Objectifying the Subjective: Building Blocks of Metacognitive Experiences in Conflict Tasks

Laurence Questienne, Anne Atas, Boris Burle, Wim Gevers

Journal of Experimental Psychology: General
2017, in press

Author's version, ©The authors
http://dx.doi.org/10.1037/xge0000370

Objectifying the Subjective: Building Blocks of Metacognitive Experiences in Conflict Tasks

Laurence Questienne and Anne Atas
Université Libre de Bruxelles

Boris Burle
Aix-Marseille Université, CNRS

Wim Gevers
Université Libre de Bruxelles

Metacognitive appraisals are essential for optimizing our information processing. In conflict tasks, metacognitive appraisals can result from different inter-related features (e.g. motor activity, visual awareness, response speed, etc.). Thanks to an original approach combining behavioral and electromyographic measures, the current study objectified the contribution of three features (reaction time, motor hesitation with and without response competition, and visual congruency) to the subjective experience of urge-to-err in a priming conflict task. Both reaction time and motor hesitation with response competition were major determinants of metacognitive appraisals. Importantly, motor hesitation in absence of response competition and visual congruency had limited effect. Because science aims to rely on objectivity, subjective experiences are often discarded from scientific inquiry. The current study shows that subjectivity can be objectified.

Keywords: Congruency; Introspection; Response competition; Electromyography

Uncovering control processes that enable to maintain goal-directed behavior is a major objective of cognitive research (e.g. Abrahamse, Braem, Notebaert, & Verguts, 2016). Such control processes are especially necessary in situations where irrelevant information has to be inhibited. Imagine waiting at a multi-rows central traffic light. When the side-line traffic light turns green, you may have the feeling that you almost reacted to this irrelevant stimulation. In the lab, control processes are often studied through conflict tasks like the Stroop (Stroop, 1935), the Flanker (B. A. Eriksen & Eriksen, 1974) or the arrow priming task (Vorberg, Mattler, Heinecke, Schmidt, & Schwarsbach, 2003). These tasks have in common that participants have to respond to a task-relevant stimulus dimension while ignoring distracting information. In the arrow priming task, for instance, participants indicate the direction of a target arrow while ignoring a prime arrow presented just before. It is objectively more difficult (slower response and more errors) when arrows are incongruent (i.e. point in opposite directions) even when the prime is subliminal (Vorberg et al., 2003).

Importantly, congruency effects are not limited to objective measures. Participants report stronger subjective experiences of "urge-to-err" or higher "difficulty" on incongruent trials (Desender, Van Opstal, & Van den Bussche, 2014; Morsella et al., 2009; Questienne, van Dijck, & Gevers, 2017), even when unaware of the congruency (Desender, Van Opstal, Hughes, & Van den Bussche, 2016). Which (combination of) features, simultaneously experienced (motor activity, visual awareness, speed, etc.), contribute to the reported experience remains to be deciphered.

Based on the literature, we identified a shortlist of features that could contribute to the experience of urge-to-err, within the context of an arrow priming task. This list is not

L. Questienne is supported by the Fund for Scientific Research (F.R.S. – FNRS, Belgium, Grant Number 1.A.875.14F). This work was partially supported by the European Research Council under the European Community's Seventh Framework Program (FP7/2007-2013 Grant Agreement no. 241077), and by Wallonia-Brussels International and the Fund for Scientific Research(F.R.S.), the French Ministries for Foreign Affairs Higher Education and Research through a Hubert Curien partnership (PHC no. 35947SC). This work was not funded by a grant from NIH, Wellcome Trust or Research Councils UK. We thank Mathieu Servant for his valuable advices. Results discussed in this article were presented at two conferences (6th Motivation and Cognitive Control Symposium, 2016, St Andrew, Scotland and the European Workshop on Cognitive Neuropsychology, 2016, Bressanone, Italy). No other formats were used to share this work.

The last two authors contributed equally to the study and are co-senior authors.

Correspondence concerning this article should be addressed to Laurence Questienne, Center for Research in Cognition and Neurosciences - Université Libre de Bruxelles, Av. F. Roosevelt 50/CP191 - 1050 Brussels- Belgium, Tel: +32 2 650 26 31, lquestie@ulb.ac.be.

