Automaticity of Musical Processing

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Abstract

For this study, the researchers utilized a classic experiment involving the Stroop Effect, modified for the purpose of introducing audio stimuli. A group of 38 participants, all Caucasian, including both males and females, ranging from 18 to 22 years of age, with one outlier of age 53, took part in the study; 25 participants could read music, while 13 could not. Using a computer program, participants engaged in a Stroop task, including both congruent and non-congruent stimuli of audio and visual types. Participants were presented with four bars of music on their computer screen and, simultaneously, listened to four bars of music that were either congruent or incongruent with the visual stimulus. Their task was to identify the bars they were hearing as quickly as possible, while paying close attention to both stimuli. Though no significant difference was found between the accuracy and reaction times of participants who reported they could read music and those of participants who reported they could not, both mean accuracy and mean reaction times were greater for participants who reported they could read music. The findings on reaction time agree with our hypothesis, and we believe that, with further research and some modifications to our method, significant results agreeing with earlier Stroop research may be found.

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Red.

Blue.

Green.

Now, looking at the words printed above, what color inks are they printed in? Is your first instinctive answer correct, or is that information overridden by the word that is printed? If you find yourself naming the word that is printed rather than the color of the text, you should not feel bad. You have fallen victim to the experiment that, perhaps, causes the most frustration among cognitive psychology students, known as the Stroop effect. This effect is a result of the fact that, as we learn to read at such a young age, reading is an automatic process that we almost cannot prevent; when we look at a written word, it is, essentially, impossible *not* to read and process it, rendering other levels of information, such as the color text a word is printed in, secondary.

The actual Stroop task measures reaction time: how long it takes to pull out the relevant information—the color of the text—and identify it. As one might expect, it takes longer to identify the word "blue," written in red ink, as being written in red than the word "blue," written in blue ink, as being written in blue (Stroop, 1938). However, contrary to what emails forwarded across the internet state, this has little to do with one's intelligence; rather, it is an effect of selective attention, cognitive flexibility, processing speed, and the automaticity of tasks (Francis, Neath, & Van Horn, 2008).

If reading words can become an automatic task, perhaps other abilities also become automatic. Athletes have "muscle memory," or automaticized movements, to do things such as return a tennis serve, field a baseball, or shoot a three-pointer in a basketball game (Solso, Maclin, & Maclin, 2008). Musicians may experience a similar effect when it comes to the actual physical playing of their instruments, knowing by habit how to move their hands in order to draw the appropriate sounds, but what about when it comes to reading music? Can reading music become automaticized in the same way that reading words does?

If it can, and does, it would follow that it could be tested in the same way automaticity of language is tested using the Stroop test—by utilizing a musical Stroop test of sorts. Stewart (2005) has utilized a musical Stroop paradigm, presenting irrelevant musical notation during such a task, and found that this led to increased reaction time, thus implying that reading the musical notation presented was obligatory for the musically literate. Similarly, Wöllner, Halfpenny, Ho, & Kurosawa (2003) found that, when music students tried to sight-read a piece of music, while another incongruent piece of music played, their inner hearing of the piece they were sight-reading was disrupted, and they were more likely to make mistakes.

Another Stroop-based experiment demonstrated a tendency to seek congruence between visual and auditory stimuli; in a test of the synaesthetic qualities of pitches and their relation to the cognitive identification of meaning, participants responded more quickly in a case in which they were presented with what they perceived to be equivalent visual and auditory stimuli (Walker & Smith, 1983).

From these studies, we developed a musical Stroop task in which participants would be shown musical notation which could be either congruent or incongruent with music played through their headphones, and they would be asked to identify the tune which was playing. We hypothesized, based on preceding research with both the original

Stroop test and its musical applications, that participants who were musically literate would have slower reaction times in the incongruent condition and would also experience more difficulty with accuracy of identification than participants who could not read music.

Method

Participants

A total of 37 students and one faculty member from a small, Midwestern college participated in this study, for a total sample size of 38 participants. There were 17 males and 21 females. Age ranged from 18-22 years, with one outlier of 53. All 38 participants were Caucasian. Of the 38 participants, 25 could read music; 13 could not. All participants had normal or corrected to normal vision; none of the participants reported having any hearing difficulties.

Stimuli

Four bars of one of six simple tunes ("Mary Had a Little Lamb," "Frere Jacques," "Jesus Loves Me," "Ode to Joy," "Yankee Doodle," or "Twinkle, Twinkle, Little Star") played at random. A musical staff, four bars long, featuring musical notation for one of the six tunes was presented in the upper half of a computer screen. Notes changed color to indicate which note was being played simultaneously with the audio stimulus. The series of notes presented were either congruent or incongruent with the tune being played, depending on the condition. There were buttons at the bottom of the screen corresponding to each tune.

