

A peer-reviewed version of this preprint was published in PeerJ on 25 June 2015.

[View the peer-reviewed version](https://doi.org/10.7717/peerj.1007) (peerj.com/articles/1007), which is the preferred citable publication unless you specifically need to cite this preprint.

Martín del Campo Ríos J, Fuggetta G, Maltby J. 2015. Beliefs in being unlucky and deficits in executive functioning: an ERP study. PeerJ 3:e1007 <https://doi.org/10.7717/peerj.1007>

Beliefs in being unlucky and deficits in executive functioning: An ERP study

Jaime Martin del Campo, John Maltby, Giorgio Fuggetta

The present study tested the Dysexecutive Luck hypothesis by examining whether deficits in the early stage of top down attentional control led to an increase of neural activity in later stages of response related selection process among those who thought themselves to be unlucky. Individuals with these beliefs were compared to a control group using an Event-Related Potential (ERP) measure assessing underlying neural activity of semantic inhibition while completing a Stroop test. Results showed stronger main interference effects in the former group, via greater reaction times and a more negative distributed scalp late ERP component during incongruent trials in the time window of 450 – 780 ms post stimulus onset. Further, less efficient maintenance of task set among the former group was associated with greater late ERP response-related activation to compensate for the lack of top-down attentional control. These findings provide electrophysiological evidence to support the Dysexecutive Luck hypothesis.

1 Running head: BELIEFS IN BEING UNLUCKY AND DEFICITS IN EXECUTIVE
2 FUNCTIONING

3 Beliefs in being unlucky and deficits in executive functioning: An ERP Study.

4 Jaime Martin del Campo ^a

5 Giorgio Fuggetta ^a

6 John Maltby ^a

7 ^a College of Medicine, Biological Sciences and Psychology, University of Leicester, Lancaster
8 Road, Leicester, LE1 9HN, United Kingdom. jm420@le.ac.uk; jm148@le.ac.uk;
9 gf43@leicester.ac.uk.

10 *Corresponding Author:* Jaime Martin del Campo, College of Medicine, Biological Sciences and
11 Psychology, University of Leicester, Lancaster Road, Leicester, LE1 9HN, United Kingdom. Tel:
12 +44 (0) 116 229 7198. Fax: +44 (0) 116 229 7196. Email: jm420@le.ac.uk.

13 **Abstract**

14 The present study tested the Dysexecutive Luck hypothesis by examining whether deficits in the
15 early stage of top down attentional control led to an increase of neural activity in later stages of
16 response related selection process among those who thought themselves to be unlucky.
17 Individuals with these beliefs were compared to a control group using an Event-Related Potential
18 (ERP) measure assessing underlying neural activity of semantic inhibition while completing a
19 Stroop test. Results showed stronger main interference effects in the former group, via greater
20 reaction times and a more negative distributed scalp late ERP component during incongruent
21 trials in the time window of 450 – 780 ms post stimulus onset. Further, less efficient maintenance
22 of task set among the former group was associated with greater late ERP response-related
23 activation to compensate for the lack of top-down attentional control. These findings provide
24 electrophysiological evidence to support the Dysexecutive Luck hypothesis.

25 **Keywords:** Luck; Executive Functions (EFs); Stroop; Event-related Potential (ERP); Anterior
26 Cingulate Cortex (ACC)

1. Introduction

Estimations of the prevalence of beliefs around luck in the population are that 50% of the population consider themselves lucky, 36% neither lucky nor unlucky, and a remaining 14% considered themselves to be unlucky (Wiseman et al., 1994). The most prominent theory within the psychological literature on beliefs around luck is irrational belief theory that forms part of Rational Emotive Behavior Therapy (Ellis, 1994). Within this theory, beliefs around luck reflect absolute beliefs about the world, where many aspects of life are attributable to chance, with luck having an external, unpredictable, and uncontrollable influence upon the individual, eventually forming the basis of emotional distress (Ellis, 1994). A more recent distinction has been made between a perception of being lucky (beliefs in good luck) or a perception of being unlucky (beliefs in bad luck) (Darke & Freedman, 1997), with the latter being found to be associated emotional distress, in terms of both hedonic and eudaimonic well-being (Maltby et al., 2008).

Consequently there is a literature that has focused on this distinction, with one theory, the Dysexecutive Luck hypothesis (Maltby et al, 2013), focusing on beliefs in being unlucky. The Dysexecutive Luck hypothesis proposes that beliefs in being unlucky are associated with poorer levels of executive functioning. There are two possible causal directions underpinning the Dysexecutive Luck hypothesis. First, individuals' deficits in executive functioning might be having a negative influence on their ability to successfully achieve goals, thereby labelling themselves to be unlucky (hence referred to as "'unlucky' individuals"). Second, individuals, believing themselves to be unlucky, fail to engage the executive functions needed for successful completion of key goals. Maltby et al. (2013) showed some initial support for the Dysexecutive Luck hypothesis. First, self-report dysexecutive symptoms accounted for unique variance in beliefs in being unlucky after controlling for established correlates of luck beliefs (personality, irrational beliefs, and self-efficacy). Second, experimental support for the Dysexecutive Luck hypothesis was demonstrated via significant positive correlations between beliefs in being

unlucky and two (shifting and inhibition) of the three components (shifting, updating, and inhibition) of Miyake et al.'s (2000) taxonomy of executive functions, and a significant negative correlation with decision-making ability using somatic markers (Somatic Marker hypothesis; Damasio et al., 1996).