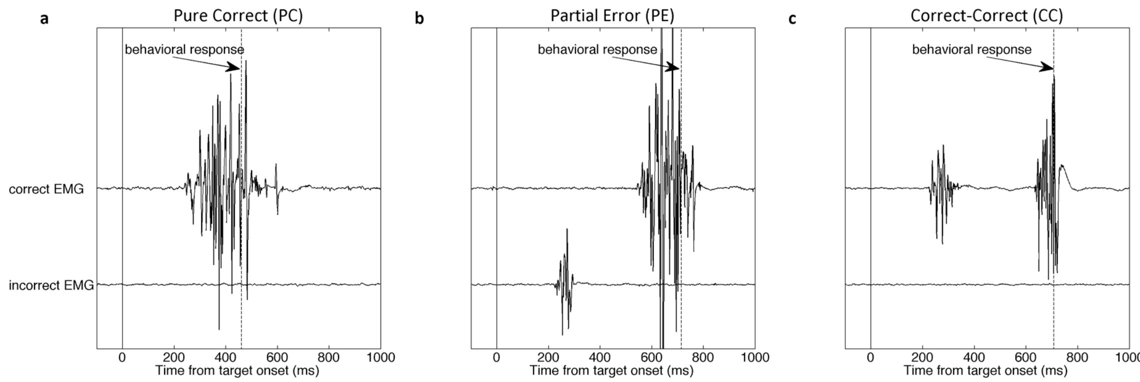

Figure 1. Example of each EMG category. a. Pure-Correct trials are trials with only one EMG activity on the correct hand. b. Partial-Error correspond to correct trials with EMG activity on the incorrect hand preceding the correct one. c. Correct-Correct trials are trials with a small activation on the correct hand occurring before the main EMG burst leading to the response.

meant to be exhaustive and can be generalized to any other conflict task. First, participants could use the evaluation of their reaction time (RT) (e.g. Corallo, Sackur, Dehaene, & Sigman, 2008) to infer their urge-to-err (*i.e.* 'I was slow on this trial so it was difficult'). Second, motor hesitation (for a related concept, see 'response fluency' in e.g. Chambon and Haggard, 2012 could influence the urge-to-err. On incongruent trials, prime and target activate competing responses (Botvinick, Braver, Barch, Carter, & Cohen, 2001) installing a motor hesitation that could trigger the urge-to-err (e.g. Morsella et al., 2009). Motor hesitation can also occur in absence of response competition (see below for a definition). Such hesitations could also trigger the urge-to-err. Third, visual aspects of the congruency can relate to the urge-to-err, even with subliminal primes, because they still modulate visual processing (Naccache & Dehaene, 2001; Ortells, Kiefer, Castillo, Megías, & Morillas, 2016). Dissociating the contribution of these features to the reported urge-to-err is challenging because they are partly confounded (e.g. incongruent trials have slower RT, higher motor hesitation). Avoiding confounds requires separate objective measure of each feature. Visual congruency is determined by trial type. RT distribution analysis allows assessing the impact of RT on urge-to-err. But motor hesitation (with or without response competition) cannot be objectified solely on behavioral measures. Recording electromyographic (EMG) activity of the muscles involved in response execution objectively reveals motor hesitation (e.g. C. W. Eriksen, Coles, Morris, & O'hara, 1985). First, on 15-20% of correct trials, subthreshold EMG activation occurs on the incorrect hand before the correct response (Figure 1b). Such 'partial-errors' occur more frequently on incongruent trials signaling the occurrence of response competition (e.g. Burle, Roger, Allain, Vidal, & Hasbroucq, 2008). Studying the urge-to-err as a function of these partial-errors allows relating the urge-to-err to motor hesitation implying response competition. Second, some correct trials contain several bursts of only correct EMG activity before button press (Figure 1c). Such multiple activations signal a motor hesitation, without necessarily involving response competition. These trials were not analyzed in detail yet (e.g. Servant, White, Montagnini, & Burle, 2015) but enable to study whether urge-to-err is specifically sensitive to response competition or to all motor hesitations.

Method

Participants

Based on a previous study on subjective experience (Questienne, Van Opstal, van Dijck, & Gevers, 2016, Experiment 2), twenty-seven healthy naive participants (6 men; 19.26 years, SD = 1.58) participated against €15/hr. This experiment was approved by the committee "CPP Sud-Méditerranée", agreement n° 1041 (RCB n°: 2010-A00745-34). Participants signed informed consent.

Material and procedure

Using the Psychopy toolbox (Peirce, 2007), stimuli were presented on a white screen on a 15-inch, 70 Hz CRT monitor. Viewing distance was 120 cm. Responses were given by thumb presses on buttons mounted on top of two cylinders grasped in each hand. EMG activity of flexor pollicis brevis was recorded (1024 Hz, Biosemi Active2, Servant et al., 2015 for procedures)[1]. Participants pressed as fast as possible the button corresponding to the direction of a target arrow, preceded by a prime arrow (Figure 2a). After each trial, participants orally judged to what extent they were about to make an error (i.e. urge-to-err) on an 8-points scale (1 = "no urge–to–err", 8 = "strong urge–to–err") or mentioned real errors (recorded as "9"). They performed 20 blocks of 64 randomized trials, preceded by 16 training trials. Congruency, arrow direction and spatial location (above or below

[1]EEG activity was also recorded for other purposes and beyond the scope of the current study

Table 1
Summary of the congruency effects on the different variables.

