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RESEARCH ARTICLE

Willingness towards cognitive engagement: a preliminary study based on a behavioural entropy approach

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Abstract
Faced with a novel task some people enthusiastically embark in it and work with determination, while others soon lose interest and progressively reduce their efforts. Although cognitive neuroscience has explored the behavioural and neural features of apathy, the why's and how's of positive engagement are only starting to be understood. Stemming from the observation that the left hemisphere is commonly associated to a proactive ('do something') disposition, we run a preliminary study exploring the possibility that individual variability in eagerness to engage in cognitive tasks could reflect a preferred left- or right-hemisphere functioning mode. We adapted a task based on response-independent reinforcement and used entropy to characterize the degree of involvement, diversification, and predictability of responses. Entropy was higher in women, who were overall more active, less dependent on instructions, and never reduced their engagement during the task. Conversely, men showed lower entropy, took longer pauses, and became significantly less active by the end of the allotted time, renewing their efforts mainly in response to negative incentives. These findings are discussed in the light of neurobiological data on gender differences in behaviour.

Keywords Individual differences · Entropy · Apathy · Initiative · Response strategy · Intention to act

Introduction

It has been said that a problem '*exists when a living organism has a goal but does not know how this goal is to be reached*' (Duncker 1945, p. 1). In daily life, this situation is extremely common. Every time, we deal with a novel task—be it cooking a new dish, assembling the ultimate IKEA dresser or solving a puzzle—we are in fact presented with a goal and the need to find a way to achieve it. It is common experience that people vary considerably in the way they approach problems. A flourishing line of research has shown that multiple cognitive strategies can be applied to problem solving (e.g., Johnson-Laird 2010; Johnson-Laird et al. 2015): for example, problems like the popular Sudoku puzzles are better dealt with by deductive reasoning (Lee et al. 2008), while complex 'series problems' rather take advantage of tactical approaches (Lee and Johnson-Laird 2013). Besides, people differ in their ways of thinking, so that some individuals appear to deviate from normative models of problem solving (cf. Stanovich and West 1998) adding to behavioural variability.

Differences also exist in availability or willingness to find solutions: Personality psychology describes ample variability in the tendency to "engage in and enjoy thinking" (need for cognition) (Cacioppo and Petty 1982) as well as in the perseverance and passion for long-term goals (grit) (Duckworth et al. 2007). Researches in the domain of social psychology further show that people vary in the degree of personal initiative they exhibit, i.e., in their attitude to be proactive, anticipating external events (rather than reacting to them) and persevering to achieve a goal, autonomously deciding what to do (Frese et al. 1997; Fay and Frese 2001). An interesting description of the variability in the way people approach situations has been provided by self-regulation theories in terms of assessment vs. locomotion attitudes

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(Kruglanski et al. 2000, 2012; Higgins 2003). Assessors would critically evaluate states in relation with alternatives, "*measuring, interpreting, or evaluating something through comparing one thing to another*" (Higgins et al. 2003, p. 297) to do just '*the right thing*' (Kruglanski et al. 2000). Conversely, locomotors would rather commit resources to reach a goal in a straightforward manner, without delays, continuously moving from one state to the next. Differently form assessors, high locomotors may always engage in the most accessible activity, irrespective of its direction, i.e., they would '*just do it*' (Kruglansky et al. 2000; Higgins et al. 2003). It is generally assumed that assessment and locomotion are independent psychological dimensions so that some individuals may be high in one or both dimensions or—in some situations—show a predominance of one orientation over the other (Kruglanski et al. 2000, 2012; Higgins 2003). In a similar way, it has been suggested that—possibly based on early life experiences—people can switch between a promotion and a prevention focus when dealing with novel states (Higgins 1998, 2000; Molden and Higgins 2008). A promotion attitude would be concerned with aspirations and accomplishments, creating a focus on achieving positive outcomes. Eagerness (approach) strategies would fit this focus, by maximizing gain pursuit even at the risk of committing errors. On the other hand, prevention orientation would be more concerned with safety, responsibilities and obligations, creating a focus on controlling negative outcomes. This would be better achieved by vigilance (or avoidance) strategies (cf. Higgins 2000), which can protect against such outcomes even at the risk of forgoing possible gains. In other words, promotion or prevention attitudes would lead individuals towards the type of behaviour that better suits their priorities, ensuring against committing those errors they most strenuously wish to avoid (e.g., either missing opportunities or securing against losses).

Surprisingly, neuroscience has only just started to explore the putative bases for such an extensive behavioural variability, focusing mainly on the detrimental effects of a lack of motivation or willingness towards cognitive effort. Recent studies, however, indicate that at the neural level, variability in connections between regions dealing with motivation to act and regions involved in action preparation could be responsible for individual differences in willingness to engage in effortful actions (*behavioural apathy*) (Bonnelle et al. 2016), thus providing a possible biological basis for the behavioural heterogeneity observed in healthy persons.

