SHORT COMMUNICATION

Emotional modulation of cognitive control in referred gifted male adolescents: A pilot study

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OBJECTIVES: Self-regulation skills might help to understand the heterogeneity of adjustment behaviors in gifted youths. This study investigates the bottom-up influence of emotional material on cognitive control abilities (specific cognitive self-regulation skills) in gifted and non-gifted adolescents.
METHOD: Nineteen gifted male adolescents and twenty non-gifted adolescents completed three versions of the Stop Signal task, measuring the bottom-up influence of emotional material on cognitive control abilities (i.e., response inhibition, proactive and reactive adjustments).
RESULTS: Response inhibition abilities of the gifted adolescents were more impaired when emotional material has been presented, compared to the non-gifted adolescents. Gifted adolescents displayed more proactive adjustments than non-gifted adolescents. Finally, although gifted adolescents displayed more efficient reactive adjustment than non-gifted adolescents, their performances were more affected by emotional material.
CONCLUSION: This study shows that referred gifted adolescents display a different pattern of bottom-up influence of emotional material on specific cognitive control processes indicating differences in self-regulations skills of gifted adolescents.
Key Words: self-regulation; cognitive control; emotion; giftedness; adolescence
Abbreviations: ACC go: Mean Success Rate in Go Trials; MRT Go: Mean Reaction Time in Go Trials; SD go: Standard Deviation of the Mean Reaction Time in Go Trials; ACC stop: Mean Success Rate in Stop Trials; SSRT: Stop Signal Reaction Time.

INTRODUCTION

Giftedness refers to individuals with higher cognitive skills than their peers [1]. However, gifted individuals are not a homogenous population [2]. Indeed, some gifted adolescents present behavioral and social maladjustment [3] as well as school difficulties [4], which might be related to self-regulation difficulties [5]. Self-regulation skills allow the individuals to face the ever-changing environment or to achieve goals by adapting emotional and cognitive processes [6]. The study of these processes might help to better understand giftedness, which was done in a very few studies.

For instance Calero et al. [7] used the “self-regulation and concentration test for children”. In this task, participants had to stay focused on a main reaction time task in the presence of tempting distractors (a video in a corner of the screen associated with a variable reward). Results revealed better self-regulation abilities in 6- to 11-year old gifted children compared to controls. Moreover Chung et al. [5] assessed differences between gifted and non-gifted 13 to 15-year old adolescents in a social decision-making task (the “iterative binary public goods game”). This task refers to a multi-player social interaction test. Results showed that gifted adolescents had higher cognitive abilities, associated with a lower capacity to process affective information compared to non-gifted adolescents.

Although these studies are interesting because they inform us about the self-regulation skills in gifted youths, both of them used only one single task, which involved many cognitive control processes (i.e., specific cognitive self-regulation skills) as well as emotional components. This does not allow distinguishing between the various cognitive control processes and specific influence of emotion on these processes. One more specific way to assess self-regulation skills is to examine the bottom-up influence of emotional information on cognitive control skills. This procedure allows a specific assessment of the complex interplay between emotion and cognition.

The current study

This study is the first one examining the bottom-up influence of emotional context on cognitive control processes (i.e., self-regulation skills) in gifted adolescents. We expected that gifted adolescents present higher cognitive control abilities than non-gifted in tasks recruiting only cognitive component. Although the bottom-up influence of emotion on specific cognitive control abilities (i.e., proactive and reactive adjustments) was never studied before, a similar detrimental effect to those observed for response inhibition [8] is expected. Indeed, according to the Dual Competition Model [9,10] emotions are preferentially processed and thus recruit part of the shared pool of attention resources leaving less resources to perform effortful cognitive processes and thus impairing cognitive control processes. Taking into account the higher emotional sensitivity [11] presented by gifted adolescents, a greater impairment of these cognitive control abilities due to the emotional material is expected in the gifted adolescents compared to the impairment observed in the non-gifted participants.