	Congruent trials		Incongruent trials				
Variables	Mean	95%CI	Mean	95% CI	Statistical test		
Behavioral Measures					F(1,26)	p	η^2_p
RT (ms)	359	[341, 377]	412	[397, 427]	526.50	< .001	.95
Error rate (%)	1.49	[0.97, 2.01]	8.84	[5.73, 11.96]	56.87	< .001	.69
EMG categories					F(1,26)	p	η^2_p
Pure-Correct (%)	76.15	[72.29, 80.01]	47.89	[40.84, 54.94]	161.02	< .001	.86
Partial-Error (%)	8.50	[6.29, 10.71]	24.50	[20.45, 28.55]	171.74	< .001	.87
Correct-Correct (%)	5.16	[3.99, 6.34]	4.43	[3.39, 5.48]	3.97	< .057	.13
Subjective experience					Z	p	r
Urge-to-err	1.82	[1.50, 2.14]	2.43	[2.08, 2.78]	-4.54	< .001	-.61

Note. RT=reaction time; CI= Confidence Interval. Repeated ANOVAs were performed, excepted on urge-to-err where a Wilcoxon non-parametric test was used because of deviation from normal distribution unresolved by data transformation. ANOVAs on error rate, Pure-Correct, Partial-Error and Correct-Correct rates were computed after arcsine square-root transformation for proportions.

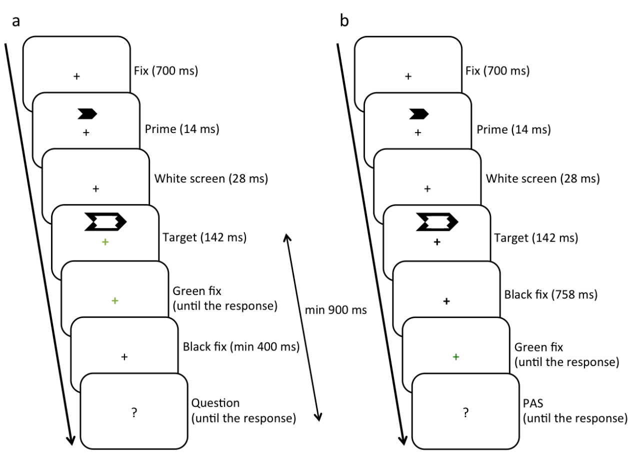

Figure 2. Example of trial in the first part (a): A trial begins with a fixation cross (700 ms), followed by a prime (1.8° *times* 0.9°) (14 ms) and a white screen (28 ms). Next, the target (2.7° × 1.1°) appears (142 ms). To mask the prime, the target has a central cutout corresponding to the shape of the superimposed left and right-pointing primes. The central fixation cross becomes green until the response. After the response, a black fixation cross lasts during at least 400 ms or longer until 900 ms passed from the onset of the target. Then, a question marked appears until the subjective response is given and encoded by the experimenter. Example of trial in the awareness test (b): The trial presentation is the same except that after the target, a black fix appears during 758 ms. Then, it becomes green and the button corresponding to the prime can be pressed , followed by the oral response to the Perceptual Awareness Scale (PAS).

fixation) were counterbalanced within each block. Participants were not informed about the presence of the primes. After this part, participants were asked whether they noticed their presence before performing an awareness test (Figure 2b). The stimulus presentation was identical, but participants indicated the prime direction. The response was given after 900 ms to decrease motor priming. This delay fitted with the minimum interval between the target and the subjective report in the first part. Then, participants orally evaluated the quality of their visual experience of the prime on the Perceptual Awareness Scale (PAS) (Ramsøy & Overgaard, 2004), a 4-point scale from (1 = "No visual experience" , 4 = "Absolutely clear image"). There were 2 blocks of 64 trials, preceded by 16 training trials.

Data processing

All Data are available at osf.io/wz9jp.

Because of technical problems, 2.27% and 3.59% of trials were lost for 2 participants. RTs slower/shorter than Median ± 3 Median Absolut Deviation computed by participant were removed (6.46 %) (Leys, Ley, Klein, Bernard, & Licata, 2013). EMG signal was high-pass filtered (10hz). Onsets of the EMG activity were manually marked based on visual inspection (see e.g. Burle, Possamaï, Vidal, Bonnet, & Hasbroucq, 2002). Importantly, the experimenter was blind to the congruency and reported experience that she/he was looking at. Three categories of trials were selected: Pure-Correct (62.23%, SD = 12.94), Partial-Error (16.38%; SD = 7.15) and Correct-Correct (4.80%; SD = 2.66) (Figure 1). Other trials (16.58%, SD=7.91) were discarded because of errors, multiple EMG bursts and/or tonic activity. The size of EMG activity was estimated as the 90th percentile of the

