Acta Psychologica 177 (2017) 17–22

Contents lists available at ScienceDirect

Acta Psychologica

journal homepage: www.elsevier.com/locate/actpsy

# Post-error response inhibition in high math-anxious individuals: Evidence from a multi-digit addition task☆

M. Isabel Núñez-Peña[a,b,e,*], Elisabet Tubau[b,c], Macarena Suárez-Pellicioni[d]

[a] Department of Social Psychology and Quantitative Psychology (Quantitative Psychology section), Faculty of Psychology, University of Barcelona, Spain
[b] Institute of Neurosciences, University of Barcelona, Spain
[c] Department of Cognition, Development and Educational Psychology, Faculty of Psychology, University of Barcelona, Spain
[d] Department of Communication Sciences and Disorders, University of Texas at Austin
[e] Institut de Recerca Sant Joan de Déu, Spain

ARTICLE INFO

*Keywords:*
Math anxiety
Post-error slowing
Post-error accuracy
Response inhibition

ABSTRACT

The aim of the study was to investigate how high math-anxious (HMA) individuals react to errors in an arithmetic task. Twenty HMA and 19 low math-anxious (LMA) individuals were presented with a multi-digit addition verification task and were given response feedback. Post-error adjustment measures (response time and accuracy) were analyzed in order to study differences between groups when faced with errors in an arithmetical task. Results showed that both HMA and LMA individuals were slower to respond following an error than following a correct answer. However, post-error accuracy effects emerged only for the HMA group, showing that they were also less accurate after having committed an error than after giving the right answer. Importantly, these differences were observed only when individuals needed to repeat the same response given in the previous trial. These results suggest that, for HMA individuals, errors caused reactive inhibition of the erroneous response, facilitating performance if the next problem required the alternative response but hampering it if the response was the same. This stronger reaction to errors could be a factor contributing to the difficulties that HMA individuals experience in learning math and doing math tasks.

## 1. Introduction

Math anxiety is defined as an adverse emotional reaction to math or to the prospect of doing math (Hembree, 1990), and it is a topic of increasing interest because of its negative consequences for math achievement (for a recent review, see Suárez-Pellicioni, Núñez-Peña, & Colomé, 2016). High math-anxious individuals (hereinafter, HMA) perform more poorly on a range of numerical and mathematical tasks and obtain lower grades in math courses they take (Ashcraft & Krause, 2007), as compared with their low math-anxious peers (hereinafter, LMA). As a consequence, they avoid this subject in their academic curriculum (Hembree, 1990), limiting their opportunities at the professional level, which may result in a lower socio-economic status. Moreover, math anxiety not only has an impact in formal settings (math classroom or math tests), but also in more everyday settings (e.g., checking a tip on a restaurant bill when other are watching; Ashcraft & Moore, 2009).

It should be noted that math anxiety has a high prevalence in the population. Evidence of this can be found in the latest PISA report (2012, Programme for International Student Assessment), in which 15-year-old students from member countries of the Organization for Economic Cooperation and Development (OECD, 2013) reported agreeing or strongly agreeing with the following statements: *I get very tense when I have to do mathematics homework* (33%), *I get very nervous doing mathematics problems* (31%), and *I feel helpless when doing a mathematics problem* (30%). Furthermore, in the United States, 25% of four-year college students and up to 80% of community college students suffer from math anxiety from a moderate to high degree (Beilock & Willingham, 2014). It is therefore important to study whether math anxious individuals do anything different when processing a mathematical problem, as compared with their low math anxious peers, as this can help to broaden our understanding of the factors contributing to the relationship between high math anxiety and low math achievement.

☆ This research was supported by the Spanish Ministry of Economy and Competitiveness under grants PSI2012-35703 and PSI2015-69915-R (MINECO/FEDER), and by the Generalitat de Catalunya under grant SGR2014-177.
* Corresponding author at: Department of Social Psychology and Quantitative Psychology (Quantitative Psychology section), Faculty of Psychology, University of Barcelona, Passeig Vall d'Hebron, 171, 08035 Barcelona, Spain.
*E-mail address:* inunez@ub.edu (M.I. Núñez-Peña).

http://dx.doi.org/10.1016/j.actpsy.2017.04.002
Received 27 May 2016; Received in revised form 8 February 2017; Accepted 7 April 2017
Available online 18 April 2017

An important issue people face when solving a mathematical problem is how they react to errors. An error can affect the answer to subsequent problems in different ways. Intuitively, one might think that an error can help to improve performance because we learn from mistakes, hence the expression "mistakes are often the best teacher". The idea here is that an error might help us realize why we committed it and to pay more attention to the following problem/task. Unfortunately, an error can also block us from effectively solving the following problem, undermining the positive contribution that the mistake can make to learning. This is usually the case when errors are particularly relevant.

Error adaptation has been widely studied (Danielmeier & Ullsperger, 2011; Dulilh et al., 2012) and different accounts have been proposed to explain reactions to errors. The conflict monitoring account (Botvinick, Braver, Barch, Carter, & Cohen, 2001) claims that after an error or conflict the response threshold will increase. Thus, when an error is detected a compensatory control mechanism is activated in order to improve subsequent performance (i.e., we become more cautious after an error). Therefore, an increase in response time (known as *post-error slowing* – hereafter referred to as PES) and in hit rate (known as *post-error improvement in accuracy*) would be predicted following an error. This prediction has been confirmed in some studies (Danielmeier, Eichele, Forstmann, Tittgemeyer, & Ullsperger, 2011; Maier, Yeung, & Steinhauser, 2011; Marco-Pallarés, Camara, Münte, & Rodríguez-Fornells, 2008) and, as a result, PES has been considered a measure of cognitive control. According to this account, post-error adjustments would reflect an adaptive mechanism that would prevent the occurrence of further errors, supporting the learning function of errors.