MATERIALS AND METHODS

Participants

The study sample is composed of nineteen boys gifted adolescents, (i.e., only boys to reduce heterogeneity of the sample and according to sex differences in emotion processing; see 12) followed in a public hospital for school difficulties or social maladjustment. Participants are aged from 12 to 18 years (M=15.13; SD=2.10); have an intellectual quotient (IQ; 13) higher than 125; have typical cognitive and affective giftedness features such as lively wit and quick thinking, very observant, alert, perceptive, and intuitive; and have no diagnosed psychiatric disorders. Twenty-four age-matched male adolescents (M=15.96; SD=1.32) from a comparable socio-economic background were recruited. Four adolescents were excluded for scores higher than the normal range (i.e., percentile 95) on the Colored Progressive Matrices [14].

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All participants, and their caretakers for children younger than 14 years, gave their informed consent to participate to the study. The procedure was approved by the local ethics committee. Participants received monetary compensation for their participation in the study.

Material and Procedure

The study consisted in the administration of 3 computerized versions of the Stop Signal task, varying in the nature of the stimuli: colored circle, neutral faces, and faces expressing emotions. The faces were selected from the Macbrain Face Stimulus database (www.macbrain.org).

Stop Signal tasks

A detailed description of the tasks as well as of the measures is provided in supplementary file. To sum up, the three tasks (differing on the material processed from circles to neutral faces and finally faces exhibiting emotions) allow us to measure various cognitive control processes, namely response inhibition (stop signal reaction time, SSRT), proactive adjustments (delayed and speeded) and reactive adjustment (post-inhibition-related error slowing) as well as the bottom up influence of emotion on these processes.

Data analyses

The distributions of the scores in each group were screened with boxplots, which allowed us to identify a small amount of outlier data (4 scores, 1.28% of the whole data), mainly in the gifted group. These scores were removed before statistical analyses in order to be able to conduct parametric analyses of variance [15]. Furthermore, the examination of skewness and kurtosis revealed that the data suited Gaussian-like distributions and therefore we used parametric statistical tests. In particular, we tested the effect of emotional context on cognitive control processes by computing analyses of variance (ANOVA) including between subject factor (i.e., groups) and a within-subject factor (i.e., conditions) on the main scores. We computed a 2 (groups: gifted vs. control) × 3 (conditions: classical, neutral vs. emotion) ANOVA on the SSRT, delayed proactive adjustment, speeded proactive adjustment and reactive adjustment. Post-hoc tests were computed with Least Square Differences (LSD). By convention the statistical significance was set at $p<0.05$. The analyses were conducted with Statistical Package for Social Sciences version 23. Additionally, we verified the null effect with JASP program using Bayesian estimate repeated measure ANOVA, to be sure that they are null effect and not resulting from a lack of power. These latter analyses revealed that all non-significant results reflecting strong evidence of null effect (high Bayesian Factors_{01}).

Table 1: Descriptive statistics.

	Conditions					
	Classical		Neutral		Emotional	
Measures	Mean	SD	Mean	SD	Mean	SD
			Control group			
ACC go	0.95	0.04	0.93	0.05	0.90	0.09
MRT go	787.18	208.71	838.06	180.83	848.99	144.08
SD go	214.05	46.97	219.05	51.67	200.96	43.06
ACC stop	0.59	0.07	0.59	0.07	0.60	0.05
SSRT	117.57	109.80	151.54	131.71	147.81	122.09
Delayed proactive	0.25	0.08	0.24	0.06	0.21	0.05
Speeded proactive	0.18	0.07	0.15	0.06	0.15	0.06
Reactive	0.03	0.11	0.01	0.10	0.05	0.08
			Gifted group			
ACC go	0.92	0.09	0.93	0.06	0.88	0.11
MRT go	750.66	246.42	787.03	198.51	837.75	180.22
SD go	218.32	73.52	212.81	68.08	206.00	54.01
ACC stop	0.58	0.08	0.57	0.07	0.58	0.07
SSRT	134.86	150.23	165.05	152.15	233.30	60.79
Delayed proactive	0.22	0.10	0.24	0.09	0.19	0.07
Speeded proactive	0.23	0.07	0.23	0.20	0.17	0.07
Reactive	0.12	0.14	0.07	0.13	0.01	0.11

Note for Table 1. Ratio proactive: ratio score operationalizing proactive adjustments (see supplementary file for details); Ratio reactive: ratio score operationalizing reactive adjustments (see supplementary file for details); Ratio risky: ratio score operationalizing risky response in Go trials (see abbreviation description above).

