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## **RUNNING HEAD: PROACTIVE CONTROL AND SOCIAL PRESENCE**

Choking under experimenter's presence: impact on proactive control and practical  
consequences for psychological science

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**Abstract:**

Evidence accumulated for more than a century on audience effects shows that being watched by others typically impairs performance on difficult tasks. However, recent research under the label of « choking under pressure » suggests that this performance impairment is, ironically, specific to the individuals who are the most qualified to succeed—those with a high working memory capacity (WMC). Here, we predicted and found that being watched by evaluative others such as the experimenter undermines proactive control on which the high-WMC individuals rely the more. These results refine our understanding of both audience and choking effects, and lead to innovative, practical recommendations for psychological science.

**Keywords:** choking, experimenter presence, working-memory, proactive control, social facilitation

## **Introduction**

The presence of observers typically impairs performance on difficult or poorly learned tasks, a phenomenon thought to be due to the energization of dominant but incorrect responses (Cottrell, 1972; Zajonc, 1965; for reviews see Bond & Titus, 1983; Geen & Gange, 1977). More recent results in humans and nonhuman primates suggest that being watched by others also interferes with executive control required to perform well on difficult tasks (Belletier & Camos, 2018; Belletier et al., 2015; Conty, Gimmig, Belletier, George & Huguet, 2010; Huguet, Barbet, Belletier, Monteil & Fagot, 2014; Wagstaff, Wheatcroft, Brunas-Wagstaff, Blackmore, & Pilkington, 2008; Wühr & Huestegge, 2010; for a review see Belletier, Normand & Huguet, in press). Of particular interest here, Belletier et al. (2015) showed that the deleterious impact of evaluative observers on executive control (assessed via the Simon task—a popular tool for measuring executive control) is actually restricted to the individuals who are the most qualified to succeed, that is, those with a high working memory capacity (WMC). More generally, there is evidence that high-pressure situations reduce executive resources and cause high-WMC individuals to perform below their actual abilities, a phenomenon called choking under pressure (Beilock & Carr, 2005; for a review see Beilock 2010). Therefore, it may be that many of audience effects on difficult tasks actually reflect choking. Nonetheless, the reason why high-WMC individuals choke in the presence of an evaluative audience remains poorly understood.

According to Braver's (2012) dual-mechanism of control theory, executive control can be achieved either through a proactive or a reactive mode. Proactive control involves active maintenance of information to prepare and anticipate a given response (the action being goal-driven), whereas reactive control involves a later recruitment of attention (the action being event-driven). There is evidence that high-WMC individuals rely more on proactive control than their low-WMC counterparts (Redick & Engle, 2011; Redick, 2014; Richmond, Redick

& Braver, 2015). Proactive control is actually more efficient than reactive control for difficult tasks and thus accounts for the overall cognitive superiority of high-WMC individuals.

Here, we tested whether the reduction of executive control in the high-WMC individuals faced with an evaluative audience (Belletier et al., 2015) can be replicated with a task specifically designed to assess proactive control, a question left unanswered in our previous research and largely neglected in the myriad of works on audience and choking effects.

## **Method**

**Participants and design.** Eighty young adults (62 females, 18 males;  $M_{\text{age}} = 19.3$ ,  $SD_{\text{age}} = 1.83$ ) participated in the study in exchange for course-credit. They all had corrected-to-normal vision. A power analysis using g-power (Faul, Erdfelder, Lang & Buchner, 2007) for a linear multiple regression analysis (including three predictors) with an alpha level of .05, a desired power of .80, and  $f^2 = .15$  (a medium size effect, see Belletier et al., 2015) indicated a needed sample size of 77 participants. The ethical approval was given by the "comité de protection de la personne, 6th committee of the region Auvergne-Rhône-Alpes", under the number IRB00008526.

## **Materials and procedure.**

*Working Memory Capacity.* We first measured participants' WMC using a computer-based version of the classic Reading Span Task (RSPAN; Daneman & Carpenter, 1980). All participants were left alone in the experimental room. Each display included a meaningful or meaningless sentence that the participants read while verifying whether it made sense (e.g., "We were fifty miles out at sea before we lost sight of land"), followed by a to-be-remembered letter. The sentences (each composed of 12-17 words,  $M = 14.4$  words,  $SD = 1.2$ ) were taken from the French version of the RSPAN (Desmette, Hupet, Schelstraete, &

Van der Linden, 1995). Meaningless sentences were created by changing only one word (*miles to lawns* in the previous example). The set size ranged from three to seven sentence-letter problems per trial with 3 trials per set size for a total of 15 trials. At the end of each set, participants had to enter the sequence of the to-be-remembered letters in the correct order. This first measure lasted about 20 minutes, followed by a rest period of 3 minutes.