Current models of hemispheric specialization have described the left hemisphere as characterized by a '*do something*' disposition (Braun 2007), as opposed to a more 'conservative' attitude of the right hemisphere, which would be better suited to support freezing or avoidance behaviour (Vallortigara and Rogers 2005). The so-called Janus model of lateralized cognition (Dien 2008), for example, ascribes a *proactive*, future-oriented focus to the left hemisphere, which would be in line with its involvement in planning (e.g., Haaland et al. 2004) and hypothesis generation (e.g., Rausch 1977), as well as with the 'interpreter' role commonly ascribed to this hemisphere (Gazzaniga 1989, 1995; Metcalfe et al. 1995; Roser et al. 2005). It is likely that this functioning mode is integral to the system, as suggested by the fact that the left hemisphere of split-brain patients cannot avoid generating causal hypotheses even when there is no pattern to read (Wolford et al. 2000) or when the resulting explanations are inaccurate or bizarre (e.g., Gazzaniga 2000). On the other hand, it is generally agreed that right-hemisphere cognitive modules process global information (e.g., Robertson and Lamb 1991a; Robertson et al. 1991b), integrating "*ongoing strands of information into a single unitary view of the past*" (Dien 2008, p. 305). Such a reactive, past-oriented, focus would aptly serve the right-hemisphere's role in vigilance (Posner and Petersen 1990) and novelty detection (e.g., Stevens et al. 2005), as well as its involvement in inhibitory and braking responses (Aron et al.2014). Taken together, these findings seem to suggest that right-hemisphere's modules associate with cautious and conservative reasoning (Marinsek et al. 2014), promoting a withdrawal-related behaviour that minimizes risk-taking **AQ1** (e.g., Gianotti et al. 2009), while cognitive modules in the left hemisphere would rather activate mentation and support proactive behaviour (cf. 'freeze and recoup' vs. 'do something', Braun 2007). In line with this hypothesis, it has been found that approach-motivated people, i.e., individuals showing a drive to achieve positive outcomes, present with a right-oriented bias, as would be predicted by a prevalent left-hemisphere involvement (Harmon-Jones 2003; Nash et al. 2010; Roskes et al. 2011). Similarly, a meta-analysis examining the neural bases of divergent thinking—a cognitive process that implies generation of multiple, original, creative responses to a problem (Beaty et al. 2014; Heilman 2016) while inhibiting unoriginal, interfering ideas that could prevent 'illumination' to emerge (Heilman 2016)—has shown activations predominantly distributed to the left hemisphere (Dietrich and Kanso 2010; Gonen-Yaacovi et al. 2013), and coherently involving brain regions associated with reasoning and executive functions (e.g., inferior frontal gyrus and posterior parietal cortex).

In recent years, it has become increasingly clear that in spite of the similarities that emerge between genders (see Hyde 2014, 2016 for a review), a significant variability exists in the way men and women attain comparable results in a variety of tasks. For example, research on mental rotation shows that men prefer a holistic strategy, while women rather adopt an analytic approach to reach the same goal (e.g., Jordan et al. 2002; Geiser et al. 2006; Heil and Jansen-Osmann 2008; Olsen et al. 2013). Similarly, in classic planning tasks—such as the Tower of London—success is achieved by relying on visual imagery in males and on executive functions in females (Boghi et al. 2006). In emotion recognition tasks, men are assumed to rely on perceptual analysis and reasoning, whereas women depend on emotional contagion and affective responsiveness (Derntl et al. 2010). Regardless of the domain, differences seem to exist also in the way men and women generally approach cognitive tasks. A recent study showed that when left in an unadorned room with the instruction to entertain themselves with their thoughts, a conspicuous part of male participants (67%)—but only a fraction of females (25%)—preferred to engage in the unpleasant activity of self-administering electric shocks rather than simply remaining alone with their thoughts (Wilson et al. 2014). This finding was ascribed to higher tendency in sensation seeking for men (Roberti 2004), but it cannot be excluded that it simply reflects individual variability in readiness to engage in thought-based activity or, alternatively, a progressive loss of motivation to perform the 'thinking' task. Indeed, boredom was found to elicit a similar behaviour in a group of participants required to watch for a full hour the repeated presentation of the same 83 s video-clip (Nederkoorn et al. 2016).

Several studies indicate that females exhibit greater left-hemisphere dominance than males (who would rather show stronger right-hemisphere reliance), possibly as a consequence of the role that steroid hormones play in regulating functional cortical asymmetries (Wisniewski 1998; Cahill 2006). Hence, the renowned 'women left, men right' distinction (Njemanze 2005; Cahill 2006) would predict some gender differences in willingness towards cognitive engagement, with a female advantage for this trait. To test this hypothesis, we studied individual attitudes towards cognitive engagement in men and women by means of a reward-independent reinforcement paradigm. This type of paradigm, which has been successfully applied to both animals (Skinner 1948) and humans (Ono 1987; Wagner and Morris 1987; Ninness and Ninness 1999; Vyse 1991), presents participants with a fictitious problem and automatically provides reinforcement cues in a pseudo-random fashion. The neutral setup allows excluding possible confounds due to problem-solving styles, which are expected to emerge if the goal is actually attainable.

A group of healthy volunteers were shown a counter and a response pad containing four white and four-coloured buttons, and were asked to make the highest score possible. No instructions were given apart from mentioning that only the coloured buttons were functioning and that the system would automatically stop working after a quarter of an hour. Unbeknownst to participants, the counter automatically added one point at pseudo-randomly distributed intervals and data were actually recorded from all buttons. To explore proactive behaviour, we collected a series of descriptive measures, such as activity/inactivity rate, whether and how the fictitious contingencies were exploited, and whether participants attempted uninstructed approaches to the task. In addition, to capture variability in participants' approach to the task, we borrowed from general physics the concept of entropy. Entropy is a dimensionless quantity that describes the tendency of a system to drift towards a state of disorder. As such, it provides a quantitative index of the randomness and complexity in the system. Higher entropy implies increased disorder and randomness, while lower entropy describes increased predictability and lower complexity. In the neuroscience domain, this function has been previously applied to quantify the degree of irregularity in postural sway patterns (Manor et al. 2010), ageing and disease-related decline (Sokunbi et al. 2011), and neurodynamics of consciousness states (Carhart-Harris et al. 2014). Here, entropy was used to capture the degree of complexity/predictability of the pattern of activity produced by each participant during the task: the higher the entropy, the more diversified and changeable the pattern of interaction with the keyboard. The lower the entropy, the more stereotyped and fixed the strategy applied.