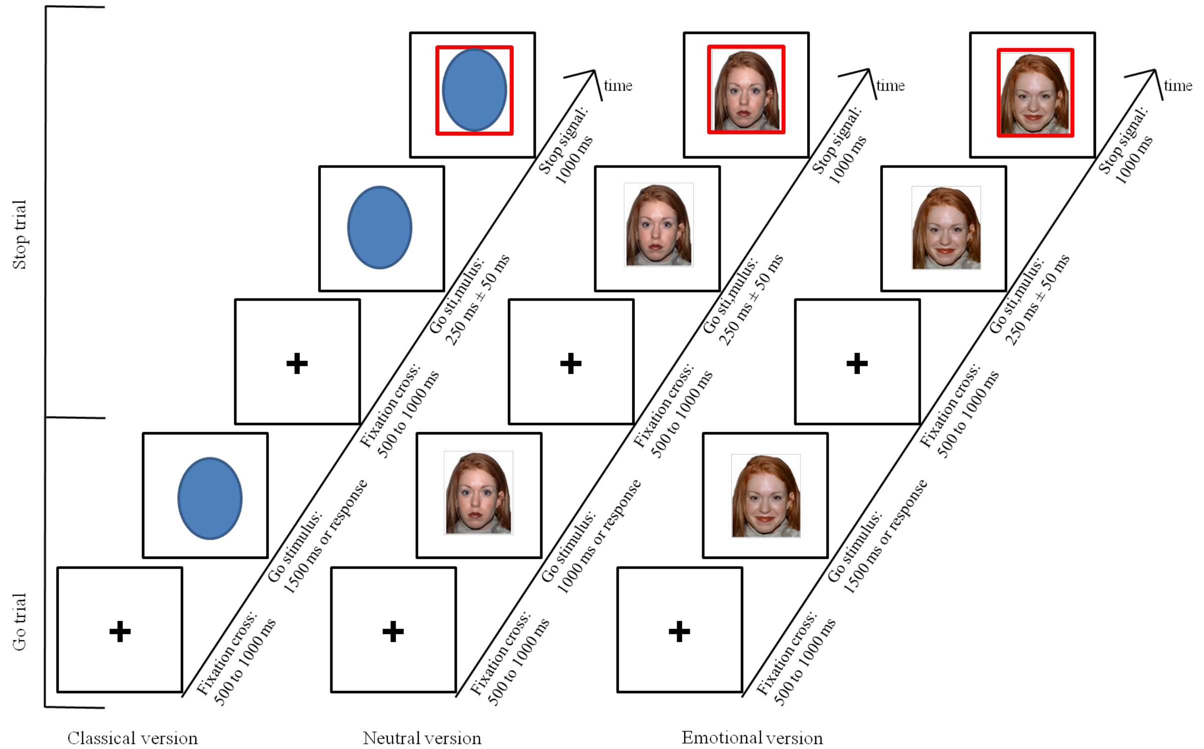

Figure 1: The three versions of the Stop Signal task. Adapted from Faces presenting sadness enhance self-control abilities in gifted adolescents by Urben S, et al.; Copyright © 2018, John Wiley and Sons, Inc. and from Balance among Cognitive Control Processes: a Case Study of a Gifted Youth by Urben S, et al. Copyright © 2018.

