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# Chronic pain in breast cancer survivors is linked with an impairment on emotion-based decisions and fatalistic time orientation

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**Abstract**

After breast cancer diagnosis, individuals have to cope with various psychological, social, and physical consequences. One such consequence is chronic pain, which can persist even after the completion of active treatments and detrimentally impact quality of life. The published literature highlights the impact of chronic pain on cognitive functions and on decision-making processes. However, little is known about the imbalance in decision-making among cancer survivors suffering from chronic pain. This study aims to explore the cognitive impairment associated with risky decision-making in breast cancer survivors experiencing chronic pain, using the Iowa Gambling Task (IGT). Sixty women voluntarily participated in this prospective, cross-sectional study. Among them, twenty had a history of breast cancer and exhibited a significant level of chronic pain, twenty had previously received a cancer diagnosis but did not experience chronic pain, and twenty had not been diagnosed with cancer. The results revealed that women with chronic pain tend to make significantly more disadvantageous choices in the IGT compared to the other groups. Moreover, participants with chronic pain tend to believe that circumstances will change regardless of their efforts to achieve something. This way of thinking may contribute to reinforcing the observed imbalance in decision-making. Our hypothesis suggests that chronic pain may trigger a "*Cascade Effect*", exerting multiple influences on decision-making and behaviors. The cognitive overload provoked by chronic pain in breast cancer survivors may not only affect individual cognitive functions, but also have a "*Cascade Effect*" on other psychological dimensions.

**Keywords** Decision-making · Chronic pain · Cancer · Cancer patients · Oncology

## Introduction

A breast cancer diagnosis exposes women to various psychological, social, and physical consequences (Munzone et al., 2019; Vaz-Luis et al., 2022). The requirement for ongoing care, short- and long-term side-effects of anticancer treatments, and comorbidities prompt *breast cancer survivors* (BCS) to modify their lifestyles and adapt their present and future personal plans (Durosini et al., 2021a, c, 2022; Durosini & Pravettoni, 2023). One of the undertreated comorbidities experienced by the BCS is *chronic pain* (CP) (Hamood et al., 2018; Lovelace et al., 2019; Masiero et al., 2023; Munzone et al., 2019), which persists even after the end of the active treatments, affecting all *survivorship trajectories* from the acute, extended and permanent "*season*" (Mullan, 1985). Studies suggest that approximately 30% of BCS experience above-average pain after the end of cancer treatment. This pain can also be experienced after 10 years following the completion of active treatment (Leysen et al., 2019). CP often arises as an unintended consequence of extensive surgical procedures or as a result of the toxicity induced by radiotherapy and chemotherapy. Additionally, CP is generally associated with anxiety, depression, catastrophizing thoughts, fatigue, and social isolation (Lovelace et al., 2019). These factors negatively affect quality of life (QoL) (Filipponi et al., 2022; Kondylakis et al., 2017) and contribute to considerable fluctuations in managing patients'

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health, and adhering to the medical treatments (Hamood et al., 2018).