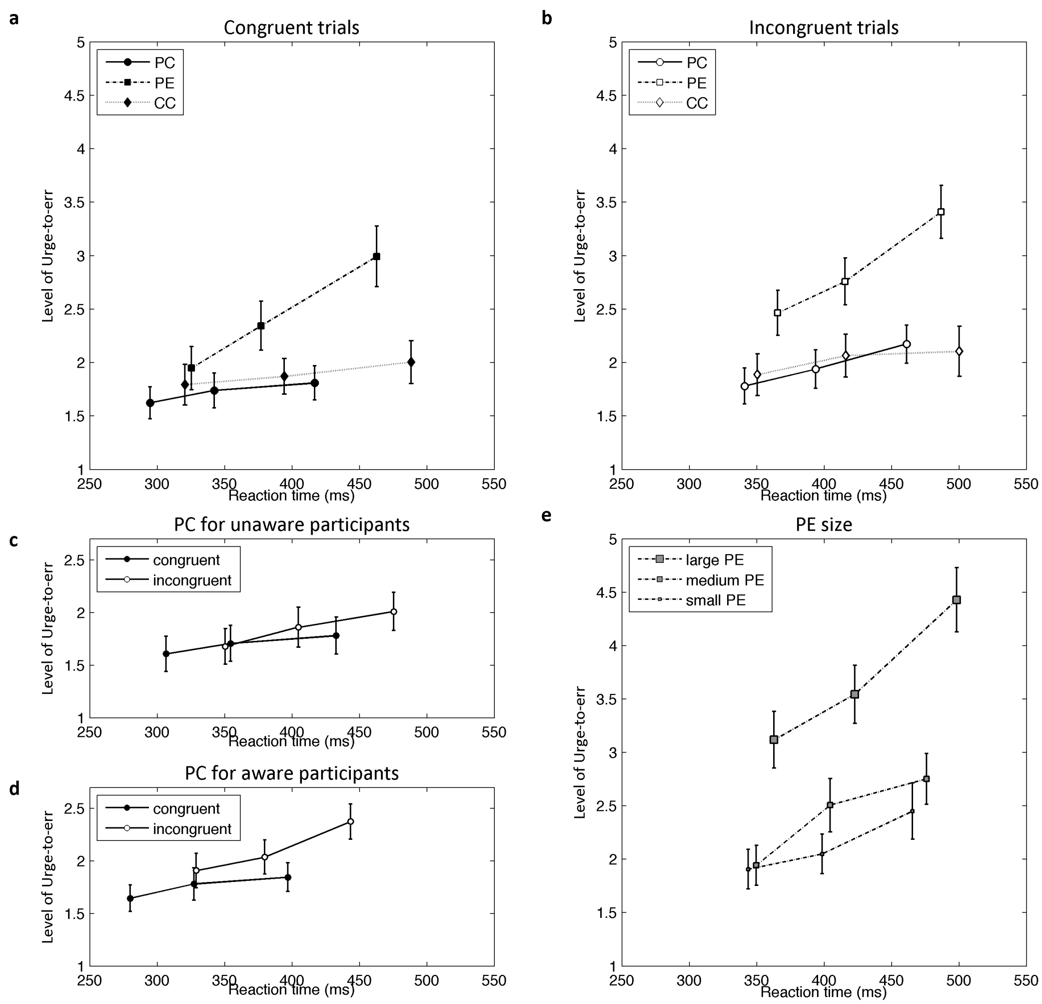

Figure 3. Distributional analysis of the urge-to-err. For different types of trials, the reaction time (RT) distributions were sorted in ascending order and binned in three classes of equal length (Ratcliff, 1979; Vincent, 1912). The mean score of "urge-to-err" is computed for each bin and plotted against the mean of RT of its bin, separately for Pure-Correct, Partial-Error and Correct-Correct trials and for congruent (a) and incongruent trials (b). The same distributional graph is plotted for congruent and incongruent Pure-Correct trials for unaware (c) and aware participants (d). Distributional graphs are plotted for three sizes of Partial-Error (e). To define small, medium and large Partial-Error, incorrect EMG sizes were sorted in ascending order and divided in three equal bins. Error bars represent standard error.

cumulative sum of the EMG signal on the 500 ms following the EMG onset (for more details, see Servant et al., 2015).

Results

Overall performances

Typical congruency effects were observed on RTs, error rates, proportion of Pure-Correct and Partial-Error trials (Table 1). The congruency effect was also observed in the urge-to-err. There were also marginally more Correct-Correct trials on congruent than on incongruent trials.