The Dysexecutive Luck hypothesis places a key emphasis on the role of executive functioning. Given the physiological basis to executive functioning (Jurado & Rosselli, 2007), the consideration of whether the Dysexecutive Luck hypothesis occurs at a physiological level is important, if only to elucidate the psychological nature of the hypothesis. Currently, there is vicarious physiological evidence for the hypothesis via measures (e.g. Switch cost task, Stroop test, and IOWA Gambling Task) that are well-established proxies for physiological functioning. For example, task-switching activates a common set of brain regions during diverse executive control operations, including medial prefrontal, superior and inferior parietal, medial parietal, and premotor cortices (Wager et al., 2004); the IOWA Gambling Task has been shown, via Functional magnetic resonance imaging (fMRI) studies, to be related to aspects of the prefrontal cortex (Li et al., 2010) and the color-word Stroop test with a series of fMRI studies has found to be related to activation in frontal lobe of structures such as the dorsolateral prefrontal cortex (DLPFC) and the anterior cingulate cortex (ACC) (Spree et al., 2006; Lansbergen, 2007; [Silton et al., 2010](#)).

To begin this consideration, we considered the Dysexecutive Luck hypothesis in terms of attentional control, because Maltby et al. (2013) found evidence for the hypothesis around key attentional processes. The cascade-of-control model proposes that during attention demanding tasks, DLPFC takes a leading role in implementing top-down attentional control and, and later ACC activity is thought to be involved in resolving response-related attentional processes ([Banich, 2009](#); [Milham & Banich, 2005](#); [Silton et al., 2010](#)). Previous studies assessing, in healthy participants, attentional control in terms of the aging brain have provided evidence that during color-word Stroop test when early DLPFC activity is relatively low, late ACC activity

increases ([Milham et al., 2002](#); [Silton et al., 2010](#)), The authors suggested that increased late response conflict is a consequence of reduced maintenance of task set, which caused a need for increased ACC activity in order to compensate for the lack of top-down attentional control and maintain adequate task performance ([Milham et al., 2002](#); [Silton et al., 2010](#)).

The current study sought to extend the Dysexecutive Luck hypothesis, by exploring whether deficits in executive functions in 'unlucky' individuals are associated with elongated (slow) reaction time, and larger (more negative) late ERP waveforms underpinning response-related selection processes specifically associated with the interference effect, in order to compensate for the lack of top-down control.

2. Method

2.1. Participants

Initially, 217 undergraduate students (180 females; Mean age = 20.34; SD = 2.1) completed the 6-item Beliefs in Being Unlucky subscale from the Beliefs around Luck scale (Darke & Freedman, 1997; Maltby et al., 2008). Responses are scored on a 5-point scale (1="Strongly Disagree" to 5="Strongly Agree"). Internal reliability estimates for this subscale are $\alpha > .85$ and the measure demonstrates validity via acceptable correlations between both peer and family ratings and predicted correlates of beliefs in being unlucky (Maltby et al., 2008). Participants were recruited from a university experiment participation scheme. The study was advertised and completed online via an electronic survey system.

Twenty five students were selected from the initial group, all of whom had the highest (item mean > 3.4) or lowest scores (item mean < 1.8) on the beliefs in being unlucky subscale. Five respondents' data was discarded and not considered in the statistical analysis due to either excessive eye-movement artifacts or inconsistent scores in a re-test of their beliefs around luck.

Thus 20 students (18 women; Mean age = 22.7; SD = 2.81) were selected for the final study. Two

final experimental groups were formed: 10 participants with the highest scores on the beliefs in being unlucky scale ('Unlucky' group; Mean = 4.63; SD = .37) and 10 with the lowest scores on the beliefs in being unlucky scale (Control group; Mean = 1.43; SD = .47). All participants had normal or corrected-to-normal vision, were unaware of the main purposes of the study, and had no history of any mental or neurological disorders. All participants, except one, were right-handed as assessed by the Edinburgh Handedness Inventory (Oldfield, 1971).

To establish further validity for the experimental groups we administered measures of dysexecutive symptoms (Wilson et al., 1996), neuroticism (Gosling et al., 2003) and self-efficacy (Chen et al., 2001). This was to profile both experimental groups in terms of those characteristics found within the wider luck literature, namely that beliefs in being unlucky are positively associated with neuroticism and dysexecutive symptoms, and negatively associated with self-efficacy (Maltby et al., 2008; 2013). A series of Mann Whitney U comparisons demonstrated that 'unlucky' individuals scoring significantly higher on dysexecutive symptoms ($U = 3.88$ $p < .001$), neuroticism ($U = 18.80$, $p = .016$), and significantly lower on self-efficacy ($U = 4.00$, $p < .001$) than the control group.