Equipment

Experiments were run on Gateway Model E4300 computers using a Java program (Krantz, 2010). The Java program used in this experiment was accessed using Internet Explorer 8.0. Stimuli were displayed on Gateway Model FPD1565 LCD monitors with a resolution of 1024x768. Participants used headphones to listen to the auditory stimuli, and also completed a demographics survey.

Procedure

Participants were given informed consent forms prior to beginning the experiment. All participants took part in both the congruent and incongruent conditions. In order to address order effects, half completed the congruent condition first and half completed the incongruent condition first. Participants were told that, while the music staff was displayed, they should watch it carefully. They were then instructed to indicate, by clicking the appropriate button, which tune was playing, rather than which tune was presented in the series of notes on the screen, as soon as they could identify it. Once a particular button was selected, it could not be unselected. There were twenty-five trials per condition, and the Java program figured both mean reaction time and accuracy. Between conditions, participants had a short break of a couple of minutes, as researchers collected the data from that condition and reset each program for the next condition.

Results

A repeated-measures ANOVA was run to analyze both the reaction time and accuracy data. The average accuracy and reaction time for music readers was greater in both conditions, but not significantly so. (For ANOVA statistics, see Table 1.) The non-significant trend for greater reaction time is demonstrated in Figure 1.

Table 1
ANOVA Statistics for Accuracy and Reaction Time in Music Readers

Dependent Variable * Congruence	
Accuracy	Reaction Time
$F(1,36)=.398$, $p=.532$	$F(1,36)=1.841$, $p=.183$

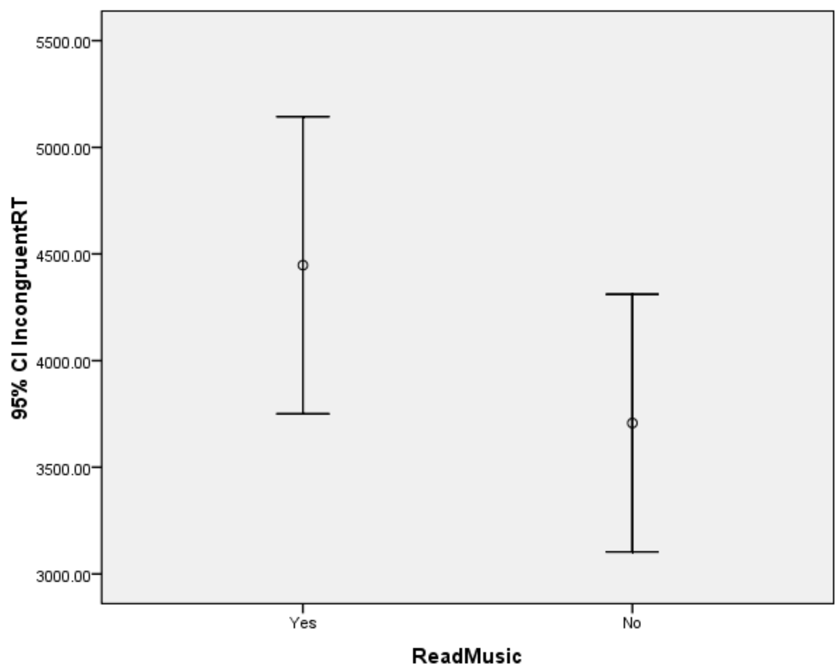

Figure 1. This graph shows the difference in reaction time in participants who could or could not read music. Note, in particular, the large error bars as potential explanation for the lack of significant difference.

Discussion

No firm conclusions can be drawn from this study. Though general patterns can be noted, statistical significance was not found. This is due, in large part, to extreme variance in both accuracy and reaction times. In a traditional Stroop task, 38 participants should show a very strong effect, with very small error, as seen in Figure 2 (Francis, Neath, & Van Horn, 2008). Because this experiment was a slow-reaction task, there was a large amount of room for variation. Minimum and maximum reaction times have a difference of up to six seconds.