Materials and methods

Participants

Thirty healthy participants (15 females; mean age 24 ± 2.8 years; education 16 ± 2.2 years) were recruited among students and personnel working in the Lyon hospital area. Sample size was established based on the previous studies applying this type of paradigm (Ono 1987; Wagner and Morris 1987; Ninness and Ninness 1999; Vyse 1991). Separate t tests were used to verify that participants in the male and female groups did not differ in terms of age (f: 23.5 ± 3.1, m: 23.8 ± 2.6, $t = -0.315$, $p = 0.75$) and education (f: 15.8 ± 1.8, m: 15.3 ± 2.7, $t = 0.546$, $p = 0.59$). In each group about 2/3 of participants were students, the rest were mid-level employees. All were right handed except for one female, who was left-handed. To gain a brief insight in the participants' psychological attitudes, after the experiment they completed three scales exploring perceived level of anxiety (Zung Self Rating Anxiety Scale, Zung 1965), impulsiveness (Barratt Impulsiveness Scale, Baylé et al. 2000), and locus of control (Levenson Locus of Control Scale, Loas et al. 1994). Separate t tests were used to verify that no differences emerged between male and female participants on these traits (Zung scale, f: 36 ± 7, m: 36 ± 4, $t = 0.0003$, $p = 0.99$; Barratt, f: 60 ± 7, m: 65 ± 4, $t = -1.470$, $p = 0.17$; Levenson, Internal f: 29 ± 6, m: 29 ± 5, $t = 0.172$, $p = 0.86$; Chance f: 15 ± 6, m: 17 ± 4, $t = -0.561$, $p = 0.58$; Powerful Others f: 15 ± 6, m: 18 ± 6, $t = -0.896$, $p = 0.38$).

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All participants were naive as to the purpose of the experiment and provided informed consent before performing the task, in agreement with the declaration of Helsinki and local ethical guidelines for behavioural non-invasive studies.

Procedure

Paradigm was derived from the one used to assess the effects of response-independent scheduling of reinforcement in animals (Skinner 1948) and humans (Ono 1987; Wagner and Morris 1987; Ninness and Ninness 1999; Vyse 1991). In a quiet room, participants were shown a counter set to zero and a response pad (Fig. 1a). Instructions were limited to indication of the goal (making a high score), time limit (a quarter of an hour), and the information that only the coloured buttons were active. They could use both hands to respond. Unbeknownst to participants, the counter automatically added one point to the score at pseudo-randomly distributed intervals (30 s or 60 s) regardless of activity from the participant (Fig. 1b). In addition, after 10 min (i.e., 2/3 of the allotted time, time of subtraction: TS), the counter removed one point from the obtained score, disrupting the additive routine. The point was re-assigned at the next counter movement and the additive routine re-established for the last 5 min of the task. In spite of what said to participants, activity on all buttons was recorded. Participants performed the task individually and were alone in the room during the experiment. One experimenter monitored their activity during the task through a hidden window. Participants were informed of the disguised observation soon after the end of the experiment. When finished, participants were debriefed on their final score and asked how they had solved the task.

Data collection and analyses

Participants' responses were collected throughout the entire session. For the purpose of analyses, we focused on three 60 s windows, hereafter labelled T1 (from attribution of point1 to

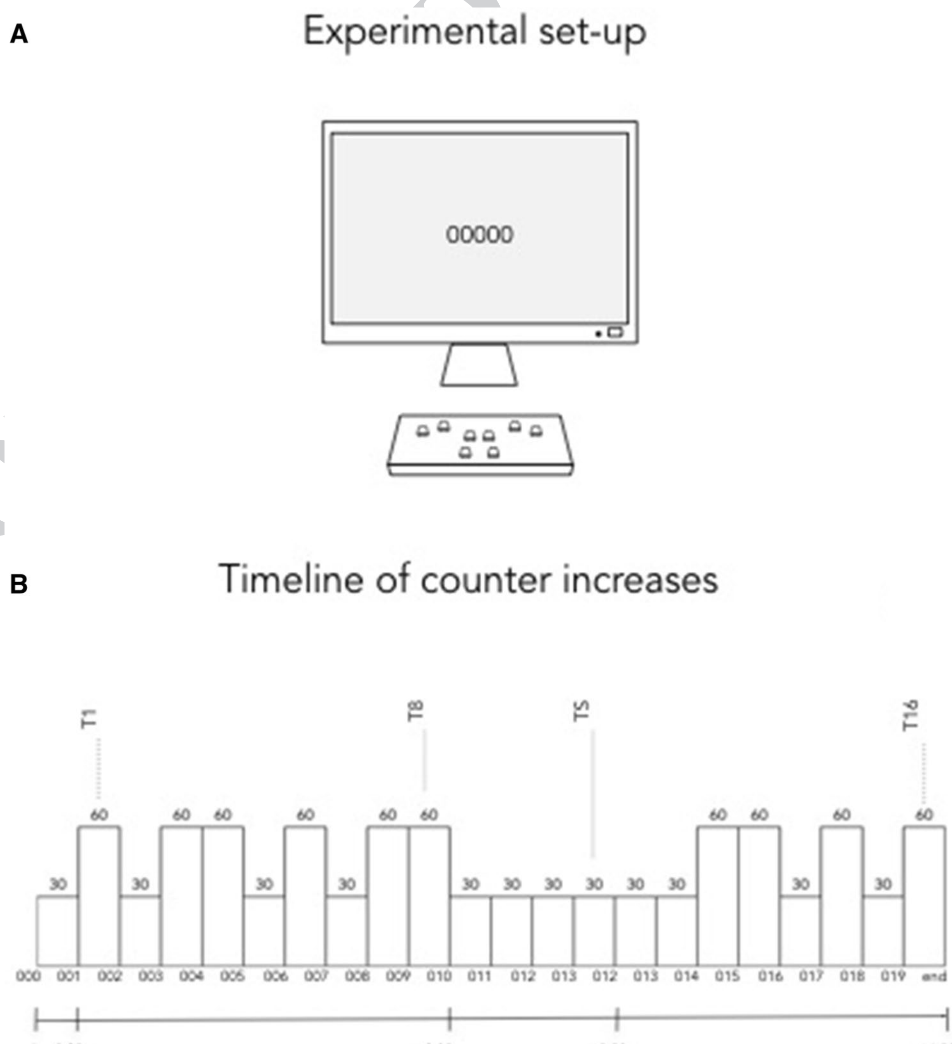

Fig. 1 **a** Schematic representation of the setup. Participants sat facing a counter initially set to 00000. Their task was to increase the score and—to do it—they had a response pad (with 4 coloured and 4 white buttons) and a quarter of an hour. They were told that only the coloured buttons had been activated. **b** Timeline of point attribution. Regardless of participants' activity, the score increased automatically in 30 s–60 s steps. Analysed time windows were the following. T1: from 1st to 2nd point (60 s); T8: halfway through the task (60 s); TS: interval after subtraction of one point (30 s); T16: last minute of the task (60 s)

point2), T8 (halfway through the task), and T16 (last minute) (Fig. 1b). In addition, for measures that required a database spanning across longer durations (e.g., overall inactivity rate, see below), we either analysed the duration of the entire session or divided the experiment in two parts of equal duration (8 min). Five basic behavioural measures were computed and analysed: activity rate, inactivity rate, response to point addition, response to point loss, and use of uninstructed buttons. In addition, we computed entropy to obtain a more comprehensive quantitative measure of variability in the participants' pattern of response across the task. Details on each measure are listed below.