For this experimental study, participants were paid 12.00 GBP. The study was approved by a University of Leicester Ethics Committee.

2.2. Experimental Measures.

The aim of the experimental measures was to record Event Related Potentials (ERPs) during a manual color-word Stroop test, based on previous Stroop ERP investigations (West & Alain, 1999; Badzakova-Trajkov et al., 2009), with modifications on the number of control stimuli.

Verbal stimuli for the Stroop test consisted of four color-words and four control non-color words. With the purpose of reducing potential cognitive confounds and bias among the verbal stimuli, the selection criterion for the control words was based and balanced according to the following linguistic characteristics from the English Lexicon Project website (Balota, et al.,

2007): (1) HAL Word Frequency, i.e., selecting words with similar frequency values from the Hyperspace Analogue to Language frequency forms corpus (Lund & Burgess, 1996); (2) Parts of Speech, i.e., selecting only adjectives and nouns; (3) Lexical Decision Task Behavioral Results, i.e. similar mean RTs (ms); (4) Grapheme-length, words that are matched by the same number of letters to their respective color-word; and (5) Syllables, all of the control words matched the number of syllables of their respective color-word.

2.3. Procedure

Participants were instructed that it was highly important during the recording to remain still, avoiding as much body movement as possible, to keep their eyes fixated at the centre of the screen, and to blink only when necessary and in between-trials when stimuli disappeared.

Subjects sat 57 cm from a computer screen, and were restricted by a head and chin rest installed between the chair and the screen to minimize head movements. Stimuli were presented at a resolution of 1,024 x 768 pixels on a 21-inch monitor with a vertical refresh rate of 100 Hz. The task and EEG triggering was constructed and generated by E-Prime 2.0 software (Psychological Software Tools, Pittsburgh, PA), running on a PC Pentium IV desktop computer. Responses were recorded with a Serial Response Box that features a 0 millisecond debounce period, which allows for a high precision on answer recording. Each trial started with 1000 msec of a white fixation cross (“+”) which was presented over a blank black background at the center of the screen. This was replaced with the target stimulus item shown for 1000 msec. A blank screen followed lasting 700 msec. Written feedback with a duration of 300 msec appeared at the center of the screen after incorrect (‘wrong’) and missing (‘missing’) responses. The speed of response timeframe remained unaltered for all trials; with a total duration for each trial being 3000 msec.

Participants were required to indicate the color font (red, blue, yellow or green) of the stimuli shown at the center of the screen via a button-box by pressing one of the four

corresponding colored buttons with the index and middle fingers of the right and left hands. All target stimuli were presented randomly with the font style ‘Courier New’ and a font size of 25 in bold style. At the beginning of the acquisition and practice phases, and before the start of each test block, a message appeared on the screen instructing the participants to press the space bar to begin the block of trials. After the space bar was pressed, the screen was blank for 2000 msec.

The total duration of each Stroop experimental session recording was 30 minutes, and consisted of three sequential phases:

- a) A color-to-key acquisition phase designed to establish a strong mapping between the stimulus colors and the correct response keys. This phase was presented in a single block of 96 trials with each of the four colors represented 24 times in a series of ‘X’s, equal in grapheme-length to the color’s name (‘xxx’ in red font, ‘xxxx’ in blue font, ‘xxxxx’ in green font, and ‘xxxxxx’ in yellow font).
- b) A practice phase consisting of 48 trials with the four types of stimuli conditions (congruent, incongruent, control congruent and control incongruent) also used on the upcoming phase. Stimuli in the congruent condition were colored-words that were presented in the color congruent to their meaning (e.g. ‘RED’ in red font). Stimuli in the incongruent condition were colored-words presented in any of the three colors that did not match their meaning (e.g. ‘RED’ in blue font). Stimuli in the control congruent condition were colored-words that were matched for their grapheme-length with the color words (e.g. ‘DOG’ in red font). Finally, stimuli in the control incongruent condition were colored-words that were mismatched for grapheme-length with the color words (e.g. ‘NORTH’ in red font). Each of these four conditions had 12 trials.
- c) A test phase (EEG recorded) that had the 4 condition trials balanced, with each presented 24 times in a single block, for a total of 96 trials per block. A brief break occurred in between blocks. Six blocks with a grand total of 576 trials were run in this phase. Stimuli in all phases were presented in a random order.

