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Influence of literacy on representation of time in musical stimuli: An exploratory cross-cultural study in Britain, Japan, and Papua New Guinea

Previous research has shown that literacy influences some dimensions of the visual (or graphic) representation of temporal events, and that concepts of time vary across cultures. The present exploratory study extends the scope of this research by examining representations of brief rhythmic sequences by individuals living in literate and non-literate societies. 122 participants were recruited at five sites: British musicians in the UK; Japanese musicians familiar and unfamiliar with English and Western Standard Notation (WSN) in Tokyo and Kyoto in Japan; language/WSN literate Papua New Guinean highlanders in Port Moresby; and non-literate BenaBena tribe members in Papua New Guinea. In the first study, participants listened to brief rhythmic sequences and were asked to represent these graphically on paper in any manner of their choosing. In the second study, participants matched the auditory stimuli with pre-constructed sets of marks varying in directionality (i.e., the direction in which they should be read to correspond with the auditory events). The responses of literate participants generally reflected the directionality of their acquired writing systems, while responses of non-literate participants conveyed no clear preference for directionality. In both studies, responses of literate and nonliterate groups in Papua New Guinea were distinct from each other.

'*Tradition is, in its very essence, unconscious. Tradition molds us, but we are always inside the mold and cannot look at it from the outside*.' Gjessing, G. (1968, p. 400)

Writing systems vary from language to language, one distinguishing feature being directionality of the text. For instance, while the conventional writing direction for most European languages using the Latin, Greek and Cyrillic alphabets is horizontal with a left-to-right directionality (H-lr), Arabic and Hebrew are written with a horizontal right-to-left direction. At the same time, Japanese kanji and Mongolian move vertically with a top-to-bottom directionality, though Japanese kanji may also appear in a horizontal left-to-right direction. In this paper, we consider whether directionality in one's acquired modes of written language might shape the depiction of non-linguistic information: In particular, might one's acquired written language influence the depiction of musically-organised sound?

Given the strong relationship between literacy and various kinds of symbolic and graphic representations (e.g., see Schmandt-Besserat, 1992) and the effect that acquisition of literacy has on the communities which make it part of their cultural practice (Goody, 1977), we set out to examine whether the previously demonstrated influence of literacy on visual representations of temporal events (e.g., Bergen and Lau, 2012; Dehaene, Bossimi and Giraux, 1993; Maass and Russo, 2003) may shape the representations of non-linguistic, musical information in five groups living in Britain, Japan, and Papua New Guinea. Of special interest was a group of BenaBena tribesmen and women of the Eastern highlands region of Papua New Guinea, who are unfamiliar with any literary or notational script.

Representation of time: language and literacy

The spatial representation of time has been shown to vary across cultures, even at a metaphorical level (Gentner, Imai, and Boroditsky, 2002). The foundations for these temporal concepts may have been laid down by biological evolution, but ‘it is cultural evolution that has determined its complexities and specificities … in interplay with linguistic resources and cultural practices’ (Núñez & Cooperrider, 2013, p. 227).

Humans appear to access culturally-specific spatial representations when making temporal judgements, even in non-linguistic tasks. In a study comparing English and Mandarin speakers, participants were asked to place into chronological order a series of images depicting time-span events (for instance, a person aging from a young boy to an old man, or filling a cup of coffee) (Boroditsky, Fuhrman and McCormick, 2010). Mandarin speakers were faster at presenting the series of events vertically than the English speakers – a finding that suggests that Mandarin speakers tend to conceive of temporal events in vertical (top-to-bottom) sequences, matching the emergence of meaning in traditional Chinese script. This contrasts with the horizontal left-to-right conception of time implied by English speakers in the study.

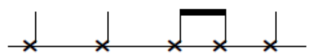
Fuhrman and Boroditsky (2010) similarly showed that Hebrew participants tend to create spatial representations of time in a horizontal right-to-left manner consistent with the directionality of the Hebrew alphabet. These findings are consistent with prior evidence that Dutch and Israeli participants' perception of temporal direction reflected the direction of their written language (Zwaan, 1965). Van Sommers (1984) found comparable results; when participants were asked to draw a visual representation of time, most provided horizontal left-to-right timelines proceeding from *earlier* on the left of the page to *later* on the right, with the second most common response being vertically top-to-bottom.

In related research, numerical magnitude appears to be generally conceived along a horizontal axis where numbers of increasing value prompt rightwards responses, and numbers of decreasing value prompt leftward responses. This observation of spatial-numerical association (known as the SNARC effect) has been found to apply to speakers of European languages and (in a reverse form) in Arabic (right-to-left) speakers (Zebian, 2005; Shaki, Fischer & Petrusic, 2009); although it was not observed in illiterate speakers (Zebian, 2005), or Iranian (right-to-left) speakers as shown in an earlier study based on a similar task (Dehaene, Bossimi and Giraux, 1993). There appears to be no horizontal numerical mapping in populations with mixed-reading habits; for those reading both Iranian and Hebrew, for example, where linguistic script is written H-rl, but numbers H-lr (Rashidi-Ranjbar, Goudarzvand, Jahangiri, Brugger & Loetscher, 2014).

Immersion in writing and graphical practices may eventually shape basic cognitive processes such as attention and memory. For instance, to examine if the orientation of a writing system affects visual attention, Chan and Bergen (2005) asked Taiwanese, Chinese and English participants to perform several spatially-oriented tasks involving memory. They found that English and Chinese participants accurately recalled images appearing on the left (the starting point of English and simplified Chinese script), while Taiwanese speakers were much more likely to correctly recall images appearing on the upper right side of a screen (the starting point of traditional Chinese script, which is predominant in Taiwan).

Overall, with some incongruities pointing to the complexity of the phenomenon, the existing evidence suggests a relationship between the directionality of script and visual representation or organization of events.