A growing body of research has begun to examine the effects of CP on cognitive functions in patients with various pain syndromes. These studies report that CP impacts *selective* and *sustained attention*, *memory*, and overall *executive functions* (Buelow & Brunell, 2020; Hess et al., 2014; Higgins et al., 2018; Koppel et al., 2017; Walteros et al., 2011; Zeng et al., 2023). Cognitive impairments in attention and memory functions have a far-reaching effect on decision-making processes involving risk (Buelow & Brunell, 2020; Zeng et al., 2023). Earlier studies have shown that experiencing pain causes an imbalance in executive control, altering the affective component in the decision-making processes. CP increases the *risk of making poor decisions* especially in situations of high uncertainty and emotional significance (Apkarian et al., 2004; Barnhart et al., 2019; Hess et al., 2014; Verdejo-García et al., 2007; Walteros et al., 2011). Gathering evidence has shed light on this occurrence, indicating that decision-making engages different cognitive functions, including memory and attention, which interact with each other. However, Walteros and colleagues (2011) pointed out that CP may reduce the attentional resources available for other tasks. For example, patients with fibromyalgia and rheumatoid arthritis often struggle to focus on a specific stimulus, disregarding competing stimuli, and they commonly report issues with *cognitive inflexibility* and *reward sensitivity* (Higgins et al., 2018). Previous studies on fibromyalgia patients noted that patients were unable to develop learning strategies during the Iowa Gambling Task (IGT), a test used to assess real-life decision-making in a laboratory setting. Specifically, these patients tend to persist in responses that yield immediate gains, but ultimately result in greater future losses (Hess et al., 2014; Verdejo-Garcia et al., 2009). Patients with CP showed a deficit in generating anticipatory skin conductance response beforehand, making disadvantageous decisions. Authors have suggested that CP affects the ability of patients to process somatic physical activation in response to external stimuli, such as skin conductance (Haberg et al., 2014). Moreover, Hess and colleagues (2014) highlighted that CP patients repeatedly shifted between advantageous and disadvantageous decks during the IGT test. Koppel and colleagues (2017) have specified that pain might be defined as a "*cognitive load*" that favors the activation of intuitive thinking (*System 1*) instead of rational thinking (*System 2*) (Evans, 2003; Tversky & Kahneman, 1974). According to Kahneman and Frederick (2002), System 1 is characterized by associative and automatic processes leading to decisions made through the use of heuristics. The activation of System 1 may be facilitated by the features of the context (such as time pressure) and emotional activation of the subjects. System 2 is characterized by conscious and rule-based processes that lead to taking decisions via a rational and evidence-based route. The introduction of a pain stimulus can divert attention away from decision-making analysis towards the experience of the pain itself. This interruption of ongoing behavior prompts the adoption of new behaviors aimed at achieving relief from pain. Pain serves as an alarm signal for the individual, indicating a disruption in the body's homeostasis. As stated by Butler and Moseley (2015), pain has a protective nature, and the experience of pain is influenced by many biopsychosocial factors.

To date, there remains a significant gap in our knowledge regarding the impact of CP on decision-making among cancer survivors. While extensive research has delved into specific phenomena such as chemo-brain, the relationship between CP and decision-making processes has received limited attention in long-standing studies. This prospective cross-sectional study examines the cognitive impairment associated with risky decision-making in BCS with chronic pain using the Iowa Gambling Task. We hypothesized that BCS with CP would exhibit impaired risky decision-making, compared to the BCS without CP during extended survivorship. We believe that the findings from our current study will provide valuable insights into the challenges, obstacles, and inner determinants influencing patients' decision-making in the field of oncology. Specifically, it will enable us to gather evidence-based knowledge regarding the role of CP in the determination of suboptimal decisions, especially when BC patients are confronted by preference-sensitive decisions characterized by high levels of uncertainty. Furthermore, these findings will contribute to enhancing our understanding of how to design and implement *decision aids* for BCS experiencing CP. Such aids, which can effectively support treatment decisions throughout the cancer pathway (Masiero et al., 2023).

## Method

### Study design and procedure

We conducted a prospective, cross-sectional study involving three groups: BCS experiencing significant chronic pain, BCS without chronic pain, and women without a cancer diagnosis. Using a convenience sampling strategy, participants were recruited through *patient associations* and *personal contacts*. No incentives were provided for participation. A series of *inclusion criteria* was established: *i*) aged 18 years or older; *ii*) fluent in Italian, both spoken and written; *iii*) free from other chronic diseases; *iv*) without psychiatric or neurological disorders. BCS involved in this study were informed about the study's aims, methodology, and expected outcomes by a trained researcher. Each participant read and signed an informed consent form before taking part in the study. Participants were taken to a quiet room and seated in front of a computer screen to complete the digital version of the Iowa Gambling Task (Bechara et al., 1994). Following this task the BCS filled out a set of self-report questionnaires evaluating pain experience, fear of cancer recurrence, time perspective and positive and negative affect. The study was conducted in accordance with the principles outlined in the Declaration of Helsinki.