177 2.4. ERP Recording and analysis

178 Continuous EEG signals were recorded by a DC 32-channel amplifier (1-kHz sampling rate, 250
179 Hz high cut-off frequency; Brain Products Inc., Germany). The EEG activity was recorded via a
180 Waveguard elastic cap, containing 64 unshielded and sintered Ag-AgCl electrodes (CAP-
181 ANTWG64; ANT, Netherlands), with an electrode layout according to the international 10–5
182 electrode system. The following electrodes were used during the recording FP2, F3, FZ, F4, FC5,
183 FC1, FCZ, FC2, FC6, C3, CZ, C4, CP5, CP1, CP2, CP6, P7, P3, PZ, P4, P8, PO7, PO3, PO4,
184 PO8, O1, OZ, and O2. The right-earlobe electrode served as on-line reference. EEG waveforms
185 were re-referenced off-line to the average of the right- and the left-earlobe electrodes. Two
186 electrodes placed in a bipolar montage at approximately 1 cm from the outer canthi of both eyes
187 served to record the horizontal electrooculogram (HEOG). The vertical electrooculogram
188 (VEOG) and blinks were recorded from one electrode positioned below the right eye and Fp2
189 referenced to the right earlobe. Electrode impedance was kept below 5 K Ω . EEGs were epoched
190 from 200 ms pre-stimulus-onset to 1000 msec post-stimulus-onset. Each EEG epoch was
191 inspected off-line, and those with ocular artifacts (as indicated by HEOG activity exceeding ± 30
192 μ V and VEOG activity exceeding ± 80 μ V) were excluded from statistical analyses. Only ERP
193 data for trials with correct responses were analyzed, therefore artifacts from eye movements and
194 excessive noise were marked bad and discarded after a selective individual trial review of each
195 participant's data. To help remove slow and sustained shifts in voltage (from non-neural origin)
196 during data acquisition and reduce high-frequency noise, averaged ERPs were filtered using 0.05
197 Hz high-pass, 30 Hz low-pass and 50 Hz notch filters.

198 Mean amplitudes of ERP waveforms in the time window of 450 – 780 ms relative to a
199 200 ms pre-stimulus baseline were obtained for each subject and each of the four conditions. This
200 late ERP time window was chosen based on visual inspection and on relevant source-ERP color-
201 word Stroop research. In particular, a recent study supported a role only for late ACC activity

202 (520-680 ms), which is related to later aspects of response selection, in differentiating Stroop
203 conditions ([Silton et al., 2010](#)). ERP mean amplitudes were measured for a selected group of 4
204 electrodes in the fronto-central scalp region (Fz, FC1, FCz, FC2). This region was chosen
205 because it was likely to reveal the brain processing associated with cognitive control, in a
206 situation requiring effective inhibition of task-irrelevant distracting information ([Badzakova-
207 Trajkov, Barnett, Waldie, & Kirk, 2009](#)).

208 *2.5. Variable creation and statistical analyses*

209 A semiautomatic filtering operation of raw RT data was carried out by E-prime 2.0 in order to
210 remove extremely slow (anticipations) and fast (retardations) responses. Consistent with other
211 studies in the area (Fuggetta, 2006), an absolute exclusion criterion excluded RTs with less than
212 150 ms and greater than 3000 ms. The magnitudes of a variety of effects were computed and
213 analyzed for all analysis. These effects were obtained after computing three different
214 combinations of conditions and mean averages in the Stroop test, such as the facilitation effect
215 (control congruent condition minus congruent condition), interference effect (incongruent
216 condition minus control incongruent condition), and Stroop effect (incongruent condition minus
217 congruent condition). Mean Error (%), and Stroop condition effects (msec) for the correct trials
218 were only used in the reported Analysis of Variance (ANOVA). Three differential effects of the
219 factor condition on the two groups of participants were quantified on the basis of ERP mean
220 amplitudes from a particular region of interest (fronto-central area) using four electrodes' activity
221 (Fz, FC1, FCz, and FC2) during the time window of 450 – 780 ms post stimulus onset and
222 reading that were used in the report ANOVA. For each ANOVA, the sphericity assumption was
223 assessed with Mauchly's test. Greenhouse-Geisser epsilon adjustments for non-sphericity were
224 applied where appropriate. Post-hoc paired t-test were Bonferroni corrected for multiple
225 comparisons. For statistical testing, $p < .05$ was considered significant.

3. Results

The mean percentage of errors in the Stroop test was 2.572 ± 0.574 % with the mean percentage of errors for the facilitation effect $M = 0.31$ ($SD = .62$), interference effect $M = 3.17$ ($SD = 0.8$) and Stroop effect $M = 4.24$ ($SD = 1.5$). An ANOVA showed a significant effect for the conditions ($F_{(1.2, 21.6)} = 7.24, p = .002, \eta^2 = .29$), with post-hoc comparisons showing a significant difference between facilitation effect compared to the interference (.308% vs. 3.167%, $p = .033$), and Stroop effect (.308% vs. 4.242%, $p = .037$), meaning that participants in both groups had significantly more errors in the interference and Stroop conditions compared to that of the facilitation condition (Stroop and interference conditions represent the conflict). These effects are expected for each Stroop test. No significant main effect for group ($F_{(1, 18)} = 1.24, p = .280$), meaning both groups performed in a similar fashion across the conditions.