RESULTS

Response inhibition

The 2 × 3 ANOVA on the SSRT revealed a significant main effect of condition, $F(2, 70)=7.24$, $p \leq 0.001$, partial $\eta^2=0.171$, no main effect of group and a significant interaction effect, $F(2,70)=3.71$, $p<0.05$, partial $\eta^2=0.096$. Post-hoc tests revealed that, although in non-gifted adolescents, no difference was observed between the conditions; in gifted adolescents, higher SSRT were observed in the emotional condition compared to the classical ($p<0.001$) and the neutral conditions ($p=0.004$). Additionally, gifted adolescents showed significantly higher SSRT than the control group in the emotional condition only ($p<0.016$).

Proactive adjustments

The 2 × 3 ANOVA on the delayed proactive adjustment ratio score revealed a significant main effect of condition, $F(2,70)=4.21$, $p<0.05$, partial $\eta^2=0.107$, but no main effect of group and no interaction. Post-hoc tests revealed that less delayed proactive adjustments were made in the emotional condition compared with the classical ($p=0.028$) and the neutral ones ($p=0.006$).

The 2 × 3 ANOVA on the speeded proactive adjustment ratio score revealed a significant main effect of group, $F(1)=6.32$, $p<0.05$, partial $\eta^2=0.153$. Gifted adolescents showed higher speeded proactive adjustment scores compared to non-gifted adolescents. This did not vary across conditions, as the main effect of condition and the group x condition interaction was not significant.

Reactive adjustments

The 2 × 3 ANOVA on the reactive adjustment ratio score revealed a significant interaction effect, $F(2,70)=4.90$, $p \leq 0.01$, partial $\eta^2=0.123$. Post-hoc tests showed that, although no difference was observed in non-gifted adolescents; in gifted adolescents, reactive adjustments scores were lower in the emotional condition compared to the classical ($p<0.001$) and the neutral ($p=0.031$) one.

DISCUSSION

A few studies investigated self-regulation skills in gifted adolescents [5,7]. Therefore, this preliminary study sought to investigate specific self-regulation skills of gifted adolescents. The main results of this study were that (a) speeded proactive adjustment (i.e., risky choices) and reactive adjustment (i.e., error monitoring) were more efficient in gifted compared to non-gifted adolescents; (b) response inhibition abilities and delayed proactive adjustment were impaired by the presentation of emotional material (bottom-up influence); and (c) a greater impact of emotional material in gifted compared to non-gifted adolescents was observed on response inhibition and reactive adjustment (i.e., error monitoring). We discussed the theoretical implications of these three findings.

Cognitive control efficiency in gifted youths

Speeded proactive adjustment (i.e., risk taking) was more important in gifted than in non-gifted adolescents. As proactive adjustments were linked to the appraisal of the likelihood of the appearance of the stop signal [16], we hypothesized that gifted adolescent showed a better understanding of the Stop Signal task procedure and thus could speed up their response when necessary and without committing more errors.

Additionally, error-monitoring abilities were higher in gifted than in non-gifted adolescents. These results are consistent with Liu et al. [17] study demonstrating in an EEG paradigm using a cued Go/No-go task that gifted adolescents had better cognitive control abilities and more efficient brain substrates with regards to response preparation and conflict monitoring. However, and contradictory to some previous studies [17,18] response inhibition as measured with the Stop Signal task was not more efficient in gifted than in non-gifted adolescents. This divergence in findings might result from the different paradigms used to measure response inhibition.

Indeed, Arffa [18] used the Stroop task in which flexibility or resistance to distractors processes are necessary to perform the task [19]. Liu et al. [17] used a cued Go/No-go task to assess response inhibition. In the Go/No-go task, as demonstrated by Verbruggen and Logan [20], due to the consistent association between a stimuli and one type of response, automatic associative learning through practice is developed over time [21]. The current study used a more appropriate paradigm to assess controlled inhibition processes, namely the Stop Signal task [20,22,23]. To reconcile these different findings, we might hypothesize that gifted adolescents have more efficient automatic associative learning, flexibility or resistance to distractors, which sustain their performance in the Go/No-go or Stroop tasks, but they do not have better response inhibition abilities, as specifically measured in the Stop Signal task.