An alternative view is offered by the orienting account (Notebaert et al., 2009), which claims that an error is an infrequent event that causes an orienting response, with post-error adjustment being considered as an attentional effect. Because of their infrequency, errors are unexpected, motivationally salient events which capture participants' attention and distract them during the processing of the subsequent stimulus. Thus, the orienting account predicts that previous errors will worsen performance, producing increased PES and a decrease in hit rate. Some studies have confirmed these predictions (Fiehler, Ullsperger, & Von Cramon, 2005; Rabbit & Rodgers, 1977). Hence, it has been suggested that post-error adjustments may result from a failure to disengage attention from the error (Carp & Compton, 2009) or from a failure to disengage from performance difficulties including increased response conflict (Compton, Arnstein, Freedman, Dainer-Best, & Liss, 2011). In this context, it is also worth noting a recent study by Van der Borght, Braem, and Notebaert (2016), who reported differences in post-error adaptations depending on trait anxiety and time. Using a Simon task they reproduced previous results showing that PES increased and post-error accuracy decreased with short inter-trial intervals (ITI), and that these effects were reduced or even reversed (for post-error accuracy) with increasing ITIs (Danielmeier & Ullsperger, 2011; Jentzsch & Dudschig, 2009). As suggested by Van der Borght, Desmet, and Notebaert (2016) these results are consistent with the idea that people have difficulties disengaging attention from the error shortly after error commission. Interestingly, the ITI effect on post-error adaptations depended on trait anxiety level. Only low-anxious individuals improved their performance when the ITI was long, suggesting that high-anxious individuals have difficulties disengaging from an error, even when time allows for it.

Finally, the inhibitory account (Ridderinkhof, 2002) suggests that the commission of an error activates an inhibitory mechanism that increases the strength of motor suppression or inhibition of responses on a subsequent trial. In this view, PES is linked to motor stopping or suppression of an action (i.e., behavioral response) that is considered inappropriate in a given context. The predictions made by this account for post-error behavioral effects are the same as those of the orienting account, namely that errors will worsen performance in the following trial, producing increased PES and a post-error decrease in accuracy. Marco-Pallarés et al. (2008) reported psychophysiological evidence supporting the inhibitory account. In their event-related fMRI experiment they found a coincidence between brain regions related to inhibition in a stop-signal task (consisting in presenting a red square in 25% of the trials, signaling to participants that they should inhibit their response) and the activation observed on correct trials occurring after error commission in a flanker task. They also found that PES correlated with an increase in beta band power, which has been associated with inhibitory processes and, specifically, with motor inhibition. These results suggest that PES is probably due to an increase in the amount of response inhibition after an error.

Although error adaptation has been widely studied, nothing is known about how HMA individuals behaviorally adapt after errors committed in a mathematical problem. This is an important question and exploring it could help in understanding the extent to which math anxiety reduces or interferes with learning from errors. In this context, Suárez-Pellicioni, Núñez-Peña, and Colomé (2013), using event-related brain potentials (ERP), found that math anxiety is related to an abnormal error monitoring processing. These authors formed two groups according to participants' level of math anxiety and asked them to perform a numerical Stroop task (participants were presented with a pair of numbers of different size and had to report the number of larger numerical magnitude while ignoring its physical size) and a classical word-color Stroop task. An increase in error-related brain activity (i.e., the error-related negativity potential - ERN) was found in the HMA group, as compared with their LMA counterparts, when they solved the numerical Stroop task, but not when they solved the classical one. Given that a source localization analysis of this component identified the right insula as being at the basis of this ERN enhancement for the HMA group in the numerical (vs. the non-numerical) task, the authors interpreted the result according to the motivational significance theory of the ERN (Hajcak & Foti, 2008; Hajcak, Moser, Yeung, & Simons, 2005) and suggested that HMA individuals might be characterized by a greater sensitivity to — and concern over — errors in numerical tasks. Suárez-Pellicioni et al. (2013) found differences between HMA and LMA participants after errors only in the ERN signature, and not at the level of post-error adjustments in performance (RT and accuracy). However, they used a numerical Stroop task and nothing is yet known about how HMA individuals react to errors in a more genuine mathematical task, like solving an arithmetic problem.

In the present study we examined post-error adjustments in high and low math-anxious individuals when they performed a multi-digit addition verification task. Two groups were formed according to their scores on the Shortened Mathematics Anxiety Rating Scale (Alexander & Martray, 1989) and on the trait subscale of the State-Trait Anxiety Inventory (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983), such that groups were extreme on the former but did not differ on the latter; thus, we could rule out the possibility that group differences could be explained by trait anxiety. In comparison with previous studies on error monitoring from our lab (Suárez-Pellicioni et al., 2013) the present study introduces two important new aspects: First, as mentioned above, we administered an arithmetic task which we believe is more informative regarding the difficulties HMA individuals face when they have to deal with math class requirements (as compared with a numerical Stroop task, which is an attentional task). Second, participants were given external error feedback, because we expected that becoming aware of their mistakes would be more emotionally arousing for the HMA group. In fact, error feedback can act in HMA individuals as a reinforcement of their own perceived low math self-efficacy, that is, of their belief in their low potential to do math successfully (Meece, Wigfield, & Eccles, 1990).

Given that previous studies have consistently shown that HMA individuals are characterized by an attentional control deficit when they have to process math information (e.g., Suárez-Pellicioni, Núñez-Peña, & Colomé, 2014, 2015), which would make them more vulnerable to distraction, and considering previous evidence from our lab