In terms of the experimental groups' performance on the Stroop test, descriptive statistics (mean, accuracy and reaction times) for the three Stroop condition effects in the two groups are shown in Table A. Mean RTs for the magnitudes of the three condition effects on the Stroop test for both groups was 78.15 ± 9.39 msec. An ANOVA for the mean RTs showed a main effect of 'Group' ($F_{(1, 18)} = 6.30, p = .022, \eta^2 = .26$). There was also a significant main factor "condition effect" ($F_{(1.2, 21.2)} = 55.9, p < .001, \eta^2 = .76$). Furthermore, there was a two-way interaction "condition effect by group" with $F_{(1.2, 21.2)} = 5.3, p = .027, \eta^2 = .23$. Post-hoc comparisons showed a significant difference between the 'unlucky' and control group for interference effect (68 vs. 132 ms, $p = .027$), and Stroop effect (90 vs. 163 ms, $p = .017$), but not in the facilitation effect (6 vs. 9 ms, $p = .766$). Means for each experimental group's RTs and accuracy are provided in Table A.

- Insert Table A here -

Figure A shows the Grand Average ERP's of the three main condition effects for both experimental groups. The time-window where the greater ERP activity occurred was in the late time window of 450 – 780 ms which showed a statistically significant main effect of 'group', with $F_{(1,18)} = 7.17$, $p = .022$, $\eta^2 = .285$. There was an overall effects significant difference with decreased ERP amplitudes for the control group compared with the 'unlucky' group (0.169 vs. -2.674 μV). More importantly, a significant three-way interaction 'Electrode * Condition effect * Group' was also found ($F_{(6,108)} = 2.21$, $p = .028$, $\eta^2 = .109$). Post-hoc comparisons of the significant 3-way interaction revealed a significant difference in the amplitude of the late ERPs between the 'unlucky' and control groups. Notably, there was a significant difference in the magnitude of interference effect for electrode Fz (0.202 vs. -3.788 μV), FC1 (-0.335 vs. -3.638 μV), FCZ (-0.078 vs. -3.663 μV), and FC2 (-0.324 vs. -3.752 μV), respectively (the study's region of interest). Moreover, there was a significant difference in the magnitude of the facilitation effect between individuals with no beliefs in being unlucky and individuals with beliefs in being unlucky for electrode Fz (0.608 vs. -2.951 μV) and FC1 (0.753 vs. -2.821 μV).

- Insert Figure A here -

4. Discussion

The first finding, consistent with Maltby et al. (2013), was that 'unlucky' individuals performed poorer in the Stroop and interference main effects when compared to the control group. The interference effect differences between groups is of great importance since it has been emphasized that the overall Stroop effect is not enough for an accurate conflict measure, and that it is necessary to have a comparison to a baseline neutral condition, with the interference effect, which measures an interference, or "cost", relative to a neutral condition, being the most reliable and robust component within the Stroop test (Henik & Salo 2004; Macleod, 1991). Electrophysiological results supported the role of late negative ERPs amplitude due to incongruent trials in differentiating 'unlucky' individuals from the control group in the magnitude of Stroop interference effect.

In the current study, we used a difference waveform (incongruent condition - control incongruent condition waveforms) in an attempt to isolate the processes specifically associated with the interference effect as in previous ERP studies ([Badzakova-Trajkov et al., 2009](#); [Markela-Lerenc et al., 2004](#)). Although the late time window chosen in the current investigation between 450 and 780 ms is an unusual epoch for Stroop-related effects, we were particularly interested to assess late-stage response-related processing, which we hypothesized being enhanced in the group of 'unlucky' individuals to compensate for their impairment in high-order attentional control processes. A recent study employed the source-waveform ERP mediation analysis ([Hayes, 2013](#)) and found that only late ACC activity (520-680 ms) was correlated with Stroop interference effect, distinguishing the waveforms between incongruent/congruent conditions (Silton et al., 2010). Thus the findings, as with previous studies, demonstrated that late-stage response-selection processes are specifically associated with ACC function ([Milham et al., 2003](#); [Silton et al., 2010](#)). Furthermore, an ERP study on color-word Stroop test (Liotti et al., 2000) found a significant difference in the incongruent relative to the congruent trials on a left temporoparietal cortex scalp

region during a late time window of 600 – 700 ms, supporting the role of late-stage response-selection processes in the Stroop interference effect.

Overall, both the indirect behavioral and direct electrophysiological results of Stroop interference effects of the present study can be interpreted when considering [Silton et al. \(2010\)](#) which integrated fMRI and ERP data to identify the time course of regional brain activity associated with top-down attentional control during the execution of a color-word Stroop test. Silton et al. demonstrated that the degree to which ACC influenced Stroop performance was depended on the level of earlier DLPFC activity. When DLPFC activity levels were high, there was little impact of ACC activity on Stroop performance, suggesting that, when DLPFC provides sufficient attentional control, ACC plays a smaller role in affecting overt performance. The finding that ACC activity was not critical for performance when DLPFC activity was high is also consistent with a prior study ([Milham et al., 2003](#)). A similar pattern of neurophysiological activity has been found in the current study in case of the individuals of the control group. The direct evidence of this interpretation is demonstrated by the minimal level of late ERP interference effect and adequate levels of behavioral performance for this group.