## Measures

### Iowa Gambling Task (IGT)

The IGT was used to assess real-life decision-making within a laboratory setting, assessing decision-making abilities under conditions of uncertainty across 100 trials divided into five blocks of 20 choices each. BCS were instructed to maximize their winnings while repeatedly selecting from four decks (A, B, C, and D) of playing cards that provided random wins and losses (Bechara et al., 1997). Two decks of cards (A and B) were designated as disadvantageous since they offered substantial wins ($100) but also imposed high penalties, which resulted in a high cost in the long run (i.e., *Disadvantageous choices*). The remaining two decks (C and D) were deemed advantageous since although they allowed smaller wins ($50), they also incurred lesser penalties resulting in a net gain in the long run (i.e., *Advantageous choices*). Differences between decks are related to long-term outcomes and the gain frequency (the number of losses vs. gains). Participants were unaware of the frequency and the magnitude of gains and losses associated with each deck, and their ability to make decisions during card selections was learned through the experiencing of punishments and rewards encountered across different decks (Bellani et al., 2009). The IGT allows the identification of several outcomes, such as the total time of response, the *NET score*, which is equal to the number of advantageous choices minus the number of disadvantageous choices [(C + D) - (A + B)] for each trail (Bechara et al., 1997; Hess et al., 2014). The *NET score* is considered a global measure of advantageous decisions and scores higher than zero suggest a monetary gain, and scores below zero suggest a monetary loss (Bechara et al., 1997). After completing the IGT, participants were asked to complete the following set of self-report questionnaires.

### Brief Pain Inventory (BPI)

The BPI is a brief self-report scale composed of nine items that assesses the pain intensity and the extent to which pain interferes with people's lives. This scale shows a strong internal consistency $\alpha = 0.91$ (Caraceni et al., 1996; Cleeland & Ryan, 1994).

### Zimbardo Time Perspective Inventory (ZTPI)

The ZTPI is a 22-item self-report scale that measures time perception in terms of present and future to detect in which direction subjects mostly orient their thoughts and actions. It comprises three subscales: *future* ($\alpha = 0.67$), *hedonistic* ($\alpha = 0.54$), and *fatalistic present* ($\alpha = 0.49$). Future-oriented people tend to believe that the course of action depends highly on their actions (e.g., Item 22: "*I am able to resist temptations when I know that there is work to be done*"). They tend to set a goal and channel all their energies towards its achievement, leaving no space for distractions. This focus leads to numerous successes. However, on the other hand, future-oriented people are not able to gratify themselves and enjoy their achievements since they immediately shift focus towards their next goal. People oriented towards the hedonistic present are pleasure-seekers and tend to shy away from responsibilities and demanding jobs (e.g., Item 1: "*I believe that getting together with one's friends to party is one of life's important pleasures*"). People oriented towards the fatalistic present believe that things will change independently of their efforts to achieve something (e.g., Item 12: "*I do things impulsively and I take decisions at the moment*"). They are headed for receiving disappointment instead of hoping for their success (D'Alessio et al., 2003).

### Positive and Negative Affect Scales (PANAS)

The PANAS is a 10-item self-report scale that measures positive and negative affective states. The first dimension, *Positive Affect* (PA), reflects the level of pleasant engagement, whereas the second dimension, *Negative Affect* (NA), explores the unpleasant engagement level over the past week. The five selected PA items have an α of 0.80, while the five selected NA items have an α of 0.74 (Thompson, 2007).

## Data analysis

A descriptive analysis was conducted to depict the features of the sample. To assess whether CP impacts emotion-based decision-making and thinking style, we conducted a set of statistical analyses. Firstly, one-way-ANOVAs were computed to assess whether the subscales of ZTPI changed depending on the level of CP. In this analysis, the three groups acted as independent variables (*CP group* vs. *noCP group* vs. *Healthy control group*), and the subscales of ZTPI as dependent variables (*future*, *fatalistic*, and *hedonistic present*). Similarly, we explored the differences between the three groups in the positive and negative affective states (PANAS). Secondly, one-way-ANOVAs were conducted to test the differences in the three groups in the decisions made in the IGT using both the *total NET score* and Total Time the participants spent completing the IGT. We performed post-hoc tests using Bonferroni adjustments for comparison between three groups. The NET score was calculated as the number of advantageous minus the number of disadvantages choices [(C + D) - (A + B)] for each trial (Bechara et al., 1997; Hess et al., 2014). Thirdly, a repeated-measures ANOVA was conducted to assess the differences between the three groups' five blocks of responses in the IGT. The analysis of the response on the five blocks of cards allows us to identify of changes in the decision-making process over time. The IGT Advantageous Choices were used as dependent variables, whereas the three conditions served as independent within-subject variables. All variables remained within the recommended critical values (Curran et al., 1996), suggesting that the data followed a normal distribution. Data were analyzed using the Statistical Package for the Social Sciences (SPSS) *Version 21*. A power analysis was conducted to ensure significant results (Cohen, 1988).