(1) Activity rate, i.e., the total number of button pressing across the entire task (and the corresponding proportion for each time window) provided the most general measure of engagement. (2) Inactivity rate, i.e., the amount of time (sec) participants spent being idle, quantified the overall duration of pauses. This was computed for entire duration of the experimental session as the total time elapsed without participants producing any response between one point attribution and the next. For example, if in the entire session a participant did not press any button only between attribution of point 10 and 11, her overall inactivity rate would be 30 s (see Fig. 1b). (3) Response to point addition, i.e., the number of times participants immediately re-used the button they had pressed right before the counter granted one point, describes some degree of action monitoring and provided a measure of the tendency to respond to apparent causation. It was separately computed for the 1st and 2nd half of the task, the maximum attainable score being 10 (i.e., the number of counter changes in each half of the task). (4) Reaction to point loss (TS in Fig. 1B), i.e., the percentage change in activity following the one point loss was used to quantify responses to the one occasion in which the counter worked backwards. This was computed by estimating the percentage difference in activity between the time window that followed point loss as compared to the time window preceding it. (5) Use of uninstructed buttons, i.e., the percentage of white buttons pressed by each participant in each representative time window was used to quantify likelihood of departing from guidelines and experimenting novel approaches to achieve the goal.

In addition to these measures, we also computed (6) entropy, i.e., a measure of the uncertainty inherent to the distribution of a variable, which was used to quantify the degree of disorder in the pattern of button presses, thus providing an objective measure of how diversified and changeable the pattern of interaction with the keyboard could be. Specifically, joint entropy (H) describes the joint distribution of a pair of discrete random variables *x* and *y*, according to the formula:

$$H(X, Y) = \sum_{y \in Y} \sum_{x \in I} p(x, y) \log (p(x, y)),$$

where *H* relative to the T1–T8 (1st half of the task) and T8–T16 interval (2nd half of the task) was used to infer how patterns varied across time, offering a description of whether participants persevered in searching for a way to increase the score throughout the entire task or reverted to a wait-and-see strategy. Finally, to provide a more traditional description of participants' interactions with the response board, we quantified the relative distribution of key presses during the task for the possible combinations of the four buttons, and grouped them according to the patterns that most consistently emerged.

For each measure, means and standard deviations (M, SD) were computed separately for the male and female participants. Due to partial loss of data from one male participant, current results refer to 29 volunteers. Differences between groups were assessed by means of Wilcoxon Matched Pairs test or Mann–Whitney test (based on findings from Shapiro–Wilk's *W* tests). Chi-square test was used to compare frequency of a given behaviour in male and female participants. Cohen's *d* (Cohen 1988) was used to measure the magnitude of gender differences, as recommended by the previous studies (Hyde 2014, 2016). Logistic regression was used to verify whether entropy affected likelihood that a given pattern of key presses belonged to a male or female participant. The binary dependent variable, i.e., gender, was coded so that 0 = female and 1 = male. The probability that the pattern belonged to a male or female participant was modelled as a function of the variable entropy (assumed to be a potential predictor of the participant's belonging in either group). Alpha level for statistical significance was set at 0.05. Bonferroni correction was applied to multiple comparisons if needed. Data analysis and entropy calculation were performed in MATLAB environment.

Results

All participants started the task as soon as the experimenter left the room. Typically, they used the right, dominant, hand to initiate the task, first pressing either the upper right (48%), or the upper left button (31%) (lower right button 14%, lower left 7%). This was true also for the one left-handed participant. Observational data further indicate that all participants used alternatively the right and left hand in the first half of the task, but most reverted to using mainly the dominant hand in the second half of the task. This behaviour was observed in both men and women. Means and standard deviation for the six computed measures are reported in Table 1.

Activity rate

In the 16 min of the experiment, participants produced on average 1648 button presses (Table 1). When the sampling

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Table 1 Main measures collected during the task

	All participants			Women			Men			*d*
	M	SD	Range	M	SD	Range	M	SD	Range	
Activity rate (N button pressed)	1648	1043	(324–4499)	1804	1053	(742–4499)	1481	1044	(324–3854)	
T1	113	72	(28–357)	116	78	(33–357)	109	67	(28–264)	0.52
T8	102	94	(0–339)	134	101	(4–339)	68	75	(0–225)	0.67
T16	79	84	(0–324)	85	83	(0–324)	73	88	(1–280)	0.04
Inactivity rate (duration in sec)	63	107	(0–540)	21	27	(0–90)	105	140	(0–540)	0.84
Resp. to point addition (prop.)	0.27	0.15	(0–0.7)	0.29	0.20	(0–0.7)	0.26	0.10	(0.1–0.5)	
1st half	0.25	0.17	(0–0.7)	0.29	0.22	(0–0.7)	0.21	0.11	(0–0.4)	0.46
2nd half	0.33	0.21	(0–0.8)	0.32	0.26	(0–0.8)	0.34	0.15	(0.2–0.7)	0.07
Resp. to point loss (% increase)	11	62	(–46 to 147)	6	63	(–46 to 147)	20	66	(– 32 to 142)	0.34
Entropy										
T1–T8	3.44	1.02	(2–5.37)	3.80	0.70	(2–5.37)	3.10	1.20	(0–4.07)	0.71
T8–T16	2.98	1.15	(0–3.92)	3.50	0.70	(2–4.54)	2.40	1.30	(0–3.93)	1.02

Mean values (M) and standard deviations (SD) for all participants. Cohen's *d* (Cohen 1988), which was used as a measure of the magnitude of gender differences, is reported in the rightmost column (see text for details)

windows are considered, activity rate was higher in the first (T1) compared to the last minute of the task (T16) for all participants ($Z = 2.02$, $p < 0.04$, $r = 0.38$). A drop in activity from the first to the middle time window (T8) was seen in men, although the difference just failed to reach significance ($Z = 1.85$, $p = 0.06$, $r = 0.49$). For the same time period, a slight, not significant ($p = 0.34$) activity increase emerged in women, who—at T8—were significantly more active than men ($U = 52$, $p < 0.02$, $r = 0.60$). In line with these findings, Cohen's d for activity at T8 was 0.67, indicating a moderate to large gender difference. Conversely, in the first and last minute of the task, Cohen's *d* was 0.52 and 0.04, respectively, suggesting a moderate to negligible gender difference.