Furthermore, Silton et al., (2010) demonstrated that in the case of low DLPFC activity, there was a relatively high late ACC activity, which affected Stroop performance with a response pattern that involved slow RT responses. These results were consistent with the idea that ACC was compensating for the lack of top-down DLPFC control ([Silton et al., 2010](#)). The pattern of results for 'unlucky' individuals in the current ERP study echoes these previous results. Indeed the individuals exhibited a significantly increased response conflict with greater RTs and larger late negative response-related ERPs during incongruent trials, compared to the control group.

The increased facilitation effect exhibited only in ERPs, could be the result of an early, nonstrategic priming effect (word 'Red' in red font), or to a deficiency in the strategic allocation of attention that may result in word-reading errors (participants read the word rather than name

the color). In terms of the interference effect, both the RTs and ERP results complement each other quite well, given that it is the only one of the three main condition effects revealing significant differences between groups. A global interpretation of these results suggests that 'unlucky' individuals had a slower processing of the interference or “cost” relative to a baseline condition in the interference effect, translating to slower RTs and greater ERPs magnitude in this condition effect when compared to the control group. Furthermore, the control group had adequate attentional resources available to perform the task and quickly resolved the ‘conflict condition,’ and did not manifest a strong interference effect in the late ERPs. This suggests that the conflict resolutions of the Stroop test occurred earlier in the control group and later on in 'unlucky' individuals.

The findings cannot confirm, at a highly specific localization level, which structures of the brain were responsible for the different main effects found in this investigation, mainly due the limited number of channels (24) used in the electrophysiological data recording. However, these effects do suggest an anatomical basis. The electrodes region of interest (fronto-central scalp) for the current findings is in agreement with other ERP investigations that are able to reveal a consistent neuroanatomical basis, correlating the Stroop effect with strong activation in the DLPFC and especially the ACC (e.g. Carter & Van Veen, 2007; Botvinick et al., 1999). Taken together, these studies strongly support a conflict-monitoring hypothesis (Bush et al., 2000), which main premise identifies the ACC as the structure of the brain responsible for signalling the occurrence of conflicts in information processing, triggering compensatory adjustments in cognitive control. In a Stroop test this event can be specifically identified in the semantic conflict generated by the incongruent stimuli.

In summary, the findings provide physiological data that supports the Dysexecutive Luck hypothesis. They suggest that increased response conflict in the context of deficits executive functions of 'unlucky' individuals, have probably caused a need for increased late ACC activity

338 which was associated with lengthened RTs, and increase magnitude of late ERPs primarily
339 involved in response-related processes. This alteration of regional neural activity is also
340 supporting the concept introduced in previous studies that ACC was compensating for the lack of
341 DLPFC attentional control in the attempt to maintain adequate task performance.

342 Main Text Word Count: 4233

References

- 343
- 344 Badzakova-Trajkov, G., Barnett, K. J., Waldie, K. E., & Kirk, I. J. (2009). An ERP Investigation
- 345 of the Stroop test: The role of the cingulate in attentional allocation and conflict
- 346 resolution. *Brain Research, 1253*, 139 -148.
- 347 Balota, D.A., Yap, M. J., Cortese, M. J., Hutchison, K. A., Kessler, B., Loftis, B., Neely, J. H.,
- 348 Nelson, D. L., Simpson, G. B., & Treiman, R. (2007). The English Lexicon Project.
- 349 *Behavior Research Methods, 39*(3), 445-459.
- 350 Banich, M. T. (2009). Executive Function: The Search for an Integrated Account. *Current*
- 351 *Directions in Psychological Science, 18*, 89-94.
- 352 Botvinick, M., Nystrom, L. E., Fissell, K., Carter, C. S., & Cohen, J. D. (1999). Conflict
- 353 monitoring versus selection-for-action in anterior cingulate cortex. *Nature, 402*, 179-181.
- 354 Bush, G., Luu, P., & Posner, M. I. (2000). Cognitive and emotional influences in anterior
- 355 cingulate cortex. *Trends in cognitive sciences, 4*(6), 215-222.
- 356 Carter, C. S., & Van Veen, V. (2007). Anterior cingulate cortex and conflict detection: an update
- 357 of theory and data. *Cognitive, Affective, & Behavioral Neuroscience, 7*, 367-379.
- 358 Chen, G., Gully, S. M., & Eden, D. (2001). Validation of a new general self-efficacy scale.
- 359 *Organizational Research Methods, 4*, 62-83.
- 360 Damasio, A. R., Everitt, B. J., & Bishop, D. (1996). The somatic marker hypothesis and the
- 361 possible functions of the prefrontal cortex [and discussion].*Philosophical Transactions of*
- 362 *the Royal Society of London. Series B: Biological Sciences, 351*(1346), 1413-1420.
- 363 Darke, P. R., & Freedman, J. L. (1997). The belief in good luck scale. *Journal of Research in*
- 364 *Personality, 31*, 486-511.
- 365 Ellis, A. (1994). Reason and Emotion in Psychotherapy. NY: Birch Lane Press.
- 366 Fuggetta, G. P. (2006). Impairment of executive functions in boys with attention
- 367 deficit/hyperactivity disorder. *Child Neuropsychology, 12*, 1-21.