## Results

### Participants

Sixty Italian women ($M_{age}$ = 54.50; $SD_{age}$ = 10.95) were enrolled in this study (*see* Table 1). Most participants were married (68.3%) and had at least one child (78.3%). The average educational level was medium-high, with 36.7% of participants who completed high school and 30% who obtained a master's degree. Participants were divided into three groups, respectively: BCS with chronic pain (*CP group*); BCS without chronic pain (*noCP group*), and healthy control (*Healthy control group*). Each group comprised 20 participants. The pain level was evaluated through the Brief Pain Inventory (BPI) (Caraceni et al., 1996; Cleeland & Ryan, 1994), a brief self-report scale designed to assesses the pain intensity and how much pain interferes with people's lives (Cleeland, 1989). The *CP group* included participants ranging from 46 to 66 years of age ($M_{age}$=55.25; $SD_{age}$=6.81). Most were married (65%) withat least one child (80%). BCS included in this group showed a significant level of CP evaluated by Brief Pain Inventory (BPI), with an average pain intensity equal to 5.05 (SD = 1.57 - ranging from 2 to 7) and an average level of interference equal to 3.08 (SD = 1.62; ranging from 0.43 to 6.29), as shown in the self-report scale that assesses pain (BPI). The administration of the BPI highlighted an average level of pain intensity equal to 5.05 and an average level of pain interference equal to 3.08. The *noCP group* included participants between 33 and 75 years of age ($M_{age}$=56.60; $SD_{age}$=12.69). Most were married (75%) with at least one child (85%). Participants included in this group did not report CP in their life (*see* Table 2). Finally, the *Healthy control group* included women who had not previously received an oncological diagnosis. Participants in this group had an average age of 51.65 ($SD_{age}$=12.30; - ranging from 24 to 63 years old). As in other groups, most women included in this group were married (65%) and had at least one child

**Table 1** Socio-demographic information for the entire sample

| | CP group | | noCP group | | Healthy control group | | $X^2$(df) | *p* |
|---|---|---|---|---|---|---|---|---|
| | *n* | % | *n* | % | *n* | % | | |
| Level of Education | | | | | | | | |
| Middle School | 4 | 20% | 3 | 15% | 1 | 5% | 4.717 (8) | 0.787 |
| High School | 7 | 35% | 7 | 35% | 8 | 40% | | |
| Bachelor | 3 | 15% | 3 | 15% | 1 | 5% | | |
| Master's degree | 4 | 20% | 6 | 30% | 8 | 40% | | |
| Other specializations | 2 | 10% | 1 | 5% | 2 | 10% | | |
| Employment | | | | | | | | |
| Self-employed worker | 2 | 10% | 1 | 5% | 4 | 20% | 11.780 (8) | 0.161 |
| Employee | 9 | 45% | 12 | 60% | 13 | 65% | | |
| Student | 0 | 0% | 0 | 0% | 1 | 5% | | |
| Housewife | 2 | 10% | 1 | 5% | 2 | 10% | | |
| Pensioner | 7 | 35% | 6 | 30% | 0 | 0% | | |
| Marital status | | | | | | | | |
| Married | 13 | 65% | 15 | 75% | 13 | 65% | 6.945 (8) | 0.543 |
| Cohabiting | 3 | 15% | 2 | 10% | 1 | 5% | | |
| Divorced | 3 | 15% | 3 | 15% | 2 | 10% | | |
| Single | 1 | 5% | 0 | 0% | 3 | 15% | | |
| Widowed | 0 | 0% | 0 | 0% | 1 | 5% | | |

(70%). Chi-square analysis highlighted no differences in the three groups (*CP group*, *noCP group*, *Healthy control group*) regarding education, employment, and marital status (*see* Table 1). In the same line, no significant differences emerged in the age of participants $F(2) = 1.095$, $p = .341$.