Representation of time: music

Given their temporal nature, acoustic events – especially musical ones – are often associated with spatialized visual metaphors. Previous studies have indicated the following cross-modal matches: pitch-height with vertical placement on an x-y plane, timbre with pattern-sign, loudness (volume) with size, and duration with horizontal length on the x-y plane (e.g., Walker, 1978; 1981; 1985; 1987); although loudness has also been associated with verticality (Eitan, Schupak and Marks, 2010) and length (Carello, Anderson and Kunkler-Peck, 1998). There have even been cases of onomatopoeia, as noted by Adachi (1997) in the depiction of attack rate information among Japanese child participants. For example, the rhythmic phrase  would be transcribed as ‘tan tan ta ta tan’ (Adachi, 1997: 417, Table 1, example 2). The act of transforming a perceived sound into an extant image has cultural implications, reflecting and influencing the perceptions of one’s social collaborators. Indeed, mental invocations of sound through metaphor (pitch in particular) vary cross-culturally (Eitan and Timmers, 2010; see also Merriam, 1964; Stone, 1981; Zbikowski, 1998). Evidence suggests that culture and other environmental influences affect individuals’ preference for those visual metaphors intended to represent sound, including exposure to cultural tools such as music notation and other graphical systems, musical training, and age (Sadek, 1987; Walker, 1987).

Previous investigations of graphic representations of music have usually used forced-choice tasks (e.g., selecting an image from an array that best matches a sound), in contrast to a study by Tan and Kelly (2004), which employed a free-drawing paradigm. Tan and Kelly found that when asked to freely make marks to represent what they heard, participants tended to create visual representations of short musical excerpts with a horizontal left-to-right alignment, with musical surface (primarily pitch or loudness) depicted with reference to an imagined vertical axis. The participants in their study resided in the United States where horizontal left-to-right directionality (English, Spanish) is dominant in representing language.

Background to the Present Study

Influenced by Tan and Kelly's (2004) free-drawing paradigm, Athanasopoulos and Moran (2013) examined the effect of cultural background on an individual's two-dimensional representation of musical sound, concluding that existing socio-cultural norms may affect the method of representation (symbolic versus iconic) based on the participants' use of signs in their everyday life. These two studies, in view of the evidence reviewed here, suggest that *the directionality of a writing system (or absence thereof) may systematically influence nonlinguistic tasks, such as the depiction of musical information in both free-drawing paradigms as well as forced-choice tasks.*

Previous studies examining the relationship between literacy and graphic representations of music have focused mostly on children. Notable in this body of work is the longitudinal data set collected by Davidson and colleagues (e.g., Davidson & Scripp, 1988) and research exploring what children's representations reveal about their experience of music and the implications for music education (e.g., Gromko, 1994; Reybrouck, Verschaffel, & Lauwerier, 2009; Upitis, 1992; Verschaffel, Reybrouck, Janssens, & van Dooren, 2010). With few exceptions (e.g., Auh & Walker, 1999, with Korean children) researchers have focused on western children. Research involving adult participants is scant, and has mainly examined the differences between individuals who are musically trained or untrained in western musical tradition (e.g., Küssner & Leech-Wilkinson, 2014; Tan & Kelly, 2004).

Regarding directionality in graphic representations of music, movement along an x-y plane has been almost uniformly observed in the aforementioned studies. For instance, in invented notations of music, young (western) children tend to create representations horizontally in a left-to-right direction (e.g., see Upitis, 1992, pp. 75-76). Similarly, when American college students who have never learned western standard notation (WSN) were asked in a semi-structured interview (Tan, 2002) and subsequent forced-choice study (Tan, Wakefield, & Jeffries, 2009) to describe their intuitions of how WSN is read, all participants in both studies moved from left to right. Although they showed no familiarity with WSN and often misinterpreted symbols – frequently treating rests as 'notes you play' and white notes (minims and semibreves) as 'silences you don't play' – they consistently moved from symbol to symbol in a left-to-right fashion similar to English script. As far as we are aware, no published cross-cultural research has directly explored the possible links between directionality of script and representation of time in musical representations.

The present investigation consists of two studies that examine how participants represent brief rhythmic sequences on paper in a free-drawing task that is open to their choice of manner of representation, and how they match these sounds with pre-drawn sets of marks that differ in directionality in a subsequent forced-choice task. The study focused on five groups:

- British nationals trained in western music who are primary speakers of English, which uses Latin characters represented horizontal left-to-right
- Japanese musicians trained in western music and familiar with English as secondary language.
- Japanese traditional musicians from Kyoto and Tokyo unfamiliar with English or WSN. Japanese can be represented with three writing systems which are written in two directions: either vertically top-to-bottom (kanji script) which is logographic, or horizontal left-to-right (kana scripts) which are syllabic.
- Papua New Guinean musicians familiar with WSN from the highland region residing in Port Moresby, literate in Tok Pisin (horizontal left-to-right directionality) and English as a secondary language.

- Non-literate BenaBena tribesmen and women from the rural highland region of Papua New Guinea.

If, in a non-linguistic activity such as the free representation of music, participants organize their responses along an axial timeline similar to their own adopted writing system and system of musical script, then individuals whose system of literacy and musical notation follows a horizontal-left-to-right directionality (English, literate Papua New Guineans) should tend to represent information similarly. Non-western educated traditional Japanese musicians may represent information vertically top-to-bottom, mimicking kanji script or traditional Japanese musical scripts, while Japanese musicians familiar with WSN may represent information horizontally from left-to-right and/or vertically from top-to-bottom. As for the non-literate members of the BenaBena tribe, this study may provide insight regarding tendencies concerning the directionality of depicting temporal information stemming from biomechanical affordances – such as optimal movements based on the anatomy of the hand and arm, motor and cognitive factors, and interactions with hand dominance (Braswell & Rosengren, 2002; Vaid, Singh, Sakhuja, & Gupta, 2002).

To the best of our knowledge, no previously published study has examined the possible relationship between directionality in writing and free-drawn graphic representation of musical stimuli in literate and non-literate groups. The present investigation therefore ventures into new territory and as such, should be viewed as an exploratory study.

Study 1: Free-Drawing Paradigm

The first study employed a free-drawing paradigm. Four participant groups listened to an array of musical stimuli varying in three parameters (pitch, duration, attack rate) of which attack rate will be the sole focus for this investigation. The instructions they were given were to *'represent the sound on paper, so that if another member of your community saw your marks, they should be able to connect them with the sound'.* This free-drawing task allowed the participants to employ their own method of representing the information and adopting their own response orientation/directionality, which is the focus of this study.