Neuroscientific perspective

According to Vaivre-Douret [24], gifted adolescents possess better abilities in executive functions and a higher processing speed. Neurological studies have underlined the central role of the prefrontal cortex in these mechanisms [25,26]. Furthermore, gifted adolescents presented a high-level of prefrontal cortical functioning within a bilateral fronto-parietal network [27,28] providing an appropriate workspace in which information can be processed [29]. Thus, the greater efficiency in terms of structural [27] and functional brain aspects [30] observed in gifted adolescents might sustain the top-down influence exerted by cognitive control when performing the Stop Signal task. However, as we mentioned above, the lack of knowledge about gifted adolescents' cognitive control asked for further studies, because our study revealed that gifted adolescents are not systematically better in all cognitive control processes as it might be over-simplistically put forward.

Bottom-up influence of emotion on cognitive control processes

The present study examined the bottom-up influence of emotional material on the various cognitive control processes assessed in the Stop Signal task. We observed that response inhibition abilities and delayed proactive adjustment were impaired, independently of giftedness, by the presentation of emotional material. The impairment provoked by the emotional material on response inhibition abilities was consistent with previous studies in adults or children [8,31,32]. In the present study, the bottom-up influence of emotional material on delayed proactive adjustment skills was described. The dual competition model [9,10] allows understanding the bottom-up influence of emotional information on cognitive control processes. More specifically, this model suggests that both cognitive and emotional abilities contribute to ongoing behaviors through a shared pool of mental resources. Emotions positively or negatively affect effortful cognitive control processes in task resolution. Indeed, because emotional information is processed preferentially, it impairs the efficiency of effortful cognitive abilities, when it is not relevant for the ongoing behaviors, by recruiting part of the cognitive resources. In the Stop Signal task performed by this study's participants, more cognitive resources were recruited to perform the Stop Signal with emotional material, compared to the Stop Signal task with classical material. This additional recruitment of shared resource lead to fewer resources available for response inhibition and delayed proactive adjustments (i.e., the ongoing behaviors) in the Stop Signal task performed on emotional material compared to the classical version, resulting in the observed detrimental effect provoked by emotional stimuli.

Greater bottom-up influence of emotion on cognitive control processes in referred gifted youths

Results of this study showed a higher impairment of response inhibition and reactive adjustments by emotional material in gifted compared to non-gifted adolescents. The fact that gifted adolescents with socio-emotional difficulties are known for their hypersensitivity and intense emotional reactivity [11] could account for the higher bottom-up influence of emotional material in gifted than in non-gifted adolescents. Indeed, the recruitment of the shared resources by emotional material might be higher in gifted than in non-gifted adolescents regarding their hypersensitivity, and thus impaired response inhibition and reactive adjustments more. This is in line with the fact that, compared to non-gifted, gifted adolescents showed higher empathy and a greater ability to understand and transform perceptions into intellectual and emotional experiences [33,34].

Future studies

In future work, we should assess the generalizability of these findings, by extending the examination of bottom up influence on cognitive control in gifted girls. The choice to recruit only boys was made because more boys consulted in child and adolescents psychiatric facilities and in order to reduce the heterogeneity between participants. Additionally, future studies should examine non-referred gifted children (i.e., without socio-emotional adaptation difficulties) to generalize the results to a wider spectrum of gifted children. Such further studies will help to have a more global picture of the bottom-up influence of emotional material on cognitive control abilities in gifted youths.

CONCLUSIONS

In the present study, gifted adolescents showed a different pattern of bottom-up influence of emotional material on cognitive control processes than control peers. Indeed, although they possessed higher cognitive control abilities, the lower efficiency due to bottom-up influence of emotional material appeared more important in gifted adolescents than in non-gifted adolescents. This study represents a step towards a better understanding of self-regulation in giftedness.

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