- 368 Gosling, S. D., Rentfrow, P. J., & Swann, W. B. Jr., (2003). A very brief measure of the big five
369 personality domains. *Journal of Research in Personality*, 37, 504–528.
- 370 Hayes, A. F. (2013). *Introduction to Mediation, Moderation, and Conditional Process Analysis*
371 The Guilford Press.
- 372 Henik, A., & Salo, R. (2004). Schizophrenia and the Stroop effect. *Behavioral and cognitive*
373 *neuroscience reviews*, 3, 42-59.
- 374 Jurado, M.B., & Rosselli, M. (2007). The elusive nature of executive functions: a review of our
375 current understanding. *Neuropsychological Review*, 17, 213–33.
- 376 Lansbergen, M. M., van Hell, E., & Kenemans, J. L. (2007). Impulsivity and conflict in the
377 Stroop test: An ERP study. *Journal of Psychophysiology*, 21, 33.
- 378 Li, X., Lu, Z., D'Argembeau, A., Ng, M., & Bechara, A. (2010). The Iowa Gambling Task in
379 fMRI images. *Human Brain Mapping*, 41, 410-423.
- 380 Liotti, M., Woldorff, M. G., Perez III, R., & Mayberg, H. S. (2000). An ERP study of the
381 temporal course of the Stroop color-word interference effect. *Neuropsychologia*, 38, 701-
382 711.
- 383 Lund, K., & Burgess, C. (1996). Producing high-dimensional semantic spaces from lexical co-
384 occurrence. *Behavior Research Methods*, 28, 203-208.
- 385 MacLeod, C. M. (1991). Half a century of research on the Stroop effect: an integrative review.
386 *Psychological Bulletin*, 109, 163.
- 387 Maltby, J., Day, L., Gill, P., Colley, A. & Wood, A. M. (2008). Beliefs around luck: Confirming
388 the empirical conceptualization of beliefs around luck and the development of the Darke
389 and Freedman beliefs around luck scale. *Personality and Individual Differences*, 45, 655–
390 660.
- 391 Maltby, J., Day, L., Pinto, D.P. & Hogan, R.A. & Wood, A.M. (2013). Beliefs in being unlucky
392 and deficits in executive functioning. *Consciousness and Cognition*, 22, 137-147.

- 393 Markela-Lerenc, J., Ille, N., Kaiser, S., Fiedler, P., Mundt, C., & Weisbrod, M. (2004). Prefrontal-
394 cingulate activation during executive control: which comes first? *Brain Res Cognitive*
395 *Brain Research*, 18, 278-287.
- 396 Milham, M. P., Banich, M. T., Claus, E. D., & Cohen, N. J. (2003). Practice-related effects
397 demonstrate complementary roles of anterior cingulate and prefrontal cortices in
398 attentional control. *Neuroimage*, 18, 483-493.
- 399 Milham, M. P., & Banich, M. T. (2005). Anterior cingulate cortex: an fMRI analysis of conflict
400 specificity and functional differentiation. *Human Brain Mapping*, 25, 328-335.
- 401 Milham, M. P., Erickson, K. I., Banich, M. T., Kramer, A. F., Webb, A., Wszalek, T., et al. (2002).
402 Attentional control in the aging brain: insights from an fMRI study of the stroop task.
403 *Brain Cognitoon*, 49, 277-296.
- 404 Miyake, A., Friedman, N.P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000).
405 The unity and diversity of executive functions and their contributions to complex “frontal
406 lobe” tasks: A latent variable analysis. *Cognitive Psychology*, 41, 49-100.
- 407 Oldfield, R. C. (1971). The assessment and analysis of handedness: the Edinburgh
408 inventory. *Neuropsychologia*, 9, 97-113.
- 409 Silton, R. L., Heller, W., Towers, D. N., Engels, A. S., Spielberg, J. M., Edgar, J. C., et al. (2010).
410 The time course of activity in dorsolateral prefrontal cortex and anterior cingulate cortex
411 during top-down attentional control. *NeuroImage*, 50(3), 1292-1302.
- 412 Spreen, O., Strauss, E., & Sherman, E. M. S. (2006). *A compendium of neuropsychological tests:*
413 *administration, norms, and commentary* (pp. 477–499). Oxford [Oxfordshire]: Oxford
414 University Press.
- 415 Wager, T. D., Jonides, J., & Reading, S. (2004). Neuroimaging studies of shifting attention: a
416 meta-analysis. *Neuroimage*, 22(4), 1679-1693.

417 West, R., & Alain, C. (1999). Event-related neural activity associated with the Stroop test.

418 *Cognitive Brain Research*, 8, 157-164.