Method

Participants

A total of 122 participants were recruited for the two studies. Participants in Great Britain were recruited through a general call from the Edinburgh University Students' Association website between March and May 2011. In Tokyo, Japan, participants were recruited in May

2010 through a general call from the Tokyo Geijutsu Daigaku, and in Kyoto through personal contacts of members of staff from the Kyoto City University of the Arts. In Port Moresby, Papua New Guinea, participants were recruited between June and August 2010 through a general call at the University of Papua New Guinea and through personal contacts of the University's members of staff. Participants among the BenaBena tribe were recruited with the assistance of local community leaders and the village school-teacher.

The same participants were involved in both studies (although only 15 of the 24 traditional Japanese group were able to participate in the first study, so 113 took part in Study 1). A description of each group is provided in Table 1. All fieldwork data were collected from participants on site in Great Britain, Japan, and Papua New Guinea.

Table 1: Participants in the study

British
Native English speakers; musically literate in Western Standard Notation (WSN) n=25 (Mean age = 23.5 years; *SD* = 4.2 years; range: 19-37 years, 10 males, 15 females; 21 right-handed, 4 left-handed) Mean age began playing a musical instrument = 6.7 years (*SD* = 1.7 years, r: 5-11 years) Mean duration of performing a musical instrument = 15.7 years (*SD* = 4.4 years, r: 11-32 years)
Japanese western

Average or expert knowledge of English; familiar with WSN n = 22 (Mean age = 27.7 years; *SD* = 7.1 years; r: 18-51 years; 10 males, 12 females; 22 right-handed). Mean age began playing a musical instrument = 8.7 years (*SD* = 9.4 years; r: 4-15years). Mean duration of performing a musical instrument = 22.4 years (*SD* = 6.9 years; r: 10-41years). NB: 20 out of the 22 participants were also familiar with a form of Japanese Traditional Notation (JTN). The majority of JTN mimics kanji script in terms of directionality (Vertically top-to-bottom)
Japanese Traditional
Literate in Japanese; literate in JTN; scant knowledge of English language; minimal to no knowledge of WSN n=24 (Mean age = 47.6 years; *SD* = 26.4 years; r: 18-87 years; 11 males, 13 females; 23 right-handed, 1 left-handed) Mean age began a musical instrument = 18.6 years (*SD* = 12.3 years; r: 3-40 years) Mean duration of performing a musical instrument = 32.6 years (*SD* = 18.5 years, r: 8-63 years) NB: Japanese schooling has featured elements of western music education since the late 19th century; therefore all Japanese musicians have had exposure to WSN (Imoto, 2006).
Literate P.N.G.
Literate in Tok Pisin/English; familiar with WSN n=25 musicians (Mean age = 19.8 years; *SD* = 4.7; r: 18-26; 21 males, 4 females; 25 right-handed) Mean age began playing a musical instrument = 12.2 years (*SD* = 8.5 years; r: 5-14 years) Mean duration of performing a musical instrument = 8.5 years (*SD* = 2.6 years; r: 8-20 years) NB: Papua New Guinea is one of the most culturally diverse countries in the world (UNESCO, 2007). Participants in Port Moresby were selected on the basis of their original geographical background and language group (Eastern Highlands, Chimbu, Western Highlands, Southern Highlands and Enga provinces), ideally speaking a Trans-New Guinea language
Non-literate BenaBena

Unfamiliar with any form of literacy or music-notational script
n=26 (Mean age by estimation = 57.1 years; *SD* = 10.5 years; r: 35-80 years; 15 males, 11 females; 26 right-handed)
NB: As members of this group were unfamiliar with script, handedness was determined by asking them with which hand they used farming tools. Participants came from six hamlets (Keni, Logo, Sifu, Opeks, Siopeks, Moweto). Music among the BenaBena tribe is a highly communal activity: active performers are not separated from a non-participating audience. Therefore, all BenaBena are considered to be musicians for the purposes of this study.

Apparatus

The musical stimuli were generated using Sibelius 6 music notation software (Avid, 2009), exported as MIDI files at a tempo of 60 beats per minute, and produced using Digidesign Pro Tools 8 (DigiDesign, 2009). They were recorded in MP3 format and replayed to participants with a Samsung K5 MP3 player through in-built (slide-out) stereo speakers. A synthesized drum sound was selected to represent the auditory stimuli due to quick onset and lack of steady state of the amplitude envelope. By exporting the stimuli as MIDI file and converting them into more 'realistic' drum timbre with ProTools, we could ensure that pitch, articulation, and loudness were unchanging.

Participants were seated approximately one metre away from this sound source. The British, Japanese and literate Papua New Guinean groups participated indoors, but by necessity the study took place outdoors with the BenaBena as the rural huts have no windows or electricity to allow for sufficient lighting. Each session was videotaped with a

Samsung F30 SD Flash camcorder on a tripod at a distance fitting the participants' comfort level, ranging from 30 to 60 cm from the surface on which they were writing.

Stimuli

The auditory stimuli consisted of twenty short rhythmic patterns. In order to create musical stimuli appropriate for the five groups, musical elements common to all fieldwork sites were incorporated. To avoid fatigue effects, the patterns varied in complexity.

Of the twenty patterns developed, the first eight patterns are displayed in Figure 1. These serve as good examples as they were completed by all participating groups, and involve symmetric variations which permit comparison between groups (see Figure 1).

The order of presentation of the stimuli was initially randomized during trial runs, and then held constant for presentation in the sequence as shown in Figure 1. Based on pilot fieldwork, we presented the stimuli in a fixed order which allowed participants to tackle simpler rhythmic stimuli before moving to more complex (dense and longer) patterns. In a pilot study using the same stimuli and procedure, order effects were not observed in British (n=4), Greek (n=4), nor in Senegalese (n=4) groups. However, for Kalash participants (n=4) (a non-literate tribe based in northwestern Pakistan), stimuli presentation which progressed gradually in complexity elicited responses whereas presentation in randomized order did not.

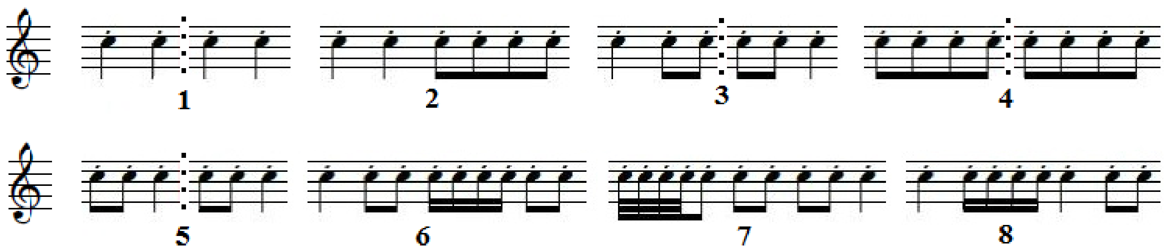


Figure 1: The symmetrical attack rate examples are numbered 1, 3, 4 and 5, with line of symmetry shown by the vertical dotted lines. The four asymmetrical examples are numbered 2, 6, 7 and 8. The numbers underneath the bars indicate the order of presentation (1 to 8).