The post-hoc power analysis (for one-way ANOVA) with a medium effect size, a 0.05 level of significance, and considering three groups revealed that the actual power is equal to 0.37, indicating a risk of incomplete detection of effects. Analyses were run with G*Power software (Faul et al., 2007).

## Analyses of variance

A series of Analyses of Variance were conducted. Homogeneity of the variances was assessed by calculating the Levene's Test of Equality of Error Variances. The Leven's Test was not significant for all the analyses, except the time variable, where statistical significance emerged.

### Time perspective and positive and negative affect

One-way-ANOVAs were conducted to assess the differences in thinking orientation, and positive and negative attitudes in the three groups (*CP group* vs. *noCP group* vs. *Healthy control group*). Data highlighted statistically significant differences in the fatalistic thinking orientation between groups ($F(2) = 5.16$, $p < .01$). BCS with CP resulted in being significantly more oriented towards a fatalistic present ($M = 2.87$, $SD = 0.86$) compared to healthy participants ($M = 2.17$, $SD = 0.60$; Bonferroni post-hoc test: $p < .01$). No statistically significant differences emerged in the positive and negative attitudes of BCS included in the three groups.

### Iowa Gambling Task

One-way-ANOVAs were computed to explore the differences in the decisions made by the three groups in IGT tasks (*CP group* vs. *noCP group* vs. *Healthy control group*) using

**Table 2** Diagnosis and treatment information of participants included in the *CP* and *noCP groups*

| | CP group | | noCP group | | $X^2$(df) | *p* |
|---|---|---|---|---|---|---|
| | *n* | % | *n* | % | | |
| Diagnosis | | | | | 1.534(3) | 0.674 |
| Ductal carcinoma in situ | 15 | 75.0 | 14 | 70.0 | | |
| Lobular carcinoma in situ | 1 | 5.0 | 1 | 5.0 | | |
| Infiltrating carcinoma | 3 | 15.0 | 5 | 25.0 | | |
| Trabecular carcinoma | 1 | 5.0 | 0 | 0 | | |
| Stage | | | | | 1.333(4) | 0.856 |
| Carcinoma in situ | 1 | 5.0 | 1 | 5.0 | | |
| Stage 1 | 1 | 5.0 | 1 | 5.0 | | |
| Stage 2 | 6 | 30.0 | 8 | 40.0 | | |
| Stage 3 | 11 | 55.0 | 10 | 50.0 | | |
| Stage 4 | 1 | 5.0 | 0 | 0 | | |
| Survivorship Phase | | | | | 7.333(3) | 0.062 |
| Less than 1 year | 6 | 30.0 | 0 | 0 | | |
| 1–3 years | 3 | 15.0 | 3 | 15.0 | | |
| 3–5 years | 6 | 30.0 | 10 | 50.0 | | |
| More than 10 years | 5 | 25.0 | 7 | 35.0 | | |
| Neoadjuvant | | | | | 2.167(3) | 0.539 |
| Chemotherapy | 7 | 35.0 | 7 | 35.0 | | |
| Chemotherapy + Endocrine + Hormonal + Biological | 1 | 5.0 | 0 | 0 | | |
| No therapy | 11 | 55.0 | 13 | 65.0 | | |
| Adjuvants | | | | | 4.634(5) | 0.462 |
| Chemotherapy | 6 | 30.0 | 5 | 25.0 | | |
| Endocrine + Hormonal | 6 | 30.0 | 4 | 20.0 | | |
| Biological + Endocrine | 1 | 5.0 | 0 | 0 | | |
| Chemotherapy + Endocrine | 3 | 15.0 | 6 | 30.0 | | |
| No therapy | 4 | 20.0 | 3 | 15.0 | | |
| Surgery | | | | | 7.612(4) | 0.107 |
| Conserving Surgery | 7 | 35.0 | 8 | 40.0 | | |
| Mastectomy | 3 | 15.0 | 8 | 40.0 | | |
| Breast reconstruction | 2 | 10.0 | 0 | 0.0 | | |
| Mastectomy + Breast Reconstruction | 8 | 40.0 | 3 | 15.0 | | |
| Conserving + Mastectomy + Breast Reconstruction | 0 | 0.0 | 1 | 5.0 | | |