Inactivity rate

Inactivity rate within the entire task was longer in men compared to women ($U = 49.5$, $p < 0.03$, $r = 0.28$) (Table 1). If the only female outlier (S23, inactivity rate = 450 s) is excluded from the analysis, Cohen's d for inactivity rate is 0.84, suggesting a large gender difference. In fact, 71% men (but only 53% of women) restrained from any activity at least once between one point addition and the next. Among participants that never took a break 64% were women [$\chi^2(1, N = 29) = 10.75$, $p < 0.005$). The first inactivity period occurred after 2 and 4.5 min in the male and female groups, respectively.

Response to point addition

When the counter added one point, all participants returned—at least once—on the button they had pressed right before the apparent gain. On average, this behaviour occurred on approx. one-third of counter changes (Table 1). In men, this behaviour was significantly more common in the 2nd half of the task ($Z = 2.19$, $p < 0.03$, $r = 0.59$]; conversely, in women, no difference emerged between the 1st and 2nd parts of the task ($p = 0.60$).

Reaction to point loss

Approx. 40% of men and 20% of women were idle in the 30 s preceding point loss; all of them resumed the task in the 30 s following point removal. The same was true for the three participants (2 men) for whom only 1–4 key presses were recorded prior to point loss. Among participants who had been active before point removal, 60% of men increased their activity rate, while half of the women actually reduced their activity, the other half either keeping it constant (25%) or increasing it (25%)[$\chi^2(1, N = 20) = 14.07$, $p < 0.001$] (Table 1).

Use of uninstructed buttons

Although none of the participants admitted to using the buttons described as "not active" by the instructions, 66% of them tried them at least once during the task. About one-third of these participants (mostly females) did so within the very first 30 s. In women in particular use of these buttons stably amounted to approx. 6% of total activity (T1 6%, T8 7%, T16 6%). In contrast, it was limited to 1% in male participants (T1 0%, T8 1% T16 1%). For this behaviour, Cohen's d indicates a moderate gender effect at T1 (0.52).

Entropy

Joint entropy was significantly higher in women compared to men (Fig. 2; Table 1) particularly in the second half of the task ($U = 51.5$, $p < 0.02$, $r = 0.43$), accounting for a more diversified pattern even when a significant part of the time had elapsed. Cohen's d relative to joint entropy was 1.02, testifying a strong gender difference in the pattern of activity produced in the second half of the task.

To support this observation, we used logistic regression to assess whether entropy scores affected likelihood that a given response pattern belonged to a man or a woman. The model correctly classified 86.6% of females and 57.1% of males (Max likelihood, final loss = 16.39, Chi-square = 7.40, $p < .0.006$; odds ratio for the classification matrix = 8.66, unit change = 0.32, −95%CL = 0.11, +95%CL = 0.93).

Differences in entropy appeared to be unrelated to basic non-cognitive measures. No significant correlation emerged between entropy and traits such as anxiety (Zung Self Rating Anxiety Scale, $r = 0.24$, $p = 0.37$, $n = 16$), impulsiveness (Barratt Impulsiveness Scale, $r = 0.44$, $p = 0.13$, $n = 13$), and locus of control (Levenson Locus of Control Scale, Internal subscale, $r = -0.24$, $p = 0.28$; Chance subscale $r = -0.01$, $p = .0.67$; Powerful Others subscales, $r = -0.21$, $p = 0.35$, $n = 22$).

Descriptive analysis of patterns of button presses

A descriptive survey on the relative use of the four instructed buttons further showed that men and women made an entirely different use of the keyboard. In Fig. 3, the relative distribution of key presses for the possible combinations of the four buttons is shown, grouped according to the most consistent patterns.

In detail, Fig. 3a shows the patterns that accounted for about 3/4 of the possible combinations of the four buttons. Their relative distribution is detailed in panel B: overall the most common patterns were sequential clockwise or counter-clockwise movements over the keyboard (35%) and sequential presses of the same key (27%), while other patterns were less frequent. Panel C further details this distribution separately for male and female participants in the two halves of the task. As can be seen, in the first half of the task, circular patterns were significantly more common in women than in men ($U = 66$, $p < 0.04$, $r = 0.32$), who rather opted for sequential presses of the same key (although the latter difference was not significant, $p > 0.05$).

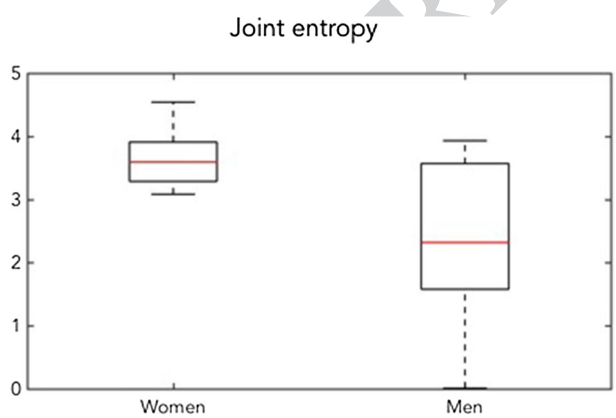

Fig. 2 Joint entropy relative to time windows T8–T16. Entropy describes the degree of disorder in the pattern of activity produced by participants. T8–T16 joint entropy informs on activity during the second half of the task (last 8 min). In the plot, the limits of each box represent the 25th and 75th percentiles, their relative distance the interquartile ranges. The red line is the sample median. Whiskers indicate adjacent values, i.e., the lowest and highest values. Entropy was significantly lower in men compared to women