419 Wilson, B. A., Alderman, N., Burgess, P. W., Emslie, H., & Evans, J. J. (1996). *BADS*:

420 *Behavioral Assessment of the Dysexecutive Syndrome*.

421 Wiseman, R., Harris, P., & Middleton, W. (1994). Luckiness and psi: An initial study. *Journal of*

422 *the Society for Psychical Research*, 60, 1-15.

423

Tables

424 TABLE A

425 *MEAN REACTION TIMES IN MILLISECONDS AND MEAN ACCURACY (%) FOR BOTH*
 426 *EXPERIMENTAL GROUPS.*

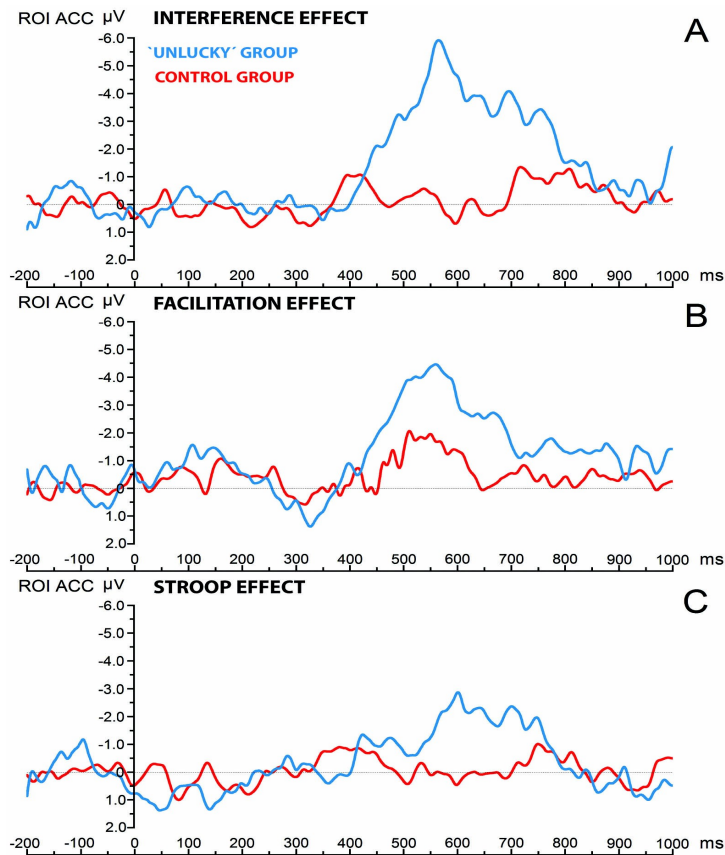
	MAIN CONDITION EFFECTS		
	INTERFERENCE (INCONGRUENT CONDITION - CONTROL INCONGRUENT CONDITION)	FACILITATION (CONTROL CONGRUENT CONDITION - CONGRUENT CONDITION)	STROOP (INCONGRUENT CONDITION - CONGRUENT CONDITION)
CONTROL GROUP			
REACTION TIME [MS] (SD)	67.77 (48.78)	6.00 (16.80)	90.01 (56.87)
ERRORS % (SD)	6.10 (1.13)	- 1.33 (0.88)	5.5 (1.48)
'UNLUCKY' GROUP			
REACTION TIMES (MS)	132.47(69.90)	9.14 (28.40)	163.50 (67.66)
ERRORS %	3.92 (4.55)	.77 (2.27)	4.70 (5.36)

427

Figures

428 FIGURE A

429 *GRAND AVERAGE ERP'S OF THE THREE MAIN CONDITION EFFECTS FOR BOTH STUDY*
 430 *GROUPS*



431 NOTES: ALL THE EFFECTS WERE OBTAINED FROM THE COMBINATION OF FOUR FRONTO-
 432 CENTRAL ELECTRODES (FZ, FC1, FCZ, AND FC2) DURING THE TIME WINDOW OF 450 – 780
 433 MSEC. THE GREATEST EFFECT WAS FOUND ON THE INTERFERENCE EFFECT (A).

434 **Acknowledgements**

435 The CONACYT in Mexico (National Council of Science and Technology) fully sponsors the
436 postgraduate research degree under which this study is completed.

437 **Authorship**

438 J. Maltby devised the original approach and developed the study concept. G. Fuggetta and J.
439 Martin del Campo designed the experimental design. Testing and data collection were performed
440 by J. Maltby for the first part of the study (Belief around Luck Scale screening), and G. Fuggetta
441 and J. Martin del Campo for the second part of the study (scales and EEG recording). J. Martin
442 del Campo and G. Fuggetta performed the data analysis and interpretation. J. Martin del Campo
443 drafted the manuscript, and G. Fuggetta and J. Maltby provided critical revisions, contributing
444 heavily on its writing. All authors approved the final version of the paper for submission.

Image of Grand Average ERP's

GRAND AVERAGE ERP'S OF THE THREE MAIN CONDITION EFFECTS FOR BOTH STUDY GROUPS