total NET score and Total Time. Analyses suggest that BCS with CP tend to choose significantly fewer advantageous cards - which allowed for small wins but for more minor penalties - and more loss frequency bias ($F(2)=15.59$, $p<.001$) than BCS without CP (Bonferroni post-hoc test: $p<.05$) and healthy controls (Bonferroni Post-hoc test: $p<.01$). In particular, BCS with CP make a significant number of disadvantageous choices ($M$=-13.00, $SD=24.54$) compared to other groups (*noCP group*: $M=10.10$, $SD=25.87$; *Healthy control group*: $M=31.00$, $SD=24.34$). Furthermore, healthy participants make a significant number of advantageous choices compared to CP (Bonferroni post-hoc test: $p<.01$) and noCP groups (Bonferroni post-hoc test: $p<.05$). Additionally, BCS with CP tend to spend significantly more time completing the IGT tasks than the participants included in the HP group ($F(2)=3.37$, $p<.05$; Bonferroni post-hoc test: $p<.05$; see Table 3).

Lastly, a repeated-measures ANOVA was performed to assess the changes in the five blocks of response to the IGT by the three groups. Data highlighted statistically significant differences between groups in the IGT choices made during the five sets of responses ($F(6.82)=6.37$, $p<.001$, $\eta^2=0.183$). Healthy participants showed a statistically significant improvement in learning over time, improving the number of advantageous choices in IGT compared to BCS without CP (Bonferroni post-hoc test: $p<.05$) and BCS with CP (Bonferroni post-hoc test: $p<.01$; *see* Fig. 1).

## Discussion

The results obtained in the current study are *promising* and contribute to shedding light on the impact of CP on decision-making processes within the complex and uncertain context of *cancer survivorship trajectories*. We have identified *two key outcomes* are essential for a deeper understanding of decision-making in the cancer domain, particularly involving a higher number of preference-sensitive decisions under conditions of risk and uncertainty.

Firstly, in line with our hypothesis, BCS experiencing CP tend to make significantly fewer advantageous choices and more disadvantageous choices in the IGT compared to other groups. Additionally, BCS with CP also tend to spend more time completing the IGT tasks compared with BCS who did not have CP. This finding is quite innovative, as it validates the significant negative impact of CP on emotion-based decision-making tasks and highlights the time-consuming nature of decision-making in this context decisions. The findings are consistent with the peer-reviewed published medical literature indicating that patients with CP tend to score lower and switch decks more frequently compared to healthy controls (Hess et al., 2014; Verdejo-Garcia et al., 2009; Walteros et al., 2011). Moreover, healthy participants showed a significant improvement in learning strategies during the Iowa Gambling Task, resulting in an increase in the number of advantageous choices compared to BCS with CP and BCS without CP. Thus, BCS exhibit a form of "*myopia for the future"* (Bechara et al., 2002, p. 1690) and show reduced interest in achieving their goal and winning as much money as possible, as instructed. The ability to learn from decision outcomes and revise decision strategies accordingly is a critical step in the decision-making process, enabling adaptive decision-making (Zeng et al., 2023). The observed results could be explained by the fact that BCS with CP, despite the absence of actual lesions, experience persistent nociceptive stimuli that may lead to altered morphology in brain regions involved in the decision-making process, such as the limbic circuit and the prefrontal cortex (Apkarian et al., 2004; Haberg et al., 2014; Ong et al., 2019; Zeng et al., 2023). Moreover, CP primarily activates the *intuitive* (System 1) rather than *rational* (System 2) thinking processes (Koppel et al., 2017). As highlighted in the literature focused on thinking, reasoning and decision-making, this activation of System 1 leads to a rapid assessment of