Dynamics analysis of urge-to-err

Urge-to-err was first plotted as a function of congruency, EMG categories and RTs distribution (Figures 3a & 3b). All slopes were positive: urge-to-err generally increased with RT. Importantly, they differed depending on the congruency and the EMG category (e.g. the Partial-Errors slope was

Table 2
Results of the contrasts decomposing the interactions of the Linear Mixed Model used for the dynamic analyze of the urge-to-err

Contrasts	Estimate	(1- α)×100 % CI	t(26835)	p	Adjusted α
RT slope PC	1.28	[0.60, 1.96]	4.97	< .001	.008
RT slope CC	1.12	[0.34, 1.88]	3.88	< .001	.008
RT slope PE	2.30	[1.58, 3.02]	8.45	< .001	.008
RT slope CC - RT slope PE	-1.18	[-1.63, -0.74]	-7.00	< .001	.008
RT slope PC- RT slope PE	-1.01	[-1.31, -0.72]	-9.08	< .001	.008
RT slope PC - RT slope CC	-0.17	[-0.55 0.22]	-1.13	.259	.008
RT slope Cong.	1.44	[0.57, 2.31]	5.42	< .001	.01
RT slope Incong.	1.69	[0.81, 2.57]	6.33	< .001	.01
RT slope Cong - Incong PC	-0.55	[-0.80, -0.29]	5.55	< .001	.01
RT slope Cong - Incong CC	-0.35	[-1.05, 0.35]	1.28	.200	.01
RT slope Cong - Incong PE	0.12	[-0.37, 0.63]	0.67	.505	.01

Note. RT=reaction time; PC = Pure-Correct trials; PE=Partial-Error trials; CC=Correct-Correct trials; Cong. = congruent trials; Incong. = incongruent trials; CI= Confidence Interval.

steeper than other EMG categories).

To statistically assess these observations, we conducted a linear mixed model (LMM) with SAS software. Urge-to-err was the dependent variable. A log-transformation was applied to meet the normality assumption. *Congruency*, *EMG category* (Pure-Correct vs Partial-Error vs Correct-Correct), *RT* (of each individual trial) and all interactions were fixed effects. RTs were centered on the mean of all trials (as such, the effect of the other factors were evaluated for the RT mean). Participants and by-participant RT slope were selected as random effects based on restricted maximum likelihood method and Akaike's Information Criterion (Akaike, 1974).

Main effects were significant (*RT*: $F(1,26) = 36.33$, $p <$ .001; *Congruency*: $F(1,26835) = 30.65$, $p < .001$; *EMG categories*, $F(1,26835) = 307.35$, $p < .001$) but modulated by higher order interactions, analyzed with contrasts (planned comparisons) and Bonferroni corrections (see Table 2). Six contrasts were conducted to analyze the interaction between *EMG category* and *RT*, $F(1,26835) = 44.91$, $p <$ .001. Urge-to-err increased with RT for all EMG categories (slope Partial-Error = 2.30, slope Pure-Correct =1.28; slope Correct-Correct =1.12). Larger slopes for Partial-Errors indicated that they were associated with stronger urge-to-err, and this difference increased with slower RTs. Five contrasts were conducted to analyze the interaction between *Congruency* and *RT*, $F(1,26835) = 4.77$, $p = .029$, and the three-way interaction, $F(1,26835) = 4.97$, $p = .007$. Urge-to-err increased with RT for both congruent (slope = 1.44) and incongruent trials (slope = 1.69). While those slopes differ on Pure-Correct trials (larger for incongruent than for congruent trials, difference = -0.55), this was not the case on Partial-Errors (difference = 0.13), nor on Correct-Correct trials (difference = -0.3484). Stimulus congruency influenced urge-to-err on Pure-Correct trials but not on Correct-Correct trials or Partial-Errors.

Prime awareness

Fifteen participants did not notice the prime (unaware group); twelve participants claimed they did (aware group). Detecting the primes was subjectively as difficult for both groups (PAS: 1.71, 95% CI [1.306, 2.116] vs 1.79, 95% CI [1.319, 2.266]), $t(25) = -0.285$, $p = .778$. However, the aware group detected the prime slightly above chance level (d' = 0.32, 95% CI [0.065, 0.582], $t(11) = 2.76$, $p = .019$), while the unaware group did not (d' = 0.01, 95% CI [-0.151, 0.168], $t(14) = 0.115$, $p = .910$). This difference was significant, $t(25) = 2.353$, $p = .027$.

