INTRODUCTION

Music and language use complex and structured sound sequences and share several perceptual and cognitive processes (e.g., Patel, 2003; Tillman, 2015). Correlations between music and language abilities, namely, reading proficiency, have repeatedly been reported (Strait, Horncamp, & Kraus, 2011).

In a longitudinal training study (ongoing) on the impact of music on reading and mathematical abilities, we have observed at pre-test correlations of reading with rhythm copy and timing skills, but not with rhythm or melody discrimination (Martins & Castro, 2016).

Aim: to study the relation between reading with music rhythm and timing abilities through working memory mediation.

METHODS

Participants

Table 1

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<thead>
<tr>
<th>N</th>
<th>Sex</th>
<th>SES</th>
<th>Handednessa</th>
<th>Age</th>
<th>IQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>81</td>
<td>43</td>
<td>38</td>
<td>23 low SES</td>
<td>12 middle SES</td>
<td>47 high SES</td>
</tr>
<tr>
<td>72</td>
<td>right-handed</td>
<td>5 left-handed</td>
<td>4 ambidextrous</td>
<td>[7.75 - 9.50]</td>
<td>[74 - 125]</td>
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SD - standard deviation; IQ - Intelligence Quotient (measured with WISC-III). 
SES - Socioeconomic status.

Tasks

- Reading: (1) reading fluency, number of correctly read words per minute; (2) single words/pseudoword reading (Portuguese SDM, Reis, Castro et al., 2015), reading of high and low frequency words and pseudowords; number of correctly read items per second.

- Auditory working memory: number of items correctly repeated (phonemes and syllables, WMS, Portuguese SDM.)

- Musical Aptitude tests (Overy et al., 2003; Moore & Overy, in preparation): (1) rhythm copy: reproduce each heard rhythm on a keyboard; (2) tap counting task ("note number detection", as termed by Overy, ib.); to count the number of taps (2, 3 or 4) heard in rapid succession (taps decreased from 1000 to 75 ms).

Data analysis

A principal component analysis was calculated with reading and auditory working memory measures that were reduced to one component each. A mediation analysis was computed to investigate the role of working memory on the relation between reading and the music related skills under analysis (SPSS mediation tool).

RESULTS

- Rhythm copy is positively correlated with reading and with auditory working memory.
- Tap counting is positively correlated with reading but not with auditory working memory.
- Auditory working memory mediates the correlation between rhythm copy and reading.
- However, the association of tap counting with reading is not mediated by auditory working memory.

<table>
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<tr>
<td>Correlation between music skills, reading skills and auditory working memory (N = 43).</td>
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<tr>
<td>Variable</td>
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<tr>
<td>Reading Skills</td>
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<tr>
<td>Auditory Working Memory</td>
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<tr>
<td>Rhythm Copy</td>
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<td>Tap Counting</td>
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** Significant at the 0.05 level with Bonferroni correction
*** Significant at the 0.01 level with Bonferroni correction

DISCUSSION

The results from this study revealed a significant indirect relation of rhythm copy with reading ability through auditory working memory. This finding is consistent with those of a growing number of studies that unveiled the link of rhythm with reading ability (e.g., Flaugnacco et al., 2014; Goswami, 2010) and with verbal working memory (e.g., Strait, Horncamp, & Kraus, 2011). More specifically, our results on rhythm copy are in line with a recent hypothesis that suggested that working memory might be a mediator of the relation between music and cognitive skills (e.g., Chen, Pentkune, & Zatorre, 2008; Lee et al., 2007).

In accordance with previous evidence (e.g., Hood & Conlon, 2004; Steinbrink et al., 2014) our results also showed a significant correlation between rapid timing skills (tap counting) and reading. Nevertheless, rapid timing did not correlate with auditory working memory, and hence no mediation effect was found.

The different results on rhythm copy and tap counting may be due to the different demands of both tasks. Working memory demands are probably higher to copy rhythms than to count taps, in the tasks used here. The rhythm sequences were typically longer than the tapping sequences and they had to be kept active in working memory in order to be replicated on the keyboard as soon as they were over. Furthermore, the rhythm copy task is analogous to the auditory working memory one since both require an overt motor response mimicking the stimulus, the difference lying on the effectors (tapping vs. speaking). In contrast, tap counting might rely more on other working memory components, namely, the articulatory loop. The counting task involves an "inner voice", or articulatory loop, that counts each tap as it is heard; a continuous representation of the tap sequence need only be maintained in working memory in the more rapid sequences, not in the slow paced ones.

Though preliminary, the findings from this study are consistent with the notion that auditory working memory is one of the mechanisms that mediates the relation between music and language abilities. Further analyses examining rhythm and timing with additional tasks, and addressing different components of working memory, will shed more light on this issue.

REFERENCES