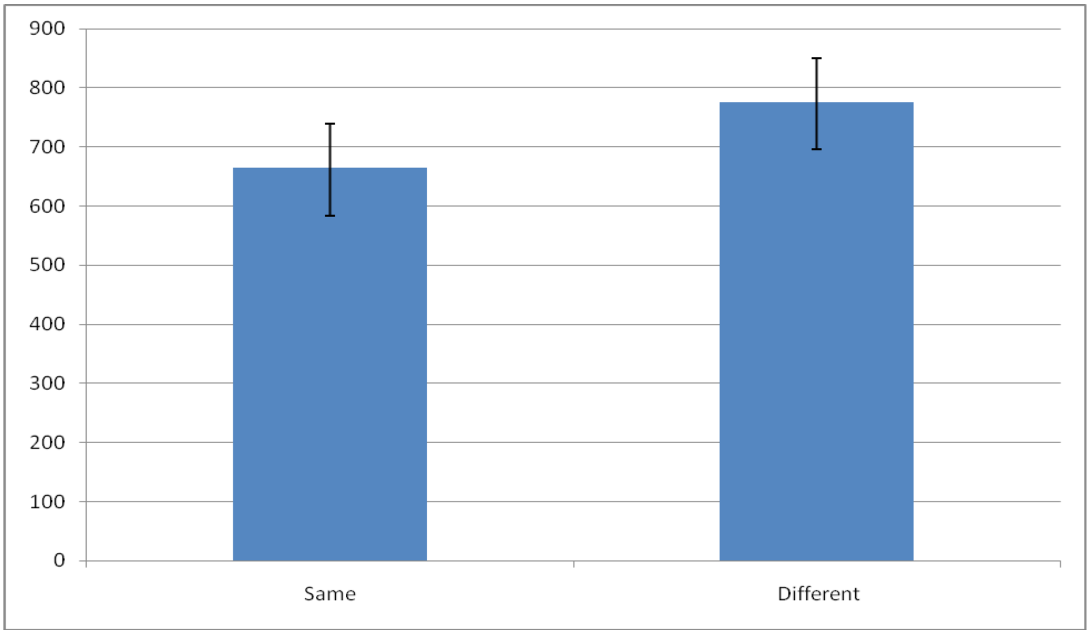

Figure 2. This graph shows a typical Stroop experiment response, with a strong effect for reaction time and small error bars, as collected by Francis, Neath, & Van Horn's CogLab software (2008).

MacLeod and Dunbar (1988) demonstrated that twenty hours of training in associating shapes and colors eliminated the normal effect found in a Stroop task. This indicates that there is a continuum of automaticity and that practice can reverse the effects of interference in a Stroop task. In our study, there was no assessment of expertise in musical training; participants simply indicated whether or not they could read music. If some participants regularly practiced music skills, others have not done so in years, but still retain the ability to read music, and still others only vaguely know how to read music and do not necessarily play an instrument or sing, but still indicated that they were musically literate on the demographic form, then this could be a contributing factor to our large error. Varying levels of practice and ability may produce varying levels of automaticity in processing, thus creating large variance in effects.

With this study, we attempted to examine the effects of incongruence on processing simultaneous auditory and visual stimuli; despite our lack of statistically significant results, based on previous research, we believe that future research would benefit from continuing to examine this effect.

For those who are musically literate, there is a tendency to interpret musical notes as music automatically, meaning that a note on a staff has automatic musical significance to a music reader (Stewart, 2005). However, this tendency is found when participants are forced to examine and process the visual stimuli. In this experiment, when the musical staff presented was incongruent with the audio stimuli, participants reported feelings of confusion and even discomfort caused by viewing the musical staff; therefore, rather than continuing to focus on the staff, and allowing it to have a direct effect on their accuracy and reaction times, participants were able to, and often did, elect, simply, to look away. Future studies examining this effect should use a more interactive visual stimulus in order to force participants to focus on and process it, as in Stewart's studies using a musical Stroop task (Stewart, Walsh, & Frith, 2004; Stewart, 2005).

In addition to utilizing more interactive visual stimuli, future study in the automaticity of musical processing might examine what associations exist between seeing musical notation and subsequent physical actions. Stewart (2004) suggests that musical training leads to the development of stimulus-response mappings that generalize outside of musical contexts—that is, "up," in the pianist's mind, also means "rightward."

Musical notation is, typically, read left-to-right, which may influence this phenomenon; also, higher notes on a staff indicate a higher pitch and would necessitate that a pianist move his or her hands rightward in order to play them, further reinforcing this association. Further research of this and similar phenomena may yield more insights as to the effects of this shift in visual-spatial mapping and other effects in processing.

Another possibility to consider is that, as there is a phonological loop for the written word once read (Solso, Maclin, & Maclin, 2008), music-reading may also be processed similarly. Initial searches into the literature find no research on this idea; however, if a person reads music in the same way they read words—that is, processing them auditorially—then, in research designs like ours, this would be like having two separate auditory stimuli to process, rather than one visual and one auditory. Though people are capable of sorting through multiple auditory stimuli to retrieve relevant information, as in the example of a person at a loud party nonetheless engaging in conversation, this might still interfere and cause problems in processing. This idea, therefore, deserves research in order to understand whether or not the phonological loop also extends to processing music.

In summary, despite our own research not producing any significant results, we remain confident, particularly upon examination of past research, that our hypothesis as to the effects of incongruent visual and auditory stimuli and the automaticity of musical processing merits further research. We hope that, by utilizing directions for future research outlined in this paper, we will be able to find significant evidence to support the idea that reading music can become an automatic process and is, therefore, subject to interference from incongruent stimuli, just as in processing the written word.

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