognitive load or reduced accuracy when judging future events. Both groups were faster and more accurate when judging personal future events compared to impersonal ones. These findings replicate those from other studies with similar paradigms[12,27] supporting the idea that personal events are easier to orient to (lower cognitive load/higher quality of orientation) than impersonal ones. This phenomenon is known as the self-reference effect, which refers to enhanced encoding, retrieval, and reconstruction of self-related information due to deeper processing and stronger associative networks in memory[28]. This advantage stems from its close link to personal goals, making it more meaningful and easily integrated into memory[29]. Importantly, our results indicate that the presence of DS is not related with this effect: individuals with DS also showed faster and more accurate processing of self-related information, confirming that the self-reference effect remains preserved in the presence of DS.

Consistent with predictions, results for Hp1b indicated that having DS is not associated with increased cognitive load and/or reduced quality of orientation to the past. Similar to what was observed with future events, participants were faster when processing personal events compared to impersonal ones, according to the self-reference effect—regardless of whether they had DS. However, unlike the judgment of future events, participants were equally accurate in judging the temporal location for either personal or impersonal events. A possible explanation is that impersonal events that are both future and non-self-related lack of any fragments of subjective experience so that persons must entirely construct them to correctly judge their temporal location[7]. In

contrast, past impersonal events, although not self-related, are supported by a pre-existing memory trace, which makes them more likely to be integrated into a mental map of the past and may facilitate orientation toward them. This could explain why participants show greater uncertainty when judging future impersonal events compared to future personal events. However, for past events, while participants may take longer to respond, they do not exhibit increased uncertainty when placing impersonal versus personal events.

Results for Hp2a, consistent with our expectations, showed that DS are associated with reduced response quality, reflecting lower decision-making effectiveness[21] in orienting toward the past, but not toward the future, while projecting themselves into the future. Importantly, this was not the case for cognitive load. Specifically, when individuals with DS projected themselves ten years ahead, despite being equally fast in responding than participants without DS, they made more errors in judging past events, sometimes considering them as future. For example, they might mistakenly think that an event such as their first blood test will occur in the future, rather than recognizing it as something that has already happened.

Thus, our findings offer a new perspective: when individuals with DS project themselves into the future, they exhibit reduced accuracy in judging past events, while their judgments about future events remain unaffected. One of our initial questions was whether individuals with DS struggle with envisioning the future only when required to represent it positively. Our findings suggest otherwise - participants with DS primarily experience difficulties in orienting to past events when projecting into the future, regardless of the event's valence. Our finding also supports evidence that accurately identifying an event as belonging to the past is essential for prospection, as future scenarios are constructed by flexibly recombining elements derived from past experiences. Relying on past information, enables the generation of future simulations that are detailed, realistic, and coherent[3,6,14]. This finding might have clinical relevance. For example, interventions could consider supporting the construction of future scenarios that are better anchored in coherent and well-grounded past experiences, which may in turn facilitate goal-oriented planning and psychological flexibility.

An alternative explanation for our findings that one might reasonably consider is that orienting oneself toward the past while simultaneously projecting into the future could represent a more demanding cognitive condition compared to others, and that individuals with DS may struggle in this context due to their more limited cognitive resources. However, this idea is not supported by the comparisons of different kinds of stimuli across conditions conducted in the Supplementary Materials section. These analyses showed that orienting towards the past while projecting oneself into the future is not the most demanding condition in terms of task requirements. In fact, participants, regardless of having DS or not, were neither slower nor less accurate when judging past events from a future perspective. If anything, the most demanding condition seems to be when participants orient to the future, rather than to the past, while projecting themselves in the future. In contrast to the idea that DS-related differences might be explained by intrinsic difficulties of the stimuli, participants with DS were still able to correctly place future events during future self-projection—despite this being arguably the most demanding condition in terms of task difficulty.

Results for Hp2b, as expected, indicated that DS are not associated with increased cognitive load and/or reduced quality of orientation to past or future when the self-projection is into the past. When projecting ten years into the past, all participants were faster in judging the temporal location of personal future events compared to all other event combinations, compatible with the self-reference effect previously discussed[28]. Moreover, in this self-projection condition, participants were faster at judging future events than past events. One might expect the opposite—that past events would be easier to orient toward than future ones—given their greater availability in the form of elements from past experiences[7,30]. However, it is important to note that this effect occurred in the past self-projection condition. When participants projected themselves ten years into the past, events that were "future" relative to that self-position may have been perceived near in time. For example, a master's degree may be considered a future event when imagining oneself in 2014, but from today's standpoint, it would have been on the horizon—possibly already anticipated or planned mentally so that participants can be fast to locate these events in the future. Importantly, this pattern of results does not hold for accuracy. All participants were equally accurate in judging the temporal location of past, future, personal, or impersonal events. One possible explanation is that when projecting into the past, experiential traces are more readily available, which may eliminate the differences in the quality of orientation towards events that are situated in the past or future, or that are personal or impersonal.

In summary, our findings suggest that DS are selectively associated with decision-making efficacy in orienting to past events when projecting oneself into the future. When participants with DS need to project themselves in the future, they make errors in locating events that have already happened in the past, mistakenly placing them in the future. This suggests that depression is not only related to a poor construction of a future with positive content, as posited by classical theories on dysfunctional prospection[5], but also with a reduced ability to correctly place events in the map of the past, an ability that is important for building future scenarios effectively.

This specific poor orientation to the past when projecting themselves in the future, and not in other conditions, may be supported by the fact our data are based on a community sample. We consider this a relevant result, as we are analysing a non-clinical sample and yet mild DS were related with altered MTT functioning. This warrants further research with persons suffering with clinically-significant depression in order to explore if clinically significant depression at different levels of severity, is related to more pronounced differences in MTT functioning, something that may help better understand the relationship between mood and cognitive processing of time and to improve treatments for those who suffer from depression.

Limits

Although this study holds 90% power to detect an association between DS and MTT, the limited sample size may have increased the risk of false negatives. Furthermore, the study was conducted on a non-clinical sample of participants with DS rather than depressive disorders, so clinical interpretations should be cautious. Additionally,

our results could reflect general cognitive and decision-making impairments common in depression[31] rather than specific deficits in future self-projection. However, a general impairment in cognition or decision-making would have led to consistently slower RTs and lower accuracy across all conditions. Since our effects appear only in future self-projection, we infer that accuracy changes in participants with DS are specifically related to this process, warranting further investigation.

Conclusions

Despite its limitations, this study provides new empirical evidence on cognitive mechanisms related to prospection in depression. DS are associated with poor future self-projection, specifically, with a poor orientation to the past when projecting the self in the future. These findings suggest avenues for further investigation in individuals diagnosed with clinically significant depression. Should these results be replicated, or if the association between diminished future self-projection and depression proves robust, psychological interventions may focus on enhancing patients' orientation to past experiences as a means of improving their ability to project themselves into the future.

Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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Author contributions

BM and AM designed the work, acquired, analysed and interpreted data and wrote the main manuscript. GD, VL and LS interpreted data and substantively revised the work. AS, CF, MC and VC revised the work.

Declarations

Competing interests

The authors declare no competing interests.

Additional information

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