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Does a non-practiced cognitive automatism withstand the test of time?

Laurent Grégoire[1,2] and Bénédicte Poulin-Charronnat[1]

Abstract

The present study aimed to ascertain whether the automaticity of a learned-cognitive process persisted after lengthy and complete cessation of practice. The musical Stroop paradigm offers the opportunity to test this specific question by evaluating the automaticity of note naming, the flexibility in manipulating practice of which is much greater than that of other cognitive automatisms like reading. Participants who previously attained a high level of musical expertise and ceased all musical practice for at least 3 years exhibited a musical Stroop effect, which attests to the automaticity of note naming. The musical Stroop effect was still observed in a subset of participants who completely ceased musical practice for more than 10 years. Our results suggest that the absence of practice, even over a very long period of time, does not eliminate the automaticity of cognitive processes.

Keywords

Stroop effect; interference; automatism; practice; musical expertise; learning

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Grégoire, Perruchet, and Poulin-Charronnat (2013) devised a new version of a musical Stroop task (for an earlier musical Stroop paradigm investigating motor automatisms in pianists, see Stewart, Walsh, & Frith, 2004). The basic arrangement comprises a musical note presented in various positions on a treble staff (see Figure 1). The name of a note is printed inside the musical note. The written name is either congruent (Figure 1a) or incongruent (Figure 1b) with the position of the note on the staff. When asked to read the written note names while ignoring the positions of the note on the staff, participants having received musical education are slowed down when the written names are incongruent with the note positions. This *musical Stroop effect* (MSE) attests to the interference[1] generated by the automaticity of note naming in musicians.

The primary motivation for studying the automaticity of note naming, instead of the automaticity of word reading as do the conventional version of the Stroop paradigm and most Stroop-like tasks (e.g., Flowers, Warner, & Polansky, 1979; Protopapas, Vlahou, Moirou, & Ziaka, 2014; Virzi & Egeth, 1985), stemmed from greater flexibility to manipulate practice. Control over the level of musical practice is tighter because musical notes are not ubiquitously present, as words are, in our daily environment. Thus, among a host of other possibilities offered for experimental exploration (e.g., Grégoire, Perruchet, & Poulin-Charronnat, 2014, 2015), and without any possible analogue in reading, the musical Stroop task provides the opportunity to observe whether the automaticity of note naming persists after extended cessation of musical practice.

It is generally argued that automatic motor skills, like riding a bike, are never forgotten (Anderson, 1983). In other words, the absence of practice would not affect the automaticity of motor skills, but what about a cognitive automatism? Very few studies focused on this specific question (Logan, 1990), and the scarce experiments on this topic were limited to a period without practice that did not exceed 15 months. After training participants to read typographically inverted text, Kolers (1976) observed persistence of inverted-reading abilities 13–15 months later. MacLeod and Dunbar (1988) reported an analogous outcome. They arbitrarily assigned a specific colour name to each of four black-and-white polygons, and participants were instructed to learn these names during successive

[1]LEAD, CNRS UMR5022, Université Bourgogne Franche-Comté, Dijon, France
[2]Affective Attention Lab, Department of Psychology, Texas A&M University, College Station, TX, USA

Corresponding author:
Laurent Grégoire, LEAD, CNRS UMR5022, Université de Bourgogne, Pôle AAFE, 11 Esplanade Erasme, 21000 Dijon, France.
Email: laurent.gregoire@u-bourgogne.fr

practice sessions. Following extensive shape-naming training, shape had an effect on colour naming in a Stroop-like task, and this interference persisted 3 months later in spite of complete cessation of shape-naming practice (Experiment 2). However, these studies were all related to an experimental learning situation and did not inform about an automatic process that has not been practised for several years. Note naming is an activity intensively practised over years by musicians, which relies on naturally occurring training and allows attaining a level of practice that is out of reach in laboratory settings. Most importantly, it is possible to find people who gained a high level of musical expertise in the past and then completely ceased musical practice.

The purpose of this study was to determine whether cognitive automatisms remained after a lengthy and complete cessation of practice. To do that, we used the musical Stroop paradigm to evaluate whether the automaticity of note naming persisted after an extended cessation of musical practice. We recruited participants who received more than 5 years of musical training, resulting in a high level of musical expertise or at least in the automatic processing of note naming. Grégoire et al. (2015) have demonstrated that note naming was automatic after only 2 or 3 years of musical practice. In addition, these participants had completely ceased to practise music or read musical notation for at least 3 years. We hypothesised that an MSE, attesting to the automaticity of note naming, should be observed.