*Proactive control.* Participants were then introduced to a task called AXCP70, in which most of the trials require proactive control (Redick, 2014). This version of the task was the first to be used to investigate the superiority of the high WMC individuals over their low WMC counterparts regarding proactive control (Redick & Engle, 2011). In each trial, two letters, a cue and a probe, were presented one at a time on a computer display. Participants were instructed to detect the sequences in which the letter A was followed immediately by the letter X. Without sacrificing accuracy, they had to press as fast as possible a “target” button if the probe was X and the previous letter (the cue) was A, and a “non-target” button in any other cases. Half the participants used their right versus left hand to respond with the “target” and “non-target” button respectively, whereas the other half used the opposite response mapping. Each letter was displayed for 500 ms. The interstimulus (cue-probe) interval (ISI) was either short (1000 ms; 50% of the trials) or long (5000 ms; 50% of the trials), as also done by Redick and Engle (2011). In a way to maintain constant the overall duration of trials, the intertrial interval (ITI) was 5000 ms when the ISI was short, and the ITI was 1000 ms when the ISI was long. Long ISI has been shown to exacerbate the differences in terms of proactive control between patients and healthy participants (Braver, Satpute, Rush, Racine & Barch 2005). As we are the first ones to investigate the effect of social presence on proactive control, we manipulated ISI to explore whether these effects are more important in the long ISI condition, but this manipulation did not lead to specific predictions.

Seventy percent of trials were target trials (i.e., AX trials). On these trials, proactive control (active maintenance of the cue “A”) is more efficient than reactive control (late response based exclusively on the target “X”). The remaining 30% trials were non-target trials among which one third were BX trials (incorrect cue but correct probe), one third were AY trials (correct cue but incorrect probe), and the last third were BY trials (incorrect cue and incorrect probe). On the BX trials, proactive control (active maintenance of the incorrect cue “B”) is more efficient than reactive control (late response based on the correct target “X”), assuming that reactive control in this case leads to more errors because the incorrect cue was not maintained as such. On the AY trials, proactive control (active maintenance of the correct cue “A”) is *less* efficient than reactive control (late response based on the incorrect target “Y”), assuming that proactive control in this case leads to wrongly anticipate the correct probe. On the BY trials, proactive control (active maintenance of the incorrect cue “B”) makes no difference with reactive control (late response based on the incorrect target “Y”). Each experimental block of trials included 56 AX trials (28 short-ISI, 28 long-ISI), 8 AY trials (4 short-ISI, 4 long-ISI), 8 BX trials (4 short-ISI, 4 long-ISI), and 8 BY trials (4 short-ISI, 4 long-ISI). Cues and probes for non-target trials were randomly picked among the letters R, S, T and U. All types of trials were randomly presented. The task was run on a Dell PC using E-prime 2.3.

*Social presence.* After 15 practice trials alone in the experimental room, participants completed two experimental blocks (112 AX trials, 16 BX trials, 16 AY trials and 16 BY trials) while being randomly assigned to one of two social presence conditions. In the “alone” condition, the experimenter (who was one of the two female experimenters) left the experimental room before task completion. In the “experimenter presence” condition, the experimenter remained in the experimental room and was positioned opposite the participant so as not to see the participants’ ongoing task, but watched them 60% of the time; an efficient

social presence condition (see Huguet, Galvaing, Monteil and Dumas, 1999; Sharma, Booth, Brown & Huguet, 2010; Spatola et al., 2018, in press).

*Expectations.* Redick and Engle (2011) found that high-WMC individuals performed better than their low-WMC counterparts on AX and BX trials on which proactive control is required. However, the recent advances on audience and choking effects questions the superiority of the high-WMC individuals under the presence of evaluative observers. Here, we expected to replicate this superiority when the participants performed the AX-CPT in isolation, but not when being watched by an experimenter, i.e., an evaluative audience potentially leading to choking.

*Post-experimental questionnaires.* Self-reports of stress, evaluation feeling, discomfort and perceived difficulty as well as demographic information were collected at the end of the session (Normand, Bouquet, & Croizet, 2014). See Text S2 for the questionnaire data.