Supplementary analyses

To assess whether aware participants drove the congruency effect on Pure-Correct trials, a specific LMM was conducted. The log-transformed level of urge-to-err on Pure-Correct trials was the dependent variable. Congruency, RT and group (aware vs unaware) and all interaction were fixed effects. Participants and by-participant RT slope were random effects. The three-way interaction was significant, $F(1,19987) = 10.31$, $p = .001$. Three contrasts (alpha = .05/3) showed that the slope difference between congruent and incongruent trials was larger in the aware group (difference = - 0.61, 98.33% CI [-1.06, -0.15]), $t(19987) = 3.21$, $p = .001$, but significant in both groups (aware : difference = -0.95, 98.33% CI [-1.31, -0.59]), $t(19987) = -6.34$, $p < .001$, unaware: difference= -0.35, 98.33% CI [-0.62, -0.07]), $t(19987) = -3.01$, $p = .003$ (Figures 3c/3d). In sum, both aware and unaware participants contributed to the congruency effect observed on urge-to-err on Pure-Correct trials. Urge-to-err as a function of the incorrect EMG size of Partial-Errors was also analyzed. A specific LMM was conducted on Partial-Errors. The log-transformed urge-to-err was the dependent variable. Only RTs, the centered incorrect EMG size and their interaction were fixed effects. *Congruency* did not improve model fitting ($LRT(4) = 3.19$; p = .561). Participant and by-participant RT slope were random effects. Effect of *RT*, $F(1,26) = 49.81$, $p < .001$, and EMG size, $F(1,5243) = 925.37$, $p < .001$, were significant and interacted, $F(1,5243) = 4.73$, $p = .030$. The slower the RT, the more urge-to-err increased with the incorrect EMG size (Figure 3e). Finally, we checked whether the size of the correct EMG activity corresponding to the behavioral response could explain the modulation of urge-to-err with the EMG category. Wilcoxon tests (because of non-normal distributions) with adjusted alpha (.05/3) showed that the size of correct EMG burst of Partial-Errors trials differed from size of EMG burst of Pure-Correct trials, $Z = -3.748$, $p < .001$. However, size of correct EMG burst on Partial-Errors and size of the second correct EMG burst of Correct-Correct trials were similar, $Z = -1.057$; $p = .290$, while they were experienced with different urge-to-err (see above). Conversely, EMG activity of Pure-Correct and second correct EMG burst of Correct-Correct trials were different, $Z = -2.643$; $p = .008$, while they were experienced similarly (see above). Thus, correct EMG associated with the behavioral response cannot explain the relation between EMG categories and urge-to-err.

Discussion

The current study aimed to disentangle the contribution of RT, motor hesitation (with or without response competition) and visual conflict to the subjective experience of urge-to-err in an arrow priming task. Participants experienced congruent and incongruent trials differently (Desender et al., 2014; Morsella et al., 2009; Questienne et al., 2017). However, the origin of these experiences has been conjectured rather than established. By combining EMG measures and RT distributions analyses, we objectified the specific role of several features and how they related to each other to form subjective experiences. So far, studies interested in the experience of urge-to-err considered RT as a confounding variable that has to be eliminated (e.g. Morsella et al., 2009). Here, using RT distribution analyses we quantified the relation between RT and urge-to-err, which appears to be linear for all trial types. Whether this relationship results from an explicit strategy (i.e. 'I was slow, therefore I report stronger urge-to-err') can be debated. Interestingly, the strength of this relationship varies as a function of the EMG pattern. The presence of a Partial-Error overall increases the urge-to-err and steepens the relationship with RT. Crucially, this was true on congruent and incongruent trials. Partial-Errors on congruent trials do not result from the prime. They probably result from implicit/explicit response expectancies (e.g. Perruchet, Cleeremans, & Destrebecqz, 2006) or stimulus repetitions/alternations (e.g. Hommel, Proctor, & Vu, 2004) etc...This indicates that urge-to-err is sensitive to response competition, irrespective of its origin. The present results likely generalize to other conflict tasks inducing response competition (e.g. Flanker task, Simon task, etc.). Whether they extend to other types of conflict, such as task-conflict (Goldfarb & Henik, 2007), remains an open issue. Importantly, Partial-Errors could have induced an offset of the RT slope (shifting the curve up) without affecting the slopes, suggesting that response competition and RTs acted independently on urge-to-err. Instead, Partial-Errors steepen the urge-to-err – RT curve, showing that both factors interact to generate metacognitive experiences. The analysis of Partial-Error size completes this pattern: the slope relating urge-to-err – RT increases with the size of the incorrect EMG of Partial-Errors, suggesting that the urge-to-err is not only sensitive to the presence, but also to the amount of response competition. In contrast, urge-to-err – RT curves for Correct-Correct trials (Figures 3a/3b) seem a continuation of the Pure Correct ones. Because Correct-Correct trials and Partial-Errors lead to similarly slow RTs (see abscissa on Figure 3a/3b), this further establishes that the increased urge-to-err on Partial-Errors is not a by-product of their longer RTs. Thus, while motor hesitation implying response competition influences the urge-to-err, motor hesitation without response competition does not. Finally, congruency contributes to urge-to-err in a limited way. A congruency effect remains on urge-to-err only on Pure-Correct trials, even for participants unaware of the primes; it hence cannot be attributed to intentional strategies (e.g. 'this was an incongruent trial, so it was difficult'). Rather, it could reflect a subjective sensitivity to some early visual processing triggered by subliminal primes (Naccache & Dehaene, 2001; Ortells et al., 2016). However, partial muscular activation overrules this sensitivity: no effect of congruency is observed on Partial-Errors nor Correct-Correct trials. This last observation on Correct-Correct trials indicates that, although motor hesitation without response competition does not increase urge-to-err, it could still have an influence. Alternatively, the congruency effect on Pure-Correct trials could be due to residual response competition. On Pure-Correct incongruent trials competitive responses could still be activated but not strong enough to achieve the muscular level. This would mean that subjectivity is sensitive to response selection steps occurring before muscular peripheral activations (Chambon & Haggard, 2012). Note that, despite the easiness of the task (e.g. few errors and overall low urge-to-err), urge-to-err can still be related to different task-related features. However, while behavioral and EMG results are similar to experiments using similar tasks without introspection (Burle et al., 2008; Vorberg et al., 2003), we cannot exclude that the introspective instruction somehow changed the task (Grützmann, Endrass, Klawohn, & Kathmann, 2014). Especially, the urge-to-err could have become salient, leading to a general overestimation of this experience. While possible, for our purposes, knowing how different features modulate this experience was more important than its absolute value.