Preparation and Practice Trials

Before the procedure started, participants were given instructions for the task and familiarized with the writing instruments: A4 graph paper (1cm x 1cm) and a ball-point pen. Only the BenaBena participants were unaccustomed to the fine-motor actions involved in holding a pen and providing responses on paper. However, their familiarity with pictorial representation through etching allowed a comparison to be drawn between etching or engraving and the concept of 'drawing' a sound. In order to facilitate participants' use of the pens, they were invited to draw simple images from their surrounding environment on plain white paper using thick coloured markers, and then ball-point pens. All participants were also given up to four practice runs to familiarize themselves with the task, using attack rate sound samples taken randomly from the database.

Procedure

The main procedure was administered either individually or in small groups (of two to four participants, sufficiently separated so as not to influence each other). The instructions given were to ‘represent the sound on paper, so that if another member of your community saw your marks, they should be able to connect them with the sound’. All instructions were provided orally in the first language of the participants. In Japan, members of staff from the Tokyo Geijutsu Daigaku and the Kyoto City University of the Arts provided assistance with the translations where necessary. In Papua New Guinea (BenaBena tribe), the local school-teacher served as the translator.

Participants were given 16 seconds to provide a written response. This timeframe was separated as follows: each individual sound sample was 4 seconds in duration followed by 4 seconds of silence, and the whole process was repeated for a total of 16 seconds. If participants were not able to provide a response, they proceeded to the next trial after this time elapsed and the next trial began directly after that.

Results

Coding

Participant responses were classified based on their method of representation of events in time (see Tan & Kelly, 2004, and Athanasopoulos & Moran, 2013) into three categories:

- Horizontal left-to-right (H-lr), imitating English / Tok Pisin / Japanese kana script, as well as Western Standard Notation (WSN).
- Vertical top-to-bottom (V-tb), loosely imitating Japanese kanji script and the majority of Japanese traditional notational scripts.
- Neither left-to-right nor top-to-bottom (NT): the participant's method of depicting information is not represented with apparent reference to a timeline.

Other variations (such as horizontal right-to-left (H-rl) and vertical bottom-to-top (V-bt) were not found in any of the spontaneous representations, but will be addressed in Study 2.

Coding was carried out by the first author in consultation with two independent coders from neighbouring disciplines (a professor of linguistics, and an advanced doctoral student in historical musicology). Coders worked independently at first. Each decision was then reached by majority rule, and discussed till consensus was reached. In rare disagreements (only 40 out of 904 items, or 4.42 %), the first author's decision was taken forward. Directionality was observed live during the task and verified in the video recordings of each session. The two other coders based their independent judgments solely on the videotapes, which consisted of close-up footage taken 30-60 cm from the surface of the paper.

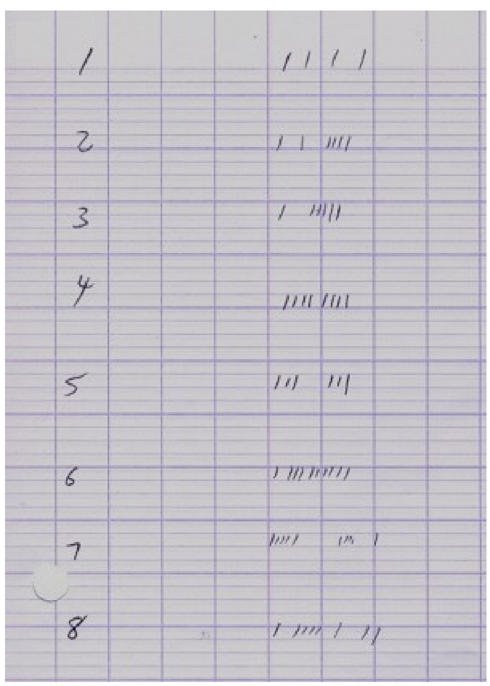
Responses from all individuals were internally consistent. In other words, all participants selected a method of representation regarding directionality during the trial runs and followed it through to the end of the procedure. Therefore each participant's response was coded first by writing axis first (H, V or NT); then if axial representation was present, the directionality (lr, rl, tb or bt) was determined. These classification terms were not disclosed to participants, who drew their responses freely without knowledge of our coding scheme. Table 2 depicts participant choice regarding directionality of responses.

Table 2. Response directionality.

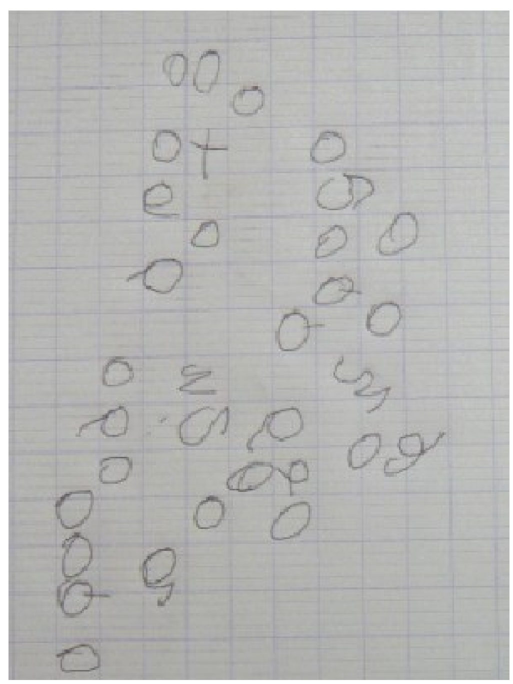
	British (n=25)	Japanese western (n=22)	Japanese Traditional (n=15)	Literate P.N.G. (n=25)	Non-literate BenaBena (n=26)
H-ltr	25	22	12	23	7
V-ttb	0	0	2	0	1
No directionality	0	0	1	2	18