Method

Participants

Twenty-six participants responded to advertisements published in Dijon local newspapers and social networks or sent by emails. Participants had to have followed a musical training programme (in a music conservatory or school) for at least 5 years before completely stopping all musical practice for at least 3 years. Advertisements also specified that participants should not review musical notation before coming to the laboratory. Two participants were removed because they reported having occasionally practised a musical activity (e.g., reading musical notation or playing an instrument) since the (declared) cessation of their musical practice. The final sample comprised 24 participants (15 females) with a mean age of 35.78 years (SD = 12.36), an average of 12.21 years (SD = 7.51) of musical training and an average period of musical practice cessation of 15.56 years (SD = 10.55). All the participants were instrumentalists during their musical training. Some of them practised a second (N = 11) and a third (N = 3) instrument simultaneously or subsequently to the first one. Five participants were also vocalists in parallel with their instrumental practice.

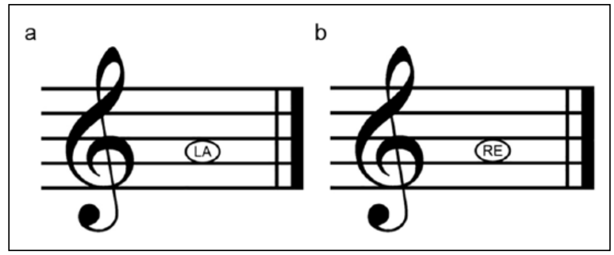

Figure 1. Examples of the two conditions used in the experiment: (a) congruent condition and (b) incongruent condition. Note that in musical French notation (and that of several other countries such as Italy and Spain), note names are DO, RE, MI, FA, SOL, LA, SI, instead of the first letters of the alphabet.

Materials

The stimuli consisted of a treble staff with a musical note, which could appear on each of the seven possible positions from C4 to B4. The name of a note was written inside the musical note. For the congruent condition, the note name was congruent with the note position on the staff (Figure 1a), whereas in the incongruent condition, note name and position were incongruent, with the name written inside the musical note being one of the six other possible note names (e.g., when the note was DO, the written name was LA, SI, RE, MI, FA, or SOL; Figure 1b).

To prevent the iconic memory of the treble staff from influencing the processing of the following note, the stimuli were randomly displayed at one of four possible positions without immediate repetition at the same location. The four positions were defined as the centre of (invisible) rectangles resulting from the exhaustive partitioning of the screen into four quadrants of equal size. Stimuli were printed in black over a white background on a computer screen. Note names appeared in standard uppercase font 14. The treble staff was 7.7 cm wide by 5.1 cm high.

Procedure

The participants performed a word-reading task in which two conditions were mixed: congruent (Figure 1a) and incongruent (Figure 1b). For each condition, the stimuli appeared six times on each of the seven locations, resulting in 42 trials per condition, and 84 trials (42 × 2) in total. On each trial, a fixation cross was displayed for 1 s at the centre of the screen before the apparition of the stimulus, which stayed on the screen until the participant's response. The interval between the response and the following trial was 1 s. The trials were pseudo-randomly ordered for each participant, excluding immediate repetitions of note locations or note names. They were displayed as four blocks of 21 trials each with a self-paced break between blocks.

Participants were asked to read aloud the printed word while ignoring the musical note. They were encouraged to respond as fast and as accurately as possible throughout the session. The response times (RTs) were recorded by a voice key. During the session, the experimenter noted error responses and voice-key malfunctions. After the experiment, the participants filled out a questionnaire about their musical training.

Results

Voice-key dysfunctions and speech failures led to the exclusion of 3.92% of the data. The proportion of reading errors was marginally greater (statistically) in the incongruent condition ($M=0.40\%$, $SD=0.92$) than in the congruent condition ($M=0.10\%$, $SD=0.51$), $t(23)=1.78$, $p=.089$, $d=.36$. RTs for correct responses beyond 3 *SD*s of the mean (0.62%) were removed. The remaining data are shown in Figure 2a (the two left bars). RTs were significantly higher in the incongruent than in the congruent condition, $t(23)=3.72$, $p=.001$, $d=.76$, JZS Bayes Factor = 31.50, in favour of the alternative hypothesis (Rouder, Speckman, Sun, Morey, & Iverson, 2009), attesting to the presence of an MSE.