To conclude, by combining behavioral and EMG measures, we show that experiences of urge-to-err stem from several features that can be disentangled. Previous work suggested that subjective experiences could trigger cognitive adaptation (Desender et al., 2014; Questienne et al., 2016). The current study discloses the building blocks of such metacognitive experiences, a crucial step to understand its relation to adaptation. More broadly, the current study opens perspectives to study metacognition and introspection in general. First, this work provides tools to describe subjective experiences in a fine-grained way. Second, subjective experiences are at the heart of human mental life, the object of psychology, but can only be accessed through introspective reports, often considered as unreliable (Nisbett & Wilson, 1977). But introspective reports seem quite reliable when they are restricted to memories of cognitive processes, without implying complex inferences (Ericsson & Simon, 1980). The current study underlines this reliability by relating introspective reports to objective measures. Whereas science aims to rely on objectivity, the current study shows that subjectivity can be objectified.

References

Abrahamse, E., Braem, S., Notebaert, W., & Verguts, T. (2016). Grounding Cognitive Control in Associative Learning. *Psychological Bulletin*, *142*(7), 693–728. doi:10.1037/bul0000047

Akaike, H. (1974). A New Look at the Statistical Model Identification. *IEEE Transactions on Automatic Control*, *19*(6), 716–723. doi:10.1007/978-1-4612-1694-0_16

Botvinick, M. M., Braver, T. S., Barch, D. M., Carter, C. S., & Cohen, J. D. (2001). Conflict monitoring and cognitive control. *Psychological review*, *108*(3), 624–652. doi:10.1037/0033-295X.108.3.624

Burle, B., Possamaï, C.-A., Vidal, F., Bonnet, M., & Hasbroucq, T. (2002, November). Executive control in the Simon effect: an electromyographic and distributional analysis. *Psychological research*, *66*(4), 324–36. doi:10.1007/s00426-002-0105-6

Burle, B., Roger, C., Allain, S., Vidal, F., & Hasbroucq, T. (2008, September). Error negativity does not reflect conflict: a reappraisal of conflict monitoring and anterior cingulate cortex activity. *Journal of Cognitive Neuroscience*, *20*(9), 1637–1655. doi:10.1162/jocn.2008.20110

Chambon, V. & Haggard, P. (2012). Sense of control depends on fluency of action selection, not motor performance. *Cognition*, *125*(3), 441–451. doi:10.1016/j.cognition.2012.07.011

Corallo, G., Sackur, J., Dehaene, S., & Sigman, M. (2008, November). Limits on introspection: distorted subjective time during the dual-task bottleneck. *Psychological science*, *19*(11), 1110–1117. doi:10.1111/j.1467-9280.2008.02211.x

Desender, K., Van Opstal, F., Hughes, G., & Van den Bussche, E. (2016, February). The temporal dynamics of metacognition: Dissociating task-related activity from later metacognitive processes. *Neuropsychologia*, *82*, 54–64. doi:10.1016/j.neuropsychologia.2016.01.003

Desender, K., Van Opstal, F., & Van den Bussche, E. (2014). Feeling the conflict: the crucial role of conflict experience in adaptation. *Psychological science*, *25*(3), 675–683. doi:10.1177/0956797613511468