The classifications are illustrated in Figure 2, showing examples from each category. The rhythmic patterns corresponding with the representations provided by the participants here are shown in Figure 1.

a)



b)



c)

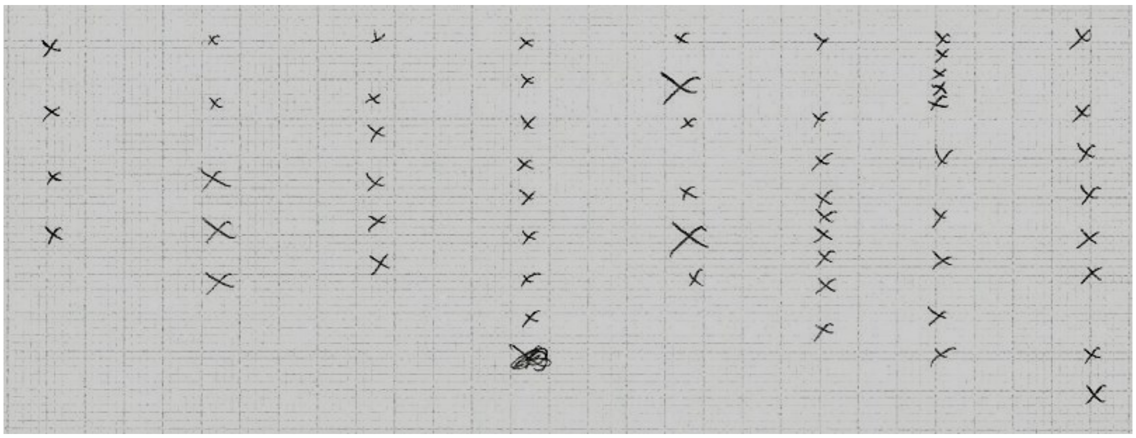
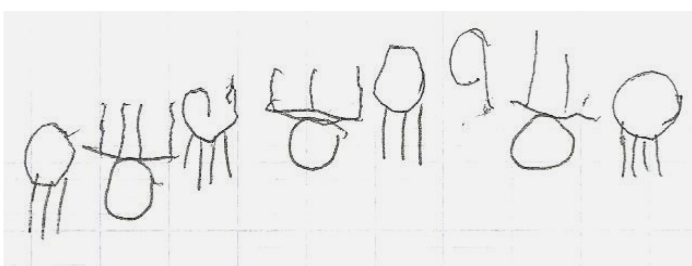


Figure 2: Examples of representations corresponding to auditory stimuli shown in Figure 1: a) Horizontally left to right by British participant; b) no clear directionality, by BenaBena participant; c) vertically top to bottom, by Japanese participant. The same 1 x 1 cm graph paper was used for all participants, thus differences in appearance are due to reproduction

Analysis

From Table 2, we see that the responses of British and western-trained Japanese musicians familiar with English are identical as all participants opted for horizontal left-to-right representation. British participants' method of representation along the horizontal left-to-right axis reflects the encoding system that they are already familiar with in both language and notated music. Japanese participants with western musical education and knowledge of English also used horizontal left-to-right representation. This could be the result of the musical nature of task itself, with participants opting for the representational method most similar to WSN. Interestingly, Japanese traditional musicians demonstrated a somewhat wider variety of responses with respect to directionality; however, the small number of participants in the group who completed this part of the procedure (n=15) did not permit formal comparisons.

The results from the Papua New Guinean groups were most striking. The majority of literate highlanders provided responses along the horizontal left-to-right timeline mimicking English and Tok Pisin script, while 18 of the 26 non-literate BenaBena participants provided responses following neither a horizontal nor vertical timeline. In informal interviews conducted after both procedures were completed, the BenaBena participants explained (through translators) that they tended to focus on producing visual representations that would accomplish the directives given to them in a manner meaningful to their peers. In other words, as instructed, they aimed to produce responses so that if another member of the community saw the representations, they would be able to link them to the sound events. Thus the BenaBena participants did not depict fine variations in the stimuli (such as the time structures of the drum sequences), but focused on such things as the physical likeness of the instruments creating the sound, with drum-heads being represented as circles. BenaBena participants who provided explanations during post-interviews mentioned that the lines in their visualisations represented the *action* of hitting the drum (either with sticks or hands), so their representations seem to encompass both iconic and enactive modes (as mentioned later in our discussion). It should be noted that the most common drum among the BenaBena is the kundu drum which is played by striking the drum head with the palm of the hand, rather than hitting it with a mallet or drum sticks. However, slit drums also exist, which are played with sticks. Stylistic differences depicting the action of a drum being struck led to different representational approaches. The orientation of the drums (positioned either above or below the vertical marks) was not explained by the participants. What was important to the BenaBena was the size of the drum-head: a bigger drum head meant that the stimulus was louder. This was particularly interesting as volume (and pitch) remained unchanged throughout the study. Some examples are depicted in Figure 3.

a. 

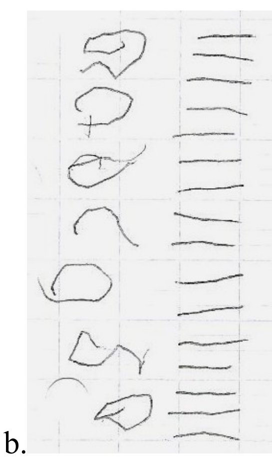
b. 

Figure 3. BenaBena depictions of rhythmic stimuli in the free-drawn study. Although participant in 3a represented each of the eight stimuli in a right-to-left order, this is not H r-l representation in our classification, as each representation functions to capture a whole rhythmic sequence. Participant in 3b used a similar method but positioned the icons vertically rather than horizontally on the paper.

With the exception of the Japanese traditional group, the data largely support our hypothesis that the directionality of a particular writing system (or absence thereof) may influence directionality of graphic representation of short musical patterns in a free-drawing paradigm.

Study 2: Forced-Choice Design

The second study tested the participants' choice on directionality of script by presenting them with eight pre-determined set of marks that depicted musical stimuli varying in attack rate. Four of these followed the four standard patterns of directionality: horizontal left-to-right, horizontal right-to-left, vertical-top-to-bottom and vertical bottom-to-top. Four additional sets of marks were created. All sets were novel to Study 2, including sets that combined elements from the four categories above. (This procedure took place after the free-drawing task, so as not to prime participants for a specific mode of representation suggested by the forced-choice design).