Debriefing session

At the end of the experiment, participants were interviewed on the score obtained, and the way that they thought points had been attributed. More than a half of participants (71% of men, 53% of women) were positive that some method or rule existed to increment the score, and most admitted to have been unable to disclose it. Eight participants creatively elaborated on the alleged method to increase the score (see Table 2). The remaining participants correctly realized that the counter worked automatically and reported it. Interestingly, although the latter participants claimed that point attribution did not depend on their own activity, their behaviour did not significantly differ from responses of participants that believed they could influence counter changes. In fact, by the end of the task, although both activity rate (aware, $N = 11$: 36 ± 49; unaware, $N = 18$: 106 ± 91) and entropy (aware: 2.92 ± 0.71; unaware: 3.01 ± 1.37) were lower in the group that became aware of the automaticity, no significant difference emerged between the two groups (activity rate, $U = 57$, $p = 0.06$, $r = 0.35$; entropy, $U = 74.5$, $p = 0.27$, $r = 0.20$). While the absence of difference could depend on the small sample size, it is also possible that it reflects the fact that participants in the '*aware*' group continued to work on the keyboard either as a mean to entertain themselves (as most of them reported), or for reasons, they failed to overtly report, such as complying with task assignment, expectations about task rewards, beliefs about possible changes in the counter functioning, and so on. The finding that most participants, independently from their reported awareness, increased their activity after point loss could support this interpretation.

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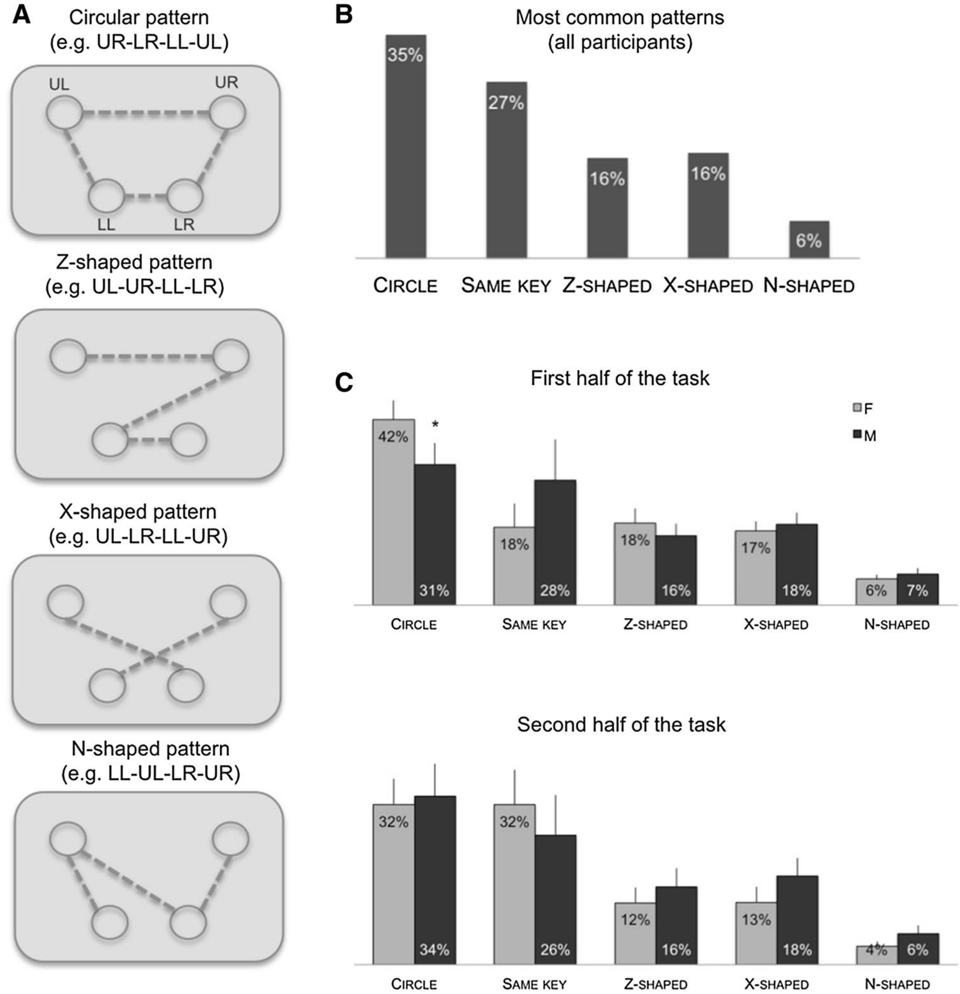

Fig. 3 Response patterns grouped according to task period and gender. **a** Characteristically shaped sequences of four consecutive key presses that were observed in the group of participants while engaged in the task. Patterns are presented according to their relative occurrence (i.e., upper panel referring to more frequently observed). **b** Percentages of patterns occurrence within all participants for the whole task; 'Same Key' refers to four consecutive presses of the same button, other labels as in **a**. **c** Percentages of patterns distribution split according to task period and gender: a significant female/male difference was found for the more frequent pattern in the first half of the task. F = females, M = males, *$p < 0.05$

Table 2 Debriefing session

ID		Response to the question: could you speculate on how the points were added?
P7	f	You had to press two or more buttons together to get a point
P12	f	You need to avoid doing the same thing twice, else you loose points
P17	f	The counter works on its own but if you find the right code you get a bonus. I realized it by pt 4 or 5
P6	m	It was an automatic system and you earned points by either not pressing the buttons or doing the same thing continuously
P11	m	The trick was not pressing the buttons. If you press, you loose points
P16	m	There was an automatic system but you still needed to keep pressing the buttons to earn points
P20	m	It works on its own. I noticed it between pt 5 and 10, but you still need to press the buttons else you loose points
P21	m	There was a shifting rule, which changed every time I disclosed it. Plus, you always needed to press some button else it penalized you