The same analyses were conducted on a subset of participants whose musical practice had ceased for at least 10 years. We obtained 15 participants (11 females) with a mean age of 41.23 years ($SD=11.68$), an average of 11.97 years ($SD=8.80$) of musical training and an average period of musical practice cessation of 21.40 years ($SD=9.21$). Voice-key dysfunctions and speech failures led to the exclusion of 3.65% of the data. The proportion of errors was numerically greater in the incongruent condition ($M=0.48\%$, $SD=1.00$) than in the congruent condition ($M=0.17\%$, $SD=0.65$), but the difference was not significant, $t(14)=1.46$, $p=.177$. RTs for correct responses beyond 3 *SD*s of the mean (0.66%) were removed. The remaining data are shown in Figure 2a (the two right bars). RTs were significantly higher in the incongruent than in the congruent condition, $t(14)=2.67$, $p=.018$, $d=.69$, JZS Bayes Factor = 3.42, in favour of the alternative hypothesis, indicating that the MSE was also present more than 10 years after the complete cessation of musical practice.

We noticed that RTs in the subgroup who had ceased musical practice for at least 10 years were longer than RTs in the entire sample. This difference could result from participants' age. In our study, most subjects ceased musical practice upon engaging in active life or higher education (before 30 years old for 83.33% of participants). Thus, the oldest participants were more likely those who had ceased musical practice for more than 10 years. Mean RTs (regardless of the condition) were significantly correlated with age, $r(22)=.750$, $p<.001$, JZS Bayes Factor = 1,091, in favour of the alternative hypothesis. However, age was not significantly correlated with the MSE, $r(22)=.066$, $p=.761$, JZS Bayes Factor = 3.78, in favour of the null hypothesis. We have also computed a corrected MSE, calculating (incongruent RT − congruent RT)/incongruent RT, to reduce the possible unreliability of the difference score employed to calculate the MSE (for analogous logic used in studies examining the phonological similarity, see Beaman, Neath, & Surprenant, 2008; Logie, DellaSala, Laiacona, Chalmers, & Wynn, 1996; Wang, Logie, & Jarrold, 2016). Age was still not significantly correlated with the corrected MSE, $r(22)=.015$, $p=.945$, JZS Bayes Factor = 3.94, in favour of the null hypothesis. These results suggest that age affects reaction times but not the MSE.

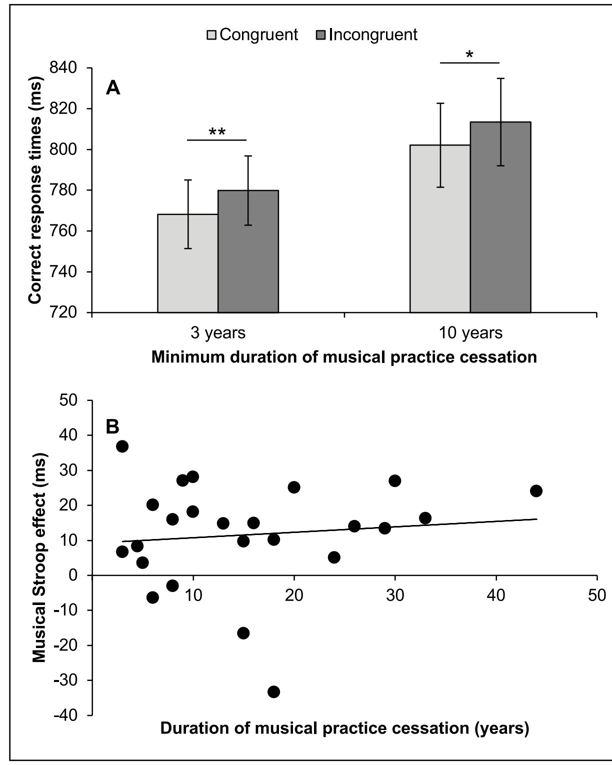

Figure 2. (a) Correct response times as a function of condition and minimum duration of musical practice cessation. Asterisks indicate significant differences within groups (*$p<.05$, **$p<.01$). Error bars represent standard errors. (b) Musical Stroop effect as a function of the duration of musical practice cessation.

Correlational analyses

To test the hypothesis that the absence of musical practice did not affect the automaticity of note naming, we performed correlational analyses between the duration of musical practice cessation and the MSE. A negative correlation would indicate a decrease in note-naming automaticity as a function of the duration of musical practice cessation. No significant relationship was observed between the MSE and the duration of musical practice cessation (Figure 2b), $r(22)=.109$, $p=.611$, JZS Bayes Factor = 3.50, in favour of the null hypothesis, indicating that the data are 3.50 times more likely to have occurred under the null hypothesis than under the alternative hypothesis, a "substantial" Bayes factor according to the coarse category scheme proposed by Jeffreys (1961). When the level of musical practice (evaluated by the number of years of musical training) was controlled, this correlation did not change markedly, $r(21) = .134$, $p = .543$, JZS Bayes Factor = 3.50, in favour of the null hypothesis, indicating substantial evidence for the null hypothesis (Jeffreys, 1961; Wetzels & Wagenmakers, 2012). The same analyses with the corrected MSE revealed no significant relationship between the corrected MSE and the duration of musical practice cessation, $r(22) = .034$, $p = .873$, JZS Bayes Factor = 3.90, in favour of the null hypothesis. When the level of musical practice was controlled, this correlation was still low and non-significant, $r(21) = .056$, $p = .800$, JZS Bayes Factor = 4.08, in favour of the null hypothesis.