We hypothesized that English participants, literate highlanders from Papua New Guinea, and the majority of Japanese participants familiar with English and western standard notation would be more likely to select marks with horizontal left-to-right encoding, while Japanese monolingual participants with no western musical training would opt for vertical top-to-bottom encoding. We did not make any clear predictions for the non-literate BenaBena group because no established literary system was in place.

Method

Procedure

Participants were presented with two A4-sized papers containing 12 rows of 8 sets of marks and a pen, and were told that they would hear 12 sounds, one for each row starting from the top of the page. Then they were asked to *'select one shape from each row that most accurately represents the sound you have just heard, indicating your response by making any mark with the pen on the pattern you have selected.'* Instructions were provided orally in the participant's first language, in a similar manner to the first study. The same apparatus (Samsung K5 mp3 player) described in the first procedure was used to reproduce the sound stimuli. Participants heard the rhythmic patterns twice. Each pattern was a maximum of 4 s long followed by 4 s silent intervals before moving to the next sound sample, resulting in a total of 16 s per pattern to provide a response. If the participant could not decide, he or she would move on to the next sound pattern. All participants were able to provide responses within the given timeframe.

Materials

The attack rate stimuli consisted of 12 rhythmic patterns developed with the same parameters as those employed in the first study (see Figure 4).

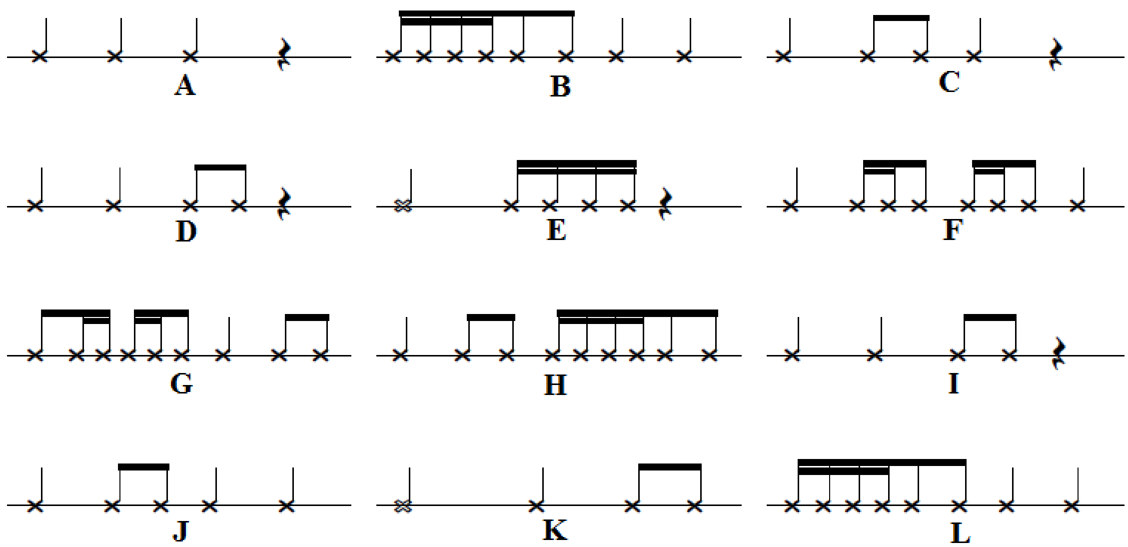


Figure 4. Attack-rate stimuli for forced choice design (created with Sibelius 6 software). The 12 variations are labelled A – L, and shown in western standard notation.

Eight visual stimuli were provided for each sound sample varying in attack rate while keeping pitch, musical articulation and loudness stable. In WSN, note values are indicated by using the colour or shape of the note head, the presence or absence of a stem, and the presence or absence of flags, beams and hooks. Rests (silence) are also indicated by symbols representing a specific duration. To create the visual representations used for stimuli, sound events were represented by vertical lines < **I** > to indicate the attack rate, while the absence of a line indicated a rest. The distance between the lines indicated the relative duration of the attack rate, similar to Repp, Bixby and Zhao (2011).

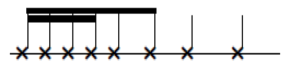
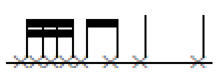
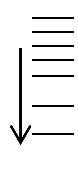
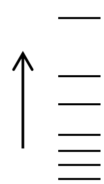
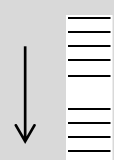
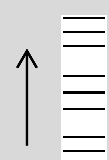
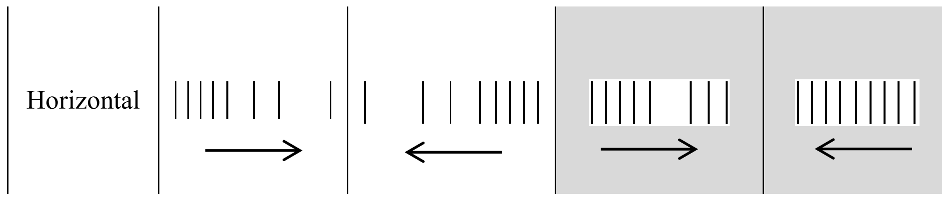
Each of the eight visual samples provided followed the parameters previously described. For example, rhythmic phrase B from Figure 4  would appear symbolically as  representing the sound stimulus in a horizontal left-to-right manner, similar to WSN and British linguistic script. Three other sets of marks representing the same number and occurrence of event onsets were depicted in horizontal right-to-left, vertical top-to-bottom, and vertical bottom-to-top symbolical representations. Four additional sets of marks consisted of patterns representing the same number of event onsets, but depicted incongruent temporal onsets (see Table 3).

Table 3. Visual representation stimuli of attack rate for the forced-choice study. For each of the 12 auditory samples, eight visual representations were generated. Half were congruent with the attack rate of the sample but varied in their directionality as shown by the arrows; the other four were incongruent in either/both grouping and/or number of onsets.

		Congruent		Incongruent	
	Vertical				



The full set of marks used in Study 2 are in Table S1, which may be found on the SAGE website.

Results

Each response was coded into one of the categories shown in Table 4 by the same three coders as for Study 1. As all participants marked their selections on the response sheets clearly (with no missing entries) and response-to-category codes were decided beforehand, agreement was 100% for a total of 1,464 items for the three independent coders.