## **Results**

Because two participants produced extremely high error rates on the AX-CPT (> 57%), all the analyses on accuracy reported below were performed on 78 participants. Concerning the analyses of reaction times (RTs), some participants failed to answer to BX trials with a long ISI ( $N = 1$ ) or with a short ISI ( $N = 1$ ), to all BX trials ( $N = 1$ ) or to all BX and BY trials ( $N = 1$ ). These participants ( $N = 4$ ) were discarded in the corresponding analyses.

**Working memory capacity.** An item was scored as “correct” when it was recalled in the correct serial position. WM span represented the percentage of correct answers at each trial weighted by the number of sentences in the trial ( $M = .686$ ,  $SD = .161$ ) and was used as a continuous variable rather than as a dichotomous one (e.g., Wicherts & Scholten, 2013).

**AX-CPT Error Rates and RTs.** Mean error rate was 11%, which comes close to what has been previously observed (Redick & Engle, 2011). Outliers RTs were identified for each participant, and rejected according to a 2.5 absolute deviation around the median (MAD)



analysis eliminating 5.3% of the data. MAD analysis is a more robust analysis than the “+/-3 standard deviations from the mean” to detect abnormal values since this method is not influenced by sample size or the value of the mean (Leys, Ley, Klein, Bernard & Licata, 2013). Mean correct RT was 554 ms.

*Trials requiring proactive control.* Proactive control leads to a better performance on the AX and BX trials. RTs and errors were therefore averaged for these two types of trials in order to obtain an index of proactive control. As the number of trials is much higher for the AX trials than for the BX trials in the version of the AX-CPT that we used, the average between the two types of trials was weighted by the number of trials. The percentage of errors and correct RTs were then submitted to linear regression analyses with WM Span (centered; Aiken & West, 1991), Social presence (isolation: -0.5; experimenter presence: +0.5) and their interaction as predictors. The regression analysis on errors was non-significant,  $F(3,71)=1.76$ ,  $p=.16$ , and none of the predictors reached significance,  $ps > .13$ . The results of the regression analysis<sup>1</sup> on RTs indicated that the predictors explained 19% of the variance  $F(3,71)=5.63$ ,  $p=.002$ ,  $R^2=.19$ . The effect of Social presence was significant,  $\beta= .29$ ,  $p = .008$ ,  $\eta^2_p=.09$ . Participants working alone responded faster ( $M=502\text{ms}$ ,  $SE=13\text{ms}$ ) than participants working in presence of the experimenter ( $M=569\text{ms}$ ,  $SE=16\text{ms}$ ). More importantly, this effect was qualified by a Social presence x WM interaction,  $\beta= .35$ ,  $p = .004$ ,  $\eta^2_p=.11$ . Simple slopes analyses (Dawson, 2014) indicated that for participants in isolation, the higher their span the faster their RTs,  $t(73)= -2.00$ ,  $p=.049$ , whereas this relationship was reversed in the presence of the experimenter  $t(73)=2.22$ ,  $p=.03$  (see Figure 1).

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<sup>1</sup> The regression remained significant when all the participants were included ( $F(3,75)=5.43$  ;  $p<.01$  ;  $R^2=.18$ ) with similar effects of Social presence ( $\beta= .35$ ;  $p = .002$ ) and Social presence x WM span interaction ( $\beta= .24$ ;  $p = .04$ ). Likewise, our findings were unchanged when using a +/-3 SD cut off (.5% of trials were discarded).

*Trials requiring reactive control.* The percentage of correct responses and the RTs in the AY trials were submitted to the same regression models. Both regressions were non-significant (on errors:  $F(3,74)=.77, p=.52$ ; on RTs:  $F(3,73)=1.18, p=.25$ ).

*Neutral trials.* The same regressions were conducted on the BY trials. The regression on the percentage of errors was non-significant,  $F(3,74)=1.39, p=.25$ . However, the regression on the RTs was significant  $F(3,73)=3.75, p=.02, R^2=.13$ . Only Social presence reached significance,  $\beta= .31; p = .006, \eta^2_p=.10$  ( $ps>.22$  for WM span main effect and Social presence x WM span interaction). Participants working in isolation were faster ( $M=489$  ms,  $SE=18$  ms) than participants working in the presence of the experimenter ( $M=562$  ms,  $SE=19$  ms).