At the end of the task, participants were asked (1) the score they had obtained and (2) how they thought points were added. As the counter worked automatically, the final score was 19 for all participants, which they dutifully reported. With respect to question (2), 71% of men and 53% of women were positive that some method or rule existed to increment the score, and most admitted to have been unable to disclose it. Eight participants creatively elaborated on the alleged method to increase the score: transcription of their responses is reported below

Discussion

As nicely pointed out by Orne in 60 s, the assumption that the participant of an experiment is a passive responder to stimuli is difficult to justify (Orne 1962). Whenever people first engage in a novel task, a variety of factors (e.g., expectations, cognitive style, and personality traits) play a role in shaping the way that the goal is attained. While the detrimental effects of apathy are well known (cf. Vansteenkiste et al. 2004; Stanton and Carson 2015), until recently, little attention has been paid to the "positive" sides of effort in task engagement (Hill and Aita 2018). To our knowledge this issue, which is well known to social and experimental psychology, has been mainly explored qualitatively, via interviews and questionnaires. In this view, the present preliminary study provides a novel, quantitative measure of individual involvement in a cognitive task, and identifies a gender-modulated pattern that could be interpreted in terms of hemispheric asymmetries. In line with the observation that activity in the left hemisphere is associated with inferential causality operations (cf. Gazzaniga 1989, 1995; Metcalfe et al. 1995; Roser et al. 2005), divergent thinking (Dietrich and Kanso 2010; Gonen-Yaacovi et al. 2013), and a generally proactive disposition (Braun 2007; Dien 2008; Tops et al. 2017), we found individual differences in eagerness to engage in cognitive tasks that could reflect a preferred left- or right-hemisphere functioning mode.

The reactive, wait-and-see attitude showed by male participants, especially when it became progressively clear that proactive behaviour was not paying, was the most ergonomically successful strategy, since participants' activity did not affect point attribution. This finding is reminiscent of observations showing that men typically outperform women at the Iowa Gambling Task (IGT). Guessing tasks akin to the IGT are usually solved either by maximizing or by a frequency matching strategy (Estes 1961; Hinson and Staddon 1983): the former leads to constantly choosing the alternative that maximises probability of reward, while the latter implies searching for the frequency pattern that allows predicting the next item. Men are assumed to acquire information more globally compared to women, in line with a more right-hemisphere-oriented functioning (Andreano and Cahill 2009; Cahill 2006). It has been proposed that IGT performance becomes progressively more dependent upon right hemispheric functioning (van den Bos et al. 2013), which could justify the male advantage at the gambling tasks. In the present experiment, men's right-oriented functioning could similarly have supported the longer pauses of inactivity recorded in the second part of the task as well as the lower entropy, which signals a shift towards an ordered—possibly repetitive—pattern of activity. Conversely, a more protracted reliance on a left-hemisphere-oriented, analytic mode of functioning, may have led female participants to explore all possible combinations, thus accounting for their higher activity rate and higher entropy. This increased engagement would be in line with models that describe the left hemisphere as characterized by a '*do something*' disposition (Braun 2007), as opposed to a more '*conservative*' attitude of the right hemisphere, which would be better suited to support freezing or avoidance behaviour (Vallortigara and Rogers 2005). The present findings also fit nicely within a recent conceptual framework proposed by Tops and co-workers (Tops et al. 2017) that describes behavioural control in terms of predictive (i.e., based on internal prediction) and reactive (i.e., guided by external stimuli) systems. The Predictive and Reactive Control Systems model theory (PARCS) accounts for individual differences in appraising and coping with challenges based on the activity of a distributed brain network in which laterality is coupled with a dorsal–ventral functional axis (Tops et al. 2017). This functional network would respond to environmental variability by providing individuals with systems enabling control within unpredictable, unstable and novel situations or stable, predictable, and familiar contexts. Reactive control would serve behaviours driven by stimuli and environmental cues, ensuring that responses are always sufficient through increased and undifferentiated activation. Conversely, predictive control would be internally organized according to model-based predictions and expectancies derived from prior experiences, allowing slowly learning by updating existing models, thanks to predictability of a stable environment. At the neural level, reactive and proactive coping would preferentially engage the right vs. the left hemisphere, and would be further modulated by lateralized dorsal and ventral corticolimbic systems, respectively. In this view, one could speculate that the protracted engagement of a right-hemisphere, reactive-oriented control system justifies the progressive demotivation observed in male participants in the present experiment, which would reflect the fact that physiological costs of undifferentiated activation cannot be indefinitely sustained.

Use of uninstructed buttons also differed between male and female participants, being more marked in the latter. The present paradigm does not allow inferring the reasons for this behaviour, which could imply either increased creativity or a different attitude towards rules. Actually, previous studies suggest that both traits could be involved. A study on variation in divergent thinking and creativity in women has shown that these abilities are enhanced during the pre-ovulatory phase, i.e., when oestrogen concentration is maximal. Conversely, tendency for stereotyped behaviour is increased during the menses when this hormone's level is minimal (Krug et al. 1994). Although we did not check for this parameter in female participants, this observation could point to the possibility that increased creativity played a role on the choice to additionally explore inactive buttons. More consistently, it has been reported that—when faced with moral dilemmas or judgments—women and men adopt different evaluation schemes (Gilligan 1977). While females show a strong care-based orientation, males rather work on justice-based parameters, which capitalize on rule-abidingness and maintenance of order (Harenski et al. 2008). This difference could account for a stronger 'expertise' of women in interpersonal relationships and of men in intergroup relations (Koscik et al. 2010). Here, a differential approach towards rules and obligations might have played a role in the different choice of departing from instructions and experimenting on the possible functioning of the additional buttons.