Ericsson, K. A. & Simon, H. A. (1980). Verbal reports as data. *Psychological Review*, *87*(3), 215–251. doi:10.1037/0033-295X.87.3.215

Eriksen, B. A. & Eriksen, C. W. (1974, January). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics*, *16*(1), 143–149. doi:10.3758/BF03203267

Eriksen, C. W., Coles, M. G. H., Morris, L. R., & O'hara, W. P. (1985, March). An electromyographic examination of response competition. *Bulletin of the Psychonomic Society*, *23*(3), 165–168. doi:10.3758/BF03329816

Goldfarb, L. & Henik, A. (2007, October). Evidence for task conflict in the Stroop effect. *Journal of experimental psychology. Human perception and performance*, *33*(5), 1170–1176. doi:10.1037/0096-1523.33.5.1170

Grützmann, R., Endrass, T., Klawohn, J., & Kathmann, N. (2014). Response accuracy rating modulates ERN and Pe amplitudes. *Biological Psychology*, *96*, 1–7.

Hommel, B., Proctor, R. W., & Vu, K.-P. L. (2004, February). A feature-integration account of sequential effects in the Simon task. *Psychological research*, *68*(1), 1–17. doi:10.1007/s00426-003-0132-y

Leys, C., Ley, C., Klein, O., Bernard, P., & Licata, L. (2013, July). Detecting outliers: Do not use standard deviation around the mean, use absolute deviation around the median. *Journal of Experimental Social Psychology*, *49*(4), 764–766. doi:10.1016/j.jesp.2013.03.013

Morsella, E., Wilson, L. E., Berger, C. C., Honhongva, M., Gazzaley, A., & Bargh, J. A. (2009). Subjective aspects of cognitive control at different stages of processing. *Attention, Perception, & Psychophysics*, *71*(8), 1807–1824. doi:10.3758/APP.71.8.1807

Naccache, L. & Dehaene, S. (2001, October). The priming method: imaging unconscious repetition priming reveals an abstract representation of number in the parietal lobes. *Cerebral cortex*, *11*(10), 966–74.

Nisbett, R. E. & Wilson, T. D. (1977). Telling more than we can know: Verbal reports on mental processes. *Psychological Review*, *84*(3), 231–259. doi:10.1037/0033-295X.84.3.231

Ortells, J. J., Kiefer, M., Castillo, A., Megías, M., & Morillas, A. (2016). The semantic origin of unconscious priming: Behavioral and event-related potential evidence during category congruency priming from strongly and weakly related masked words. *Cognition*, *146*, 143–157. doi:10.1016/j.cognition.2015.09.012

Peirce, J. W. (2007). PsychoPy—Psychophysics software in Python. *Journal of Neuroscience Methods*, *162*(1), 8–13. doi:10.1016/j.jneumeth.2006.11.017

Perruchet, P., Cleeremans, A., & Destrebecqz, A. (2006). Dissociating the effects of automatic activation and explicit expectancy on reaction times in a simple associative learning task. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*(5), 955–965. doi:10.1037/0278-7393.32.5.955

Questienne, L., Van Opstal, F., van Dijck, J.-P., & Gevers, W. (2016, November). Metacognition and cognitive control: behavioural adaptation requires conflict experience. *The Quarterly Journal of Experimental Psychology*, 1–15. doi:10.1080/17470218.2016.1251473

Questienne, L., van Dijck, J.-P., & Gevers, W. (2017, May). Introspection of Subjective Feelings Is Sensitive and Specific. *Journal of Experimental Psychology: Human Perception and Performance*. doi:10.1037/xhp0000437

Ramsøy, T. Z. & Overgaard, M. (2004, March). Introspection and subliminal perception. *Phenomenology and the Cognitive Sciences*, *3*(1), 1–23. doi:10.1023/B:PHEN.0000041900.30172.e8

Ratcliff, R. (1979). Group reaction time distributions and an analysis of distribution statistics. *Psychological Bulletin*, *86*(3), 446–461. doi:10.1037/0033-2909.86.3.446

Servant, M., White, C., Montagnini, A., & Burle, B. (2015, July). Using Covert Response Activation to Test Latent Assumptions of Formal Decision-Making Models in Humans. *Journal of Neuroscience*, *35*(28), 10371–10385. doi:10.1523/JNEUROSCI.0078-15.2015

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, *18*(6), 643–662. doi:10.1037/h0054651

Vincent, S. (1912). The function of the vibrissae in the behavior of the white rat. *Behavioral Monographs*, *1*, 1–82.

Vorberg, D., Mattler, U., Heinecke, A., Schmidt, T., & Schwarsbach, J. (2003). Different time courses for visual perception and action priming. *Proceedings of the National Academy of Sciences of the United States of America*, *100*(10), 6275–6280. doi:10.1073/pnas.0931489100