As Table 4 shows, our main hypothesis was somewhat supported by the results yielded by the forced-choice procedure in our second study. The vast majority of the British participants selected sets of marks representing the auditory stimuli in a horizontal left-to-right fashion. Most of the Japanese participants familiar with English and WSN also opted for horizontal left-to-right depictions, with vertical top-to-bottom depictions as the second choice. The Japanese traditional musicians' responses showed a surprisingly similar pattern of responses to the Japanese group familiar with WSN, despite their supposed unfamiliarity with horizontal representations. The most striking difference was found between the responses of the literate Papua New Guinea group and their non-literate BenaBena counterparts: The majority of literate highlanders chose horizontal left-to-right depictions whereas non-literate participants from the BenaBena tribe selected mainly random responses (not based on any clear directionality and without internal symbolic organisation) and horizontal left-to-right responses. These random responses were selected by very few individuals in the other groups, and were a frequent choice only among the BenaBena participants.

Table 4. Participants' choices regarding the forced-choice selection of set marks.

Participants		**Directionality of responses in Study 2 (forced-choice)**				
	n	H-lr	H-rl	V-tb	V-bt	Incongruent
British Participants	25	**90.67 %**	1.67%	3%	1.33%	3.33%
Japanese familiar with WSN	22	**75.52%**	3.08%	**16.8%**	2.8%	1.8%
Japanese traditional	24	**72.61%**	1.79%	**20.7%**	0.6%	4.3%
PNG familiar with WSN	25	**78.9%**	7.2%	6%	2.5%	5.4%
BenaBena traditional	26	**41.11%**	**14.98%**	1.6%	0	**42.31%**

Note: All categories comprising 15% (rounded up to nearest whole number) or more of the sample are shown in boldface. (The percentages are based on all responses for the group (i.e., 12 choices for each participant) because unlike Study 1, responses to the forced-choice procedure were not always internally consistent. Therefore percentages reflect the proportion of all total responses in that category for each group).

It should be noted that the BenaBena participants were reluctant to provide responses to the forced-choice task. During the post-procedure interviews, the participants explained through their translators that the pre-selected sets of marks could not represent the attack-rate sound stimuli. A comparison between the responses provided by the BenaBena participants in the free-drawing investigation in Study 1 and the pre-selected marks in the second study may reveal the reason why: the majority of the BenaBena participants' representations depicted the auditory events of each discrete stimuli as a stand-alone icon based on a similarity between the sounds and their visual representations (i.e., drums being hit by sticks). They did not use arbitrary symbolic encoding requiring the spatial representation of time on orthogonal axes. When the BenaBena participants were presented with a symbolic method that differed fundamentally from the iconic mode of representation they had employed, the sets of marks may not have seemed fitting or appropriate to them.

General Discussion

The two studies provide some evidence in line with the hypothesis that directionality of script may influence depiction of non-linguistic information. More specifically, the focus was on the directionality of graphic representations of time-ordered events in the form of brief rhythmic patterns, as created by individuals at five sites in Britain, Japan, and Papua New Guinea. Results from the first study employing a free-drawing paradigm showed that linguistic script seemed to predispose individuals with the tendency to depict information along a timeline, in a manner generally consistent with the directionality of their script (except for the traditional Japanese group). In addition, familiarity with a writing system also seemed to influence mode of representation, as non-literate participants presented data iconically rather than symbolically.

More consistent results regarding directionality were obtained from the forced-choice design, as the difference between the Japanese participants and the other groups became more noticeable with respect to the occurrence of vertical representations of musical events (similar to Japanese kanji, top-to-bottom in directionality). The possible influence of acquired literacy becomes more prominent on closer inspection of the data obtained from Papua New Guinea: the responses of most literate participants in Port Moresby (familiar with Tok Pisin and English script, both read left-to-right) showed a clear preference for left-to-right directionality in both free-drawing and forced-option tasks, whereas the majority of representations by non-literate BenaBena participants showed no clear directionality.

Overview: Graphic Representations and Directionality

All manner of graphic representations such as drawings, script, and other notation systems rely on the acquisition and development of a number of interrelated skills – including fine motor and cognitive abilities and social competencies – each of which is moulded by the daily activities which constitute distinctive cultural environments. The two studies presented here contribute to the growing evidence that various modes of graphic representation (such as writing, drawing and notations) may not develop in isolation but in an interlocking and reciprocal manner (e.g., see Schmandt-Besserat, 1992).

For instance, pre-school-age children typically draw limbs in their early representations of humans in this order: right leg, left leg; and if arms are included: right arm, left arm. However, by school age, the majority of western children use a *left-right sequence* for forming arms and legs, a shift that some researchers believe demonstrates the influence of English script and other left-to-right writing systems (e.g., Goodnow, 1977, p. 52-53). Adults who read script from left-to-right also tend to draw simple figures by constructing the picture in a generally rightward direction, whereas adults who read script right-to-left tend to move leftward (Vaid, Singh, Sakhuja, & Gupta, 2002). As a consequence, left-to-right readers (English, Hindi) typically draw items such as pencils, cars, fish, and elephants facing toward the left whereas right-to-left readers (Urdu and Arabic) are more likely to face them to the right (Vaid, 1995; van Sommers, 1984).

It is possible that individuals develop certain motor habits or routines that may lead to a proclivity to represent other non-linguistic aspects of experience in the same manner. The first of our studies appears to demonstrate that motor habits shaped by reading and writing could influence the production of representations capturing short rhythmic sequences. This was shown most convincingly in the highly consistent data from our British participants, compared to the lack of clear directionality in the BenaBena group. Over time, the hand (and eye) may be trained to move in one direction more easily than another when performing graphic tasks.

The influence of cultural practices may even override biomechanical factors (stemming from the anatomy of the hand and arm, and the nervous system) with respect to preferred plane of movement. Based on biomechanical affordances, most people make hand movements away from the body's midline more easily than toward the body (van Sommers, 1984) so most right-handed individuals make left-to-right hand movements more easily, and most left-handed individuals make right-to-left movements with greater ease – though one's respective reading and writing system can override these tendencies. This is well illustrated in our Papua New Guinea data: the literate group in Port Moresby provided mainly left-to-right representations (in line with Tok Pisin and English script) while the majority of responses provided by the illiterate BenaBena group showed no clear directionality. Van Sommers' widely-cited finding may explain why 7 of the 8 (exclusively right-handed) BenaBena members who did produce directional representations created them in a left-to-right manner. Similarly, Vaid et al. (2002) found that illiterate individuals living in India showed no directionality bias in pictorial drawing tasks as a group, but directionality was predicted by handedness in line with van Sommers' observations.