The current study addresses a relatively unexplored topic and should be considered as preliminary, because it presents two major limitations. First, the sample size is comparatively small for a gender differences' study, which suggests that conclusions should be taken with care: further studies should be run to confirm the present observations on larger groups of participants. Second, in interpreting the present findings, it should be recalled that we only explored a limited set of the variables that could play a role in variability in willingness to engage in cognitive activity. An alternative account for the differential behaviour of participants in the present experiment could in fact be found within the framework of self-regulation theories (Higgins 1998, 2000, 2003; Kruglanski et al. 2000, 2012; Molden and Higgins 2008). In this view, it could be assumed that male and female participants oscillated between a more pronounced assessment/prevention focus and a more pronounced locomotion/promotion, respectively. The longer pauses and reduced use of uninstructed buttons in males could be viewed as an indication of their attempt to do '*the right thing*', preventing possible negative outcomes. The higher entropy recorded in the pattern of activity of female participants could instead reflect keenness to accomplish the goal, ensuring that no opportunities for it are missed, even if this could mean taking the risk to commit errors. In keeping with these theories, men would appear to have favored a vigilance/avoidance strategy, while women would have rather chosen an approach/eagerness strategy to solve the current task. Further studies directly exploring possible relations with these personality traits could provide a more definite description.

Moreover, it could also be that recreational habits, such as experience in video gaming activity and/or competitiveness in these games, may have affected participants' behaviour at a task like the one selected here. In fact, even if this was constructed as a response-independent reinforcement paradigm, participants were actually given a goal to pursue (achieve a high score) and this could have differently impacted on individuals used vs. not used to play computer games. However, according to a recent review on the topic (Reid 2012), videogame players are mostly men, and male players are reported to play longer hours than females. Accordingly, one could have expected increased motivation linked to this type of habit to eventually boost activity mainly in the male group, which does not seem to be reflected in the present results.

It could also be noted that besides possibly promoting competitiveness—the task used here also implied allocation of mental processes that participants could have rather chosen to direct towards other activities than its solution. The so-called opportunity cost model (Kurzban et al. 2013) suggests that given the impossibility of running all tasks at once, the brain must prioritize among possible computations by assigning costs and benefits to the candidate options. Within this framework, the costs of allocating mental processes to a task would equal the value of the next-best use of those mental processes. Rewards, expected utility and benefits that would be foregone by engaging in one task would thus provide a measure of the mental effort involved, eventually (though not necessarily) leading to ceasing one activity in favor of another. Although here, we did not collect measures of subjectively perceived mental effort, it could be speculated that participants' behaviour partly reflected the opportunity costs of continuing vs. stopping pursuing the indicated goal. Namely, rather than assuming a lateralization hypothesis (i.e., a conservative right-hemisphere disposition), it could be that participants' who gave up searching for a pattern in the second half of the task may have in fact deemed the cognitive effort involved as overriding potential benefits, especially since the experimenter was not in the room (thus making social disapproval less of an issue) (e.g., Kurzban et al. 2013).

In any case, whatever the reading one takes of the present findings, they indicate for female participants a certain degree of proactivity, persistence and self-starting attitude, which—although compatible with a more left-hemisphere-oriented functioning mode—may be viewed as somewhat unexpected with respect to what proposed by social stereotypes. Behaviourally, these traits have been typically associated with the concept of personal initiative, i.e., the readiness to initiate actions and assess things independently. When compared to findings from other domains, which commonly describe more personal initiative in men (Koellinger et al. 2013; De Pater et al. 2009; Jackson et al. 2001; Wasserman and Richmond-Abbott 2005; Fallows 2005), our results may in fact indicate a possible incongruity. While the dimension of the present sample could account for this finding, it is also possible that the reason for the discrepancy lies in the fact that the previous studies explored initiative mostly from a social perspective, namely, within strongly

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biased contexts. Work-related gender stereotypes indicate that traits such as entrepreneurship and business-like attitudes are more positively associated with masculine than with feminine traits (Ahl 2006). According to the Stereotype Threat Theory (Steele 1992, 1997), stereotypes strongly affect the behaviour of the individuals towards whom prejudices are directed. Recent studies have shown that proactive people are deeply affected by stereotypes—being extremely sensitive to the impressions others have of them (Dutton et al. 1997; Crant 2000; Gupta and Bhawe 2007). In a similar way, it is possible that social stereotypes impact on women's behaviour, smothering the proactive attitude that emerges in the neutral task applied here. Indeed, both boys and girls acquire gender stereotypes from an early age, as a longitudinal study on Disney Princess engagements has recently demonstrated (Coyne et al. 2016). We can thus speculate that in contexts subjected to gender stereotypes, reports of women's low personal initiative may in fact represent the epiphenomenon of some form of stereotype threat.

Although different problems require different mental operations, all solutions benefit from the drive motivating whoever embarks in a task. In this view, variability in attitudes towards cognitive engagement is likely to affect optimal performance as well as consistency across time, introducing a relatively undetermined source of variability. On this respect, the present findings suggest a note of caution as to the use of gender-unbalanced samples in experimental tasks. With few exceptions, studies in cognitive neuroscience are conducted on a mixed population of male and female participants. Data from the two groups are pooled to obtain an image of how the "average brain" works. However, men and women are known to rely on different strategies when solving cognitive and affective tasks (Jordan et al. 2002; Geiser et al. 2006; Heil and Jansen-Osmann 2008; Olsen et al. 2013; Boghi et al. 2006; Derntl et al. 2010; Stoet 2016), indicating that averaging may inevitably cancel out information and that gender-unbalanced samples produce biased results (cf. Bell et al. 2006). The novel finding here is that even in a fictitious cognitive task—men and women showed different attitudes towards cognitive engagement. Women emerged as enthusiastic participants, likely to attend to the task throughout the allotted time, but less eager to believe a cover story and keen on checking for themselves about efficacy of instructions to optimize performance. Conversely, men could be relied upon complying with rules but—as time went by—seemed to become progressively less involved with the task. These idiosyncrasies should be considered when recruiting volunteers for studies in cognitive neuroscience.

In conclusion, results of this preliminary study highlight a gender modulation in the strategy adopted as well as in the cognitive approach to a novel task, the neutral setup directly allowing for individual dispositions to emerge. Clustering of performances according to gender fits well with previous research focussing on creative thinking demonstrating that men and women differently use their cognitive potential in contexts in which finding ideas for a solution is involved (Abraham et al. 2014).

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures were in accordance with the ethical standards of the local committee and with the 1964 Helsinki declaration and its later amendments.

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