**Table 3** Mean, standard deviation, $p$-value, and effect size ($\eta^2$) for Zimbardo Time Perspective Inventory (ZTPI), positive and negative affect scale (PANAS), and Iowa Gambling Task (IGT)

| | CP group | | noCP group | | Healthy control group | | $p$ | $\eta^2$ |
|---|---|---|---|---|---|---|---|---|
| | M | SD | M | SD | M | SD | | |
| ZTPI | | | | | | | | |
| Future | 3.20 | 0.56 | 3.50 | 0.47 | 3.55 | 0.47 | 0.070 | 0.089 |
| Hedonistic | 2.47 | 0.45 | 2.24 | 0.32 | 2.34 | 0.40 | 0.190 | 0.057 |
| Fatalistic Present | 2.87 | 0.86 | 2.63 | 0.60 | 2.17 | 0.60 | 0.009 | 0.154 |
| PANAS | | | | | | | | |
| Positive | 3.62 | 0.77 | 3.93 | 0.58 | 3.64 | 0.57 | 0.248 | 0.048 |
| Negative | 2.29 | 0.80 | 2.27 | 0.75 | 2.15 | 0.59 | 0.801 | 0.008 |
| IGT | | | | | | | | |
| Advantageous Choices | 43.50 | 12.27 | 55.05 | 12.94 | 65.50 | 12.17 | < 0.001 | 0.354 |
| Loss Frequency | 56.50 | 12.27 | 44.95 | 12.94 | 34.50 | 12.17 | < 0.001 | 0.354 |
| Net score | -13.00 | 24.54 | 10.10 | 25.87 | 31.00 | 24.34 | < 0.001 | 0.354 |
| Time (in seconds) | 816601.25 | 1057913.98 | 506088.60 | 339960.96 | 277540.85 | 257469.19 | 0.041 | 0.106 |

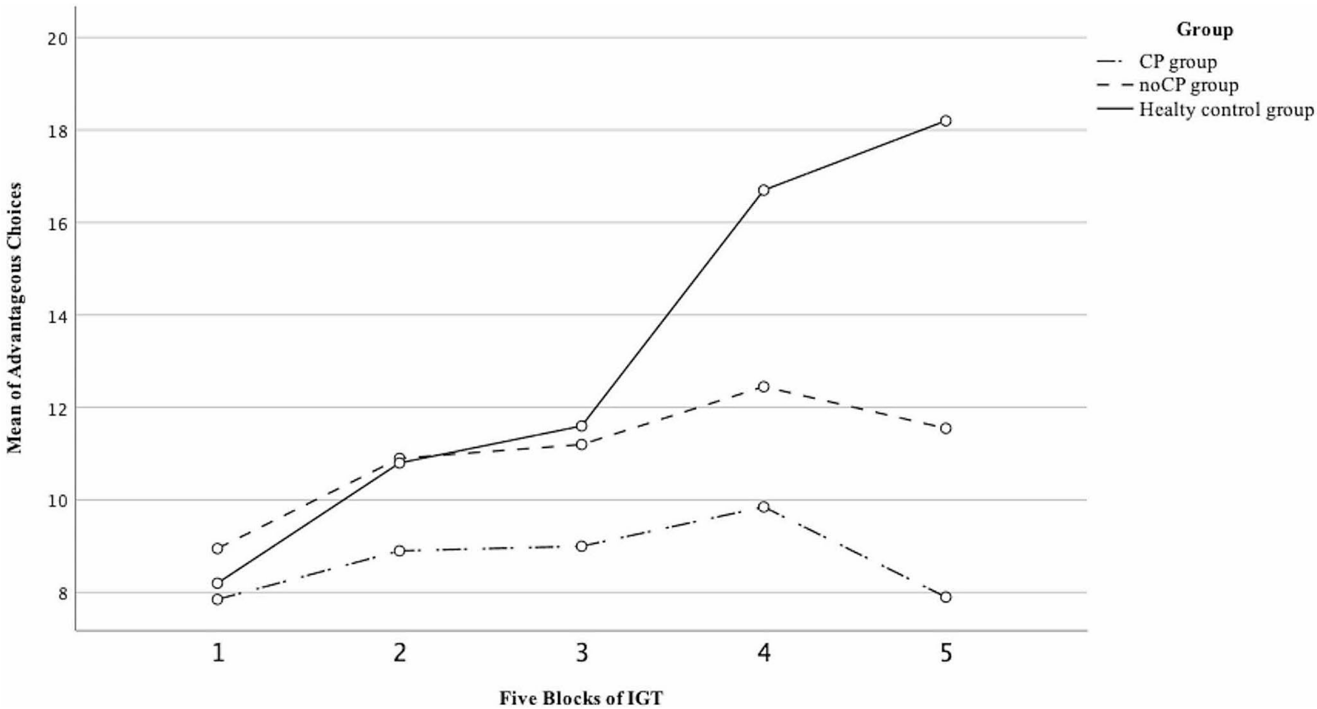


**Fig. 1** Advantageous choices in the Iowa Gambling Task by the three groups of participants

decision attributes, which potentially resulting in suboptimal decisions and an increased risk of using heuristics that may bring to cognitive biases (Evans, 2003).