Beyond biomechanical constraints, and the formation of simple motor routines habituated in muscle and action, there is a deeper influence of cultural practice in shaping fundamental conceptions of time and space which may be reflected in many forms of expression including metaphor and gesture, and in notational systems that capture events unfolding in time – such as speech, music, and story. (An overview of the related literature was provided in our introduction [see also Núñez & Cooperrider, 2013]). Further, the values and conventions absorbed through formal training in a particular musical tradition can continue to shape our temporal representations (cf. Bamberger (1991) on figural versus metrical representations of rhythm)[i]. This is not independent of motor development; the ability to depict temporal stimuli in a time-ordered fashion requires nimbleness and fast motor responses – which in turn facilitates the creation of traces along a dominant axis. For instance, the ability to record a fast rhythmic pattern in our free-drawing task by means of unit-by-unit markings requires rapid responses and a dexterity with pen and paper that the BenaBena group did not possess. This may, in part, have led to the tendency of the BenaBena to provide representations that captured the auditory events in a more global and less linear or sequential fashion than the other groups. (Compare figures 2a and 2c with figure 2b.)

We also observed some suggestion of a shift from iconic to symbolic representation. Bruner (1966) proposed that learning occurs through a sequence of three modes of representation - *enactive*, *iconic*, and finally *symbolic* - each characterizing the main way information is encoded and stored in memory. In this scheme, our early engagements when encountering something new are primarily based in action (enactive). Next, learning becomes image-oriented, based on storing images with physical resemblances to the experience (iconic). Finally, there is the abstract stage in which arbitrary symbols come to 'stand for' ideas or concepts (symbolic).

In the present study, the BenaBena group's representations of the rhythmic sequences were mainly iconic, capturing the physical likeness of drums and sticks creating the sounds they heard. The majority of the British, Japanese, and literate Papua New Guinea groups generally opted for producing a linear sequence of discrete symbolic markings (often in a "one-stroke-per-sound" manner) and their relative durations in the free-drawing task. However, the brevity of the auditory stimuli and simplicity of the notations only afforded a suggestion of true symbolic representation. Interestingly, the downward strokes (Figure 2a) that a large number of participants spontaneously drew for the free-drawing task - and the stems in the forced-choice task - may also be interpreted as somewhat 'enactive', mimicking the physical action of drum strokes. Indeed, as mentioned in our first study, some BenaBena participants mentioned that the stroke marks represented the action of hitting the drum with hands or sticks.

Methodological Considerations

Cross-cultural research involving remote locations poses a set of distinct challenges for researchers. The present study involved five sites in three countries, the furthest of which (East Highlands Province in Papua New Guinea, where the BenaBena reside) can only be accessed by truck with a 15 km drive on unpaved road from the nearest town of Goroka. The BenaBena villages do not have electricity or running water. All necessary devices - mp3 player, video camera and mobile phone – relied on a single solar charger, so power and other resources were quite limited.

These challenges placed some practical constraints on our procedure. For instance, for the second study, it would have been ideal to present the sets of marks on single sheets of paper to avoid showing the options in multiple rows and columns which could prime participants toward a particular organization in their responses. As the present study constitutes a portion of a larger investigation involving additional tasks, the transport of additional paper stock to our remote locations posed a significant logistical challenge. Limited electricity and the BenaBena's lack of familiarity with technology also precluded options such as touchpads and lightpens, which would have been ideal for presentation of auditory and visual stimuli, and recording of responses.

The criteria for selection of participants also posed logistical challenges for recruitment. In Tokyo and Kyoto, most young Japanese traditional musicians are familiar with WSN and English script. Therefore, in order to meet criteria for the study, it was necessary to recruit older participants for this group. With respect to the BenaBena, although mostly not literate, younger members from 18 years through their 20s have more exposure to writing and print through contact with missionaries and trips to Goroka. To recruit participants lacking familiarity with any literary or notational script, the sample therefore naturally shifted to age 35 years and above. For these reasons, the traditional Japanese and BenaBena groups were considerably older than the others. Although we caution readers as to the possibility that cultural differences may be conflated with cohort effects and/or age effects (e.g., sensory capacities, motor dexterity, and working memory), for the purposes of this research, it was more important to meet the criteria for the study than to adhere strictly to uniformity of age.

Another challenge was the language barrier, and we were fortunate to have the assistance of professors in Japan and Port Moresby and a BenaBena schoolteacher who served as the main translators. This was key as we were also interested in the social dimension of the study – after all, the instructions framed the procedure as a perspective-taking task. While we kept the actual procedure consistent from group to group, we allowed flexibility for preliminary and post-procedure routines – for instance, offering all participants the opportunity to discuss ideas with each other before and after the procedure (though not during). That only the BenaBena chose to do so is a natural reflection of music as a highly communal activity in their society. This introduced a social element that made the task different from the groups that chose to work independently, and it is possible that conferring together may have somewhat homogenized their responses. At the same time, the social exchanges were an opportunity for researchers to understand how the BenaBena approached the task; much was learned that might otherwise not have been revealed.

This study ventured into new territory, laying the foundation for future investigations on the possible links between literacy and musical representations. Care was taken to be culturally sensitive in the creation and presentation of stimuli, orientation to writing tools, implementation of trial runs and procedure, and meaningful interpretation of data in the context of post-interviews. The procedure and all materials were also tested in a pilot study. However, we note the exploratory nature of this research and draw our conclusions cautiously.

We join Vaid and colleagues (2002, p. 598) and many others in pointing to the mounting evidence that 'reading/writing biases are not found only for…linguistic stimuli, but rather "invade" perception or production of nonlinguistic stimuli as well'. To the best of our knowledge, our studies may be the first to extend this to representations of musical rhythms, through preliminary cross-cultural findings that encompass both literate and non-literate societies.

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[i] But note that during the Keynote speech at the Society for Music Perception and Cognition at Vanderbilt University in August 2015, Bamberger explained that she no longer conceives of a shift from figural to metrical representation – that is, not a *replacement* of one with another way of thinking – but that one prepares for the other as emergent possibilities developing throughout life.