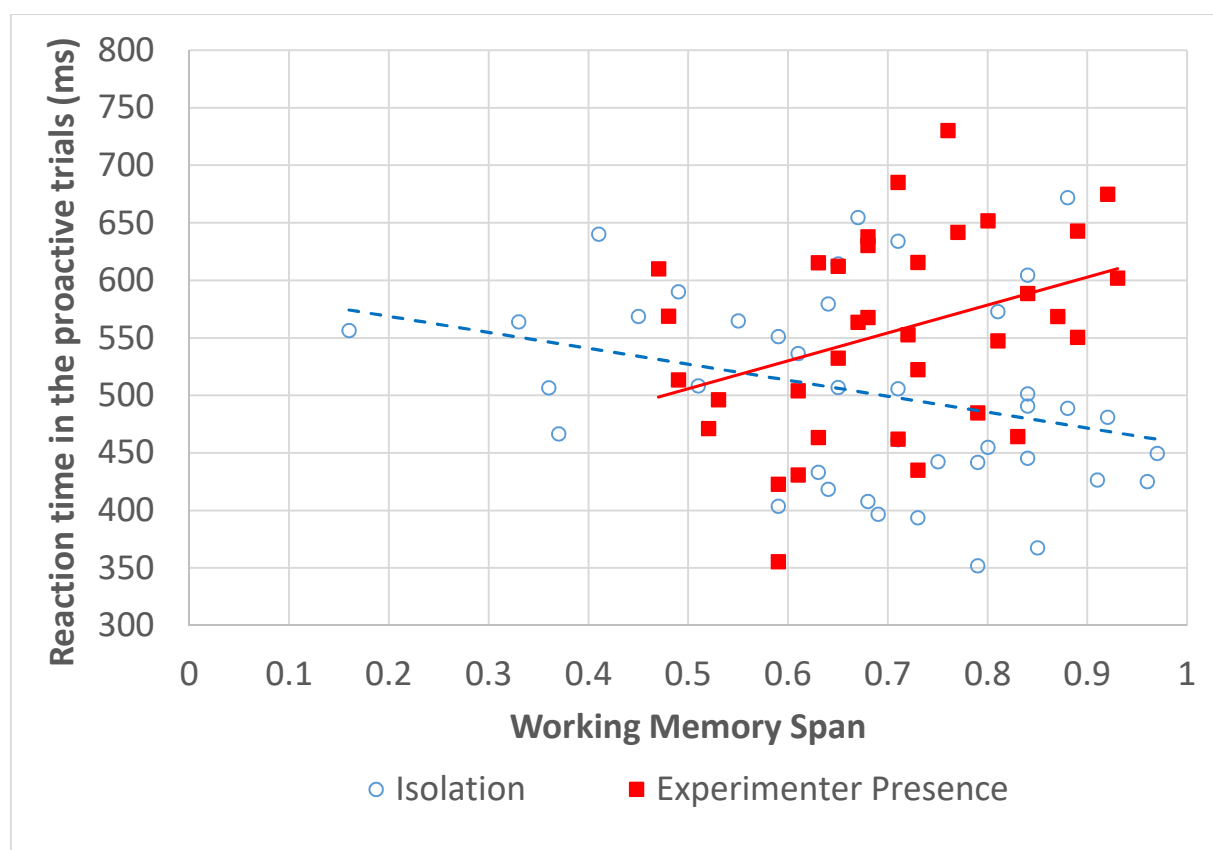


Fig 1. Reaction times on the proactive trials (AX and BX) as a function of working memory span in both social presence conditions: isolation (circles) and experimenter presence

(squares), with regression lines (full and dotted line for experimenter presence and isolation, respectively).

*Effect of ISI.* The same analyses on proactive, reactive and neutral trials were conducted on the long and short ISI trials. The same pattern of results as before was observed, indicating that the effect of the experimenter presence was the same on both ISI (See Text S1 for the full analyses).

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*Comparison between proactive and reactive trials.* Because the AXCPPT 70 contains much more proactive trials than reactive trials, it is not well adapted to a direct comparison between these two types of trials. However, it is worth noting that the results of the same regression analysis as before on the difference between proactive and reactive trials (rather than proactive trials alone) were also consistent with our approach. The regression was not significant on accuracy ( $p=.20$ ), but was significant on RTs:  $F(3,71)=3.25$ ,  $p=.03$ ,  $R^2=.12$ , with a significant Social presence x Working memory span interaction,  $\beta=.26$ ,  $p=.04$ ,  $\eta^2_p=.06$ . Simple slopes analyses indicated that, under isolation, the higher span the higher the advantage of proactive trials over reactive trials  $t(73)=-2.25$ ,  $p=.03$ . This relationship was not found in the presence of the experimenter  $t(73)=1.04$ ,  $p=.30$ . Thus, in this critical experimenter's presence condition, working memory span did no longer predict the performance difference between proactive and reactive trials.