Discussion

The current study aimed to determine whether a cognitive automatism persisted after a protracted period without practice. The musical Stroop paradigm, which lends itself well to test this question, was used to evaluate whether note-naming automaticity is still present in musicians who completely ceased to practise music for several years. The word-reading task of the musical Stroop paradigm (Grégoire et al., 2013) was performed by participants who had achieved a high level of musical expertise in the past before ceasing all musical practice for at least 3 years. Results revealed an MSE, reflecting the automaticity of note naming, with a medium-to-large size effect. Interestingly, the MSE was also observed in a subset of participants who had completely ceased to practice music or read musical notation for more than 10 years. Thus, the note-naming automaticity persists despite complete and extended cessation of musical practice.

There was no indication of a relationship between the MSE and the duration of musical practice cessation, with substantial evidence for the null hypothesis, suggesting that these two variables are independent. The same result was observed when the level of musical practice (reached before the cessation of musical training) was controlled. However, due to interindividual differences, the number of years of musical training is probably not the most accurate indicator of musical expertise. Two musicians with the same number of years of musical training can differ substantially in musical practice and note-naming ability. Thus, our data do not permit to firmly conclude that the absence of musical practice would not affect the automaticity of note naming. Nevertheless, our results show that if the level of note-naming automaticity declines in the absence of musical practice, the decay must be relatively weak because we observed a reliable MSE, even in a subgroup of participants who had ceased musical training for an average period of 21.40 years.

This study demonstrates Stroop interference after a protracted period without practice of the irrelevant dimension (i.e., note naming). Despite the abundant literature on the Stroop effect, no prior study reported a similar result, mainly because the irrelevant dimension used in the Stroop paradigm is usually related to natural learning without possible interruption of practice (e.g., reading). To our knowledge, only one study revealed a Stroop effect after a period without practice of the irrelevant dimension, but the interruption only lasted 3 months (MacLeod & Dunbar, 1988). Note also that in our situation, the practice of the *relevant* dimension (i.e., reading) has never been interrupted. Grégoire et al. (2014) proposed a model (based on the connectionist model of Cohen, Dunbar, & McClelland, 1990) in which the pattern of interference observed in the musical Stroop task depends on the relative strength of the two competing dimensions (reading and note naming). In this model, the strength of a process is a function of the amount of practice. Thus, the more the difference between the strength of word reading and note naming increases (in favour of reading), the more the MSE decreases, and vice versa. In the current study, word reading has continued to be practised while note naming was not (during the musical practice cessation), probably resulting in an attenuation of the MSE. However, this potential reduction was not sufficient to extinguish the MSE. This reinforces our conclusion about the persistence of the automaticity of note naming.

Automatic processes are characterised by different features, the most commonly accepted of which are irrepressibility (i.e., the activation of an automatic process is involuntary and difficult to suppress once started, such as reading in the classic Stroop effect or note naming in the MSE), efficiency (i.e., an automatic process requires minimal attentional capacity), and speed (Moors & De Houwer, 2006; Perruchet, 1988). Previous research reported perseveration of efficiency and speed up to 15 months after the practice cessation (e.g., Kolers, 1976; see also, Fisk & Hodge, 1992). The present study demonstrates that the irrepressibility of automatic behaviour is also very resistant to the absence of practice, even after 10 years of training cessation. It is worth adding that the features of automaticity do not necessarily evolve at the same pace, though it is commonly admitted that they evolve in parallel (Moors & De Houwer, 2006). Logan (1985) suggested that "each property has its own time-course of change with practice" (p. 373).

To conclude, this study extends our knowledge about the robustness of learning and reveals that the automaticity of a cognitive process (acquired through an extensive and natural training) persists even after a very long period without practice.

Declaration of conflicting interests

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ORCID iD

Laurent Grégoire https://orcid.org/0000-0002-3519-6395

Note

1. For the sake of simplicity, the difference between incongruent and congruent conditions is here termed interference, even though part of the effect may arguably be due to facilitation in the congruent condition.

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