Secondly, another noteworthy finding is related to the tendency of BCS to orient their thoughts and behaviors based on their specific *time perception*. Specifically, the data revealed that BCS with CP tend to believe that circumstances will change regardless of their efforts to achieve something (*fatalistic present*). BCS who lean towards a fatalistic present lack confidence in their abilities and the effectiveness of their actions, believing that their actions will not change anything. This mindset tends to reinforce the observed decision-making imbalance. BCS with CP, due to the *long-term and reiterative experience of the pain*, have developed a kind of "*learned helplessness*" (Maier & Seligman, 1976), which reduces any motivation to seek out effective learning strategies during the IGT. This phenomenon aligns with previous studies (Higgins et al., 2018; Walteros et al., 2011) indicating that all cognitive resources (e.g. attentive) are allocated to pain management, thereby reducing their availability for other tasks.

## Conclusions

The results suggested that chronic pain may trigger a "*Cascade Effect*", leading to multiple, consecutive, and interrelated effects on brain morphology, cognition, decision-making, and behaviour. We argue that the cognitive overload brought about by CP in BCS does not solely affect isolated cognitive functions, but it exerts a "*Cascade Effect*" on other personal areas. For instance, BCS with CP might experience difficulties in evaluating clinical outcomes associated with anticancer treatments, leading to reduced medication adherence and diminished self-efficacy in pain management, ultimately interfering with their quality of life. Future studies are warranted that probe deeper into the "*Cascade Effect*" and its role in decision-making in real-life contexts.

## Limitations

Despite the innovative results and insights arising from our study, certain limitations warrant recognition. The first pertains to the relatively small sample size. However, compared with previous research (Haberg et al., 2014) the relation between CP and impairment in decision-making process focused on patients with the same clinical diagnosis, thus improving the homogeneity of the study. There is also a need to evaluate decision-making processes at different time points to mitigate the risk that the observed imbalance in decision-making might be related to the chemotherapy-related cognitive impairment, or "chemo-brain", phenomenon associated with anticancer treatments. However, the majority of the BCS (34 up to 40) enrolled in the study are in the extended and permanent survivorship phase (3–5 years and more than 10 years, respectively), and the duration of chemo-brain can vary (Kovalchuk & Kolb, 2017). Therefore, the risk of a confounding effect related to the chemo-brain is negligible. Another limitation pertains to the IGT used to assess decision-making ability in BCS. Indeed, even though IGT permits assessing real-life decision-making, it is conducted in a controlled setting. Thus, the artificial nature of the IGT might have affected participants' behaviors. However, despite this limitation the IGT remains a widely used neuropsychological task for evaluating decision-making processes and their association with CP (Apkarian et al., 2004; Buelow & Brunell, 2020; Haberg et al., 2014; Hess et al., 2014; Verdejo-Garcia et al., 2009; Zeng et al., 2023). Lastly, future studies should also consider other factors that may affect human decision-making under conditions of risk and uncertainty. These factors could include personal characteristics (e.g., gender, age), psychological traits (e.g., personality; John & Srivastava, 1999) emotional intelligence (Durosini et al., 2021b), self-curiosity (Aschieri et al., 2016, 2020; Aschieri & Durosini, 2015), clinical variables (e.g., stage of cancer survivorship) and environmental influences (e.g., life stress events). It is crucial for future studies to explore the psychological, social, and environmental factors that may impact decision-making under uncertainty as well as the psychological determinants of the chronic pain experience.

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**Data availability** The dataset analyzed during the current study is available from the corresponding author upon reasonable request.

## Declarations

**Ethical approval** All procedures performed in the study were in accordance with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

**Consent to participate** Informed consent was obtained from all individual participants included in the study.

**Conflict of interest** On behalf of all authors, the corresponding author states that there is no conflict of interest.



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