## **Discussion**

There is evidence that high-Working Memory Capacity (WMC) individuals rely more on proactive control (i.e., on the active maintenance of information to anticipate a given response) than their low-WMC counterparts (Redick, 2014; Redick & Engle, 2011; Richmond, Redick & Braver, 2015). This central feature of high-WMC individuals accounts for their superiority over the low-WMC individuals on difficult tasks (Braver, 2012; Engle,

2002). However, previous results showed that the relationship between Working Memory (WM) and executive control in a Simon Task is reversed in the presence of an evaluative audience (Belletier et al., 2015). Therefore, we extended these results to one task known to be a sound measure of proactive control, the AX-CPT70, with the idea that this type of control would be impaired by the presence of others, thereby reducing specifically the performance of high-WMC individuals.

Our results showed that when participants worked alone (experimenter outside the experimental room), the higher was their WM span the faster they were on proactive control trials (AX and BX trials). This relationship was reversed when participants were watched by the experimenter (inside the experimental room), similarly to what was observed on RTs in the Simon task (Belletier et al., 2015). The presence of the experimenter made no difference on AY trials measuring reactive control. These findings indicate that being watched by evaluative others such as the experimenter undermines proactive control but does not seem to impact reactive control. However, the version of the AX-CPT that we used here is known to require essentially proactive control (Redick, 2014). Future research should therefore make use of different variations of the AX-CPT to test whether the presence of an evaluative audience—especially the experimenter presence—undermines proactive control more than reactive control, and whether reactive control is or is not immune to social presence effects and why. Moreover, we used a version of the task in which short and long ISI are mixed, which could have increased the executive demand and therefore have made participants more vulnerable to the executive cost of the experimenter presence. Besides that, the effects of social context were the same with both ISI, providing evidence that these effects are robust and did not necessitate a long delay between cue and target to be observed.

Altogether, our results refine our understanding of both audience and choking effects. More than a century of research on audience effects (Guerin, 2010) shows that being watched

by others typically impairs performance on difficult tasks. Previous findings indicated that being watched by others reduced both the range of cue utilization (Baron, 1986; Huguet et al., 1999; Normand et al., 2014) and executive attention (Wagstaff et al, 2008; Wühr & Huestegge, 2010). However, this long tradition failed to consider that social impairment effects may actually be restricted to high-WMC individuals who typically choke under pressure (Beilock & Carr, 2005; Gimmig, Huguet, Caverni & Cury, 2006). Not only do the present findings strengthen our confidence that the deleterious impact of evaluative audience (when any) reflects choking, but also help specifying which operative mode of control is impaired. Likewise, past research on choking showed that cognitive control and underlying prefrontal activity are reduced in high-WMC individuals under evaluative pressure (Beilock & Carr, 2005; Decaro, Thomas, Albert & Beilock, 2011; Lee & Grafton, 2015; for reviews see Beilock, 2010; Yu, 2015), but did not specify which component of control is altered. The present findings show that choking induced by evaluative audiences may reflect reduced proactive control.

Finally, the present research also leads to practical recommendations for psychological science. The large majority of psychological experiments imply the presence of an experimenter at some points in time (either intermittently or throughout participants' task performance) and space (close to or distant from the participants), with varied behaviors (more or less evaluative, cold or warm, etc.). However, the potential impact of the experimenter's presence and behavior on cognitive processes has been largely overlooked. If simply being watched by the experimenter leads the individuals with higher WMC to choke on tasks relying on proactive control, then even subtle variations in the experimenter's presence and behaviors from one study to another (if not within the same study from one participant to another) may cause dramatic changes in performance, resulting in potentially contradictory findings. These changes reflecting variations in the experimenter's presence and

behaviors may occur in all fields of psychology whenever proactive control is at stake, from research on executive functions or intelligence in cognitive or developmental psychology to research on emotion and personality traits (Braver, 2012). Also consistent with this view, there is evidence that a third party observer in the context of neuropsychological testing may be associated with poorer performance on measures of verbal learning, memory, fluency, attention, and executive functions (Eastvold, Belanger & Vanderploeg, 2012). More generally, experimenter effects are not new (for recent examples, see Doyen, Klein, Pichon & Cleeremans, 2012; Foroughi, Montfort, Paczynski, McKnight & Greenwood, 2016). However, past research in this area focused on the effect of experimenter's expectations (and sometimes participants' beliefs about the experimenter's expectations), while we focus here specifically on the effects of experimenter's presence.

As such, our results suggest to systematically include details about the experimenter's presence and behavior in the method section of research articles, which seems just as important as other details related to the task itself (distance to the computer screen, visual angle relative to stimuli, SOA, etc). All these indications are crucially needed to better standardize the conditions both within the same study from one participant to another and from one study to another, to ensure replicability.

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Supplemental Material for

**Choking under experimenter's presence:**  
Impact in Proactive control and practical consequences for  
psychological science

**This file contains:**

Analyses on ISI and Questionnaire

**Text S1: Analyses on ISI.**

*Short vs Long ISI in proactive trials.* The percentage of errors and correct RTs for long and short ISI proactive trials were submitted separately to a linear regression with the WM Span (centered; Aiken & West, 1991), the Social Presence (isolation: -0.5; experimenter presence: +0.5) and their interaction as predictors. The regression models were significant on RTs for both short ISI,  $F(3,70)=6.34, p<.001, R^2=.22$  and long ISI,  $F(3,70)=4.89, p=.004, R^2=.17$ . In both cases, Social presence (short ISI:  $\beta= .32, p = .004, \eta^2_p=.11$ ; long ISI:  $\beta= .25; p = .02, \eta^2_p=.07$ ) and Social presence x WM Span interaction (short ISI:  $\beta= .33, p = .006, \eta^2_p=.10$ ; long ISI:  $\beta= .35, p = .005, \eta^2_p=.11$ ) were significant with a pattern of interaction similar to the one observed when short and long ISI were merged. The regression models on the percentage of errors were non-significant (short ISI:  $F(3,74)=.60, p=.62$ ; long ISI:  $F(3,74)=1.49, p=.22$ ).

*Short vs Long ISI in reactive trials.* Concerning the reactive trials, the regression models were significant neither on RTs (short ISI:  $F(3,73)=.59, p=.62$ ; long ISI:  $F(3,73)=1.39, p=.25$ ) nor on percentage of errors (short ISI:  $F(3,74)=1.33, p=.27$ ; long ISI:  $F(3,74)=.30, p=.83$ ).

*Short vs Long ISI in neutral trials.* Finally, on the neutral trials, the regression was significant on the RTs for the short ISI ( $F(3,73)=4.10, p=.01, R^2=.14$ ), but not for the long ISI ( $F(3,73)=2.61, p=.06$ ), although in both cases we found a similar slow-down in the presence of the experimenter (effect of the context on the short ISI:  $\beta= .34, p = .003, \eta^2_p=.12$ ; long ISI:

$\beta = .25, p = .03, \eta^2_p = .06$ ). However, the regressions on the percentage of errors were not significant (short ISI:  $F(3,74) = .83, p = .48$ ; long ISI:  $F(3,74) = 1.68, p = .18$ ).

### **Text S2: Analyses on Questionnaire.**

The final questionnaire was made of 4 items (Normand, Bouquet, & Croizet, 2014) measuring Stress (“I felt rather stressed during the task”), Evaluation Feeling (“I felt evaluated during the task”), Discomfort (“I was quite comfortable during the task”, reversed) and Perceived Difficulty (“I had difficulties during the task”). Participants answered all these items according to a 7-point Likert scale anchored from “strongly agree” to “strongly disagree”. We first assessed the internal consistency of an index of perceived anxiety combining the 4 items ( $\alpha = .71, M = 3.38, SD = 1.19$ ).

Belletier et al. (2015) showed that participants’ level of perceived anxiety was unaffected by the presence of the experimenter. To test if it was also the case in the present data, we ran a linear regression with the WM Span (centered), Social Presence (isolation: -0.5; experimenter presence: +0.5) and their interaction as predictors. The regression model was significant  $F(3,76) = 3.22, p = .03, R^2 = .11$ . The effect of Working memory span was significant ( $\beta = -.30, p = .01, \eta^2_p = .08$ ). This effect was qualified by a significant interaction ( $\beta = -.31, p = .01, \eta^2_p = .08$ ) between working memory span and social presence. As indicated by simple slopes analyses, in isolation, the relationship between perceived anxiety and working memory was not significant  $t(76) = .10, p = .92$ . In the presence of the experimenter, the higher the span the *lower* the level of perceived anxiety  $t(76) = -3.06, p = .003$ . Thus, consistent with earlier findings (Belletier et al., 2015), it seems that the deleterious effect of the experimenter presence observed on proactive control was not related to higher anxiety